# Coastal and Estuarine Water Quality: 2018 Annual Data Report

R Ingley

December 2019

Technical Report 2019/027

RIMU Research and Evaluation Unit

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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# Executive summary

Auckland Council monitors the state of the environment in the region as required under section 35 of the Resource Management Act 1991 (as amended, RMA). The collection of long-term data is necessary to understand natural variability so that we can detect trends that may be attributed to land use and/or climate change and to subsequently assess the efficiency of council initiatives, policies and strategies.

Auckland Council operates a long-term, region-wide coastal and estuarine water quality monitoring programme. The programme includes 31 sites, representative of Auckland's three main harbours (Kaipara, Waitematā and Manukau) and the east coast of the Hauraki Gulf. Water samples are collected monthly on an outgoing tide by helicopter, boat and from land. Water quality analysis is based on 16 parameters including physical variables, nutrients, and water clarity.

This annual report summarises data collected during 2018 and documents changes to the monitoring programme or analysis methods over time. Long-term trend analysis is forthcoming in 2020 (see previous trend analysis in *Marine water quality state and trends in the Auckland region from 2007 to 2016*, TR2018/015).

Individual parameters assessed were generally consistent with patterns previously reported. Several anomalous events (i.e. concentrations higher than previously recorded) were observed which coincided with very high rainfall. Nationally, a 'marine heatwave' of unusually warm sea surface temperatures was recorded in 2018.

The Water Quality Index (WQI) summarises a selection of parameters into five classes (ranging from poor to excellent) based on exceedances of guideline values that are representative of open coast, or estuarine water quality in the Auckland region. Guidelines can be aspirational, and more stringent than regulatory triggers or thresholds. Fifty-five per cent of sites assessed had 'good' to 'fair' water quality based on 2016-2018 median values (i.e. water quality that occurs half of the time), compared to 32 per cent of sites in 2014-2016. Sites that improved water quality class were mostly located in the central Waitematā and Kaipara harbours. Changes in WQI scores over time do not necessarily indicate statistically valid trends; however, the results presented here are consistent with recent trend analysis (2007-2016) that showed water quality improving across the region.

Proximity to freshwater inputs and associated contaminants, and reduced flushing in upper tidal creeks generally results in 'poor' water quality while open coast and harbour mouth sites generally have 'good' water quality. Several sites within the Manukau Harbour and one site within the Kaipara Harbour had water quality which was poorer than would be expected given the salinity (and expected degree of mixing) at the site.

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# 1.0 Introduction

The marine environment in the Auckland region encompasses two oceans, four major harbours and numerous estuaries. Within these are a wide variety of marine habitats which support a diverse range of plants and animals, including seaweeds, invertebrates, mangroves, seagrass, shellfish, marine mammals, fish and sea birds. The beaches also provide many options for recreational activities across the region.

The aesthetics, use, and health of coastal waters are influenced by the quality of surface water that runs from the land through streams, rivers, overland flow paths and stormwater. Water quality is also influenced by natural seasonal and decadal variation as well as climatic changes.

Auckland Council operates long-term state of the environment programmes that include monitoring of river water quality and ecology, coastal and estuarine water and sediment quality and benthic ecology. Microbiological contamination of beaches and recreational water quality are monitored through the Safeswim programme, www.safeswim.org.nz

Long-term data is necessary to understand what natural variability looks like so that we can detect real trends that may be attributed to land use and/or climate change. Combining analysis of river and coastal water quality and ecological monitoring is also important to provide an integrated overview of the physical, chemical and biological condition of the region. This type of combined analysis is undertaken on a five-yearly basis in the *State of the Environment* reports (Auckland Council, 2015).

State of the environment reporting is supported by individual programme state and trend analysis, and annual data reports. The purpose of this report is to communicate the state of our coastal and estuarine water quality based on the coastal and estuarine water quality programme for 2018.

Auckland Council's coastal and estuarine water quality programme focuses on nutrient and water clarity parameters that can be altered by differences in land use, point source discharges direct to the coast, land erosion, and activities in the coastal environment. These parameters also fluctuate naturally due to changes in ocean hydrodynamics, seasonal and climatic variation. Other contaminants associated with urban land use and stormwater contamination, such as metals, are monitored in Auckland Council's river water quality (Buckthought, 2019) and in estuarine sediment and ecology programmes (Mills, 2016; Hewitt *et al.,* 2012) and are not assessed here.

In general, for long-term monitoring programmes, chronically high levels of contamination (those existing for a long time or constantly recurring) are of more concern than a single exceedance, depending on the magnitude (Griffiths, 2016).

Short-term, high magnitude events may be the result of natural variation, an unusual climatic event, or a one-off incident (e.g. sewage overflow). This does not discount the possibility that acute, short-term exposure to high concentrations of contaminants can have an adverse ecological effect. However, the chance of intercepting short-term events is limited due to the monthly sampling design required to support long-term monitoring.

While individual parameters are reported here, the Water Quality Index (WQI) provides a summary of the overall state of water quality at each site by incorporating key parameters into a single score.

The index represents the deviation from “natural” coastal or estuarine conditions (as reflected by the guideline values) in the Auckland region and is indicative of consistently high, chronic, concentrations at that site over time. It does not indicate whether the water quality is suitable for a particular purpose or activity.

The coastal and estuarine water quality programme is designed to meet the following objectives:

- Satisfy Auckland Council’s Resource Management Act 1991 section 35 obligations with respect to the state of the environment and reporting.
- Contribute to our ability to maintain and enhance the quality of the environment (Local Government Act 2002).
- Help inform the efficacy and efficiency of policy initiatives and strategies.
- Assist with the identification of large scale and/or cumulative impacts of contaminants associated with varying land uses and disturbance regimes and link these to particular activities.
- Provide baseline, regionally representative data to support the resource consent process and associated compliance monitoring for coastal and estuarine environments.
- Continuously increase the knowledge base for Aucklanders and promote awareness of coastal and estuarine water quality issues and subsequent management.

## 1.1 Council directives

Monitoring of coastal and estuarine water quality falls under the directives of Auckland Council policies. The programme fits under the "Environment and Cultural Heritage" component of the Auckland Plan 2050. A key issue for the region is to manage the effects of growth and development on our natural environment.

Specific objectives include managing and minimising the effects of present and future urban and rural development, growth, and intensification across the region.

The water quality parameters provide information on the condition of the region's coastal and estuarine environment, and feedback on management actions. This is part of the feedback loop necessary to confirm that Auckland Council's management strategies are effective in sustaining ecosystem functions and opportunities for future use. By achieving this outcome, we are working towards Auckland Council's vision of being a world-class city.

## 1.2 Supporting reports

Previous reports can be obtained from Auckland Council's Knowledge Auckland website www.knowledgeauckland.org.nz. Coastal and estuarine water quality data can be accessed at the Environmental Data Portal. For further enquiries and data supply, please email environmentaldata@aucklandcouncil.govt.nz

For the most recent comprehensive trend analysis, please refer to *Marine water quality state and trends in the Auckland region from 2007 to 2016* (Foley *et al*., 2018 TR2018/015). Recommendations are made in this report along with analyses of long-term changes in water quality for the Auckland region.

A snapshot of the status can be found in Auckland Council's *The health of Auckland's natural environment in 2015* report which briefly summarises marine water quality issues and the pressures facing the Auckland region and its ecological health (Auckland Council, 2015).

# 2.0 Methods

## 2.1 Programme design

Auckland Council's Research and Evaluation Unit (RIMU) collects coastal and estuarine water quality samples monthly from surface waters by helicopter, boat and from land. Collection of water samples by helicopter enables sites spread over a broad area to be sampled within a narrow time window created by tidal constraints, making comparison between sites more robust.

Natural temporal variation in water quality is avoided as much as possible by maintaining a consistent sampling time relative to the tidal cycle. Samples are collected approximately 10 minutes to 2.5 hours after high tide for the Kaipara Harbour, Waitematā Harbour and Hauraki Gulf sites and 2.5 to 4 hours after high tide for the Manukau Harbour. Maintaining a consistent sample time improves the power of long-term trend detection.

Sites in the inner Hauraki Gulf, Kaipara Harbour, Tāmaki Strait and Manukau Harbour are collected by helicopter, sites in the upper and central Waitematā Harbour are collected by boat and Tāmaki Estuary sites are collected from land.

## 2.2 Site locations

Sites are representative of six geographically distinct areas. Monitored site locations are summarised in Table 2-1 and illustrated in Figure 2-1.

- 6 sites in the inner Hauraki Gulf (including 2 sites in Mahurangi Harbour)
- 6 sites in the Kaipara Harbour
- 8 sites in the Waitematā Harbour
- 2 sites in the Tāmaki Estuary
- 1 site in the Tāmaki Strait (at the mouth of the Wairoa River)
- 8 sites in the Manukau Harbour.

Each monitoring site was selected to provide information on:

- A range of exposure levels including open coast, harbours, large estuaries and tidal creeks.
- The three main harbours and large estuaries.
- Areas with a variety of contributing catchment land uses, ranging from urban to rural.

Table 2-1: Current coastal and estuarine water quality sites grouped by location.
Spatial reference is in NZTM coordinates and the year which sampling began is also listed.

| | Site | Easting | Northing | Year initiated | Exposure Level | Dominant adjacent land use* |
|---|---|---|---|---|---|---|
| East Coast | Goat Island | 1761787 | 5984944 | 1993 | Open Coast | Rural* |
| | Ti Point | 1760058 | 5978931 | 1991 | Open Coast | Rural* |
| | Mahurangi Heads | 1754225 | 5960548 | 1993 | Estuary | Rural* |
| | Dawsons Creek | 1753782 | 5966175 | 1993 | Estuary | Rural |
| | Orewa | 1753660 | 5949837 | 1991 | Open Coast | Urban/Rural* |
| | Browns Bay | 1757497 | 5935771 | 1991 | Open Coast | Urban/Rural* |
| Kaipara Harbour | Shelly Beach | 1723871 | 5952426 | 1991 | Estuary | Rural* |
| | Kaipara River | 1725504 | 5947101 | 2009 | Estuary | Rural |
| | Makarau Estuary | 1727396 | 5953730 | 2009 | Estuary | Rural |
| | Kaipara Heads | 1708534 | 5970421 | 2009 | Estuary | Rural* |
| | Tauhoa Channel | 1717821 | 5970063 | 2009 | Estuary | Rural* |
| | Hoteo River | 1726691 | 5967495 | 2009 | Estuary | Rural |
| Waitematā Harbour | Chelsea | 1753721 | 5922776 | 1991 | Estuary | Urban* |
| | Whau Creek | 1748588 | 5920563 | 1991 | Estuary | Urban |
| | Henderson Creek | 1746715 | 5923855 | 1991 | Estuary | Urban |
| | Hobsonville | 1749453 | 5927353 | 1993 | Estuary | Urban |
| | Paremoremo Creek | 1745717 | 5930201 | 1993 | Tidal Creek | Lifestyle/Native |
| | Rangitopuni Creek | 1742734 | 5930626 | 1993 | Tidal Creek | Rural |
| | Brighams Creek | 1742829 | 5928227 | 1996 | Tidal Creek | Urban |
| | Lucas Creek | 1749892 | 5932176 | 1993 | Tidal Creek | Urban |
| Tāmaki Estuary | Tāmaki | 1769303 | 5916944 | 1992 | Estuary | Urban* |
| | Panmure | 1765553 | 5913693 | 1992 | Estuary | Urban |
| Tāmaki Strait | Wairoa River | 1786561 | 5910769 | 2009 | Estuary | Rural |
| Manukau Harbour | Grahams Beach | 1749431 | 5897517 | 1987 | Estuary | Urban/Rural* |
| | Clarks Beach | 1749746 | 5888100 | 1987 | Estuary | Rural |
| | Waiuku Town Basin | 1752923 | 5879195 | 2012 | Tidal Creek | Rural |
| | Shag Point | 1748335 | 5908549 | 1987 | Estuary | Urban/Rural |
| | Puketutu Point | 1753938 | 5908791 | 1987 | Estuary | N/A |
| | Weymouth | 1764080 | 5897952 | 1987 | Estuary | Urban/Rural |
| | Mangere Bridge | 1758048 | 5910932 | 1987 | Estuary | Urban |
| | Manukau Heads | 1741520 | 5900335 | 2009 | Estuary | Urban/Rural* |

** Open coast and main harbour body/harbour mouth sites are less subject to direct influences from adjacent land use*

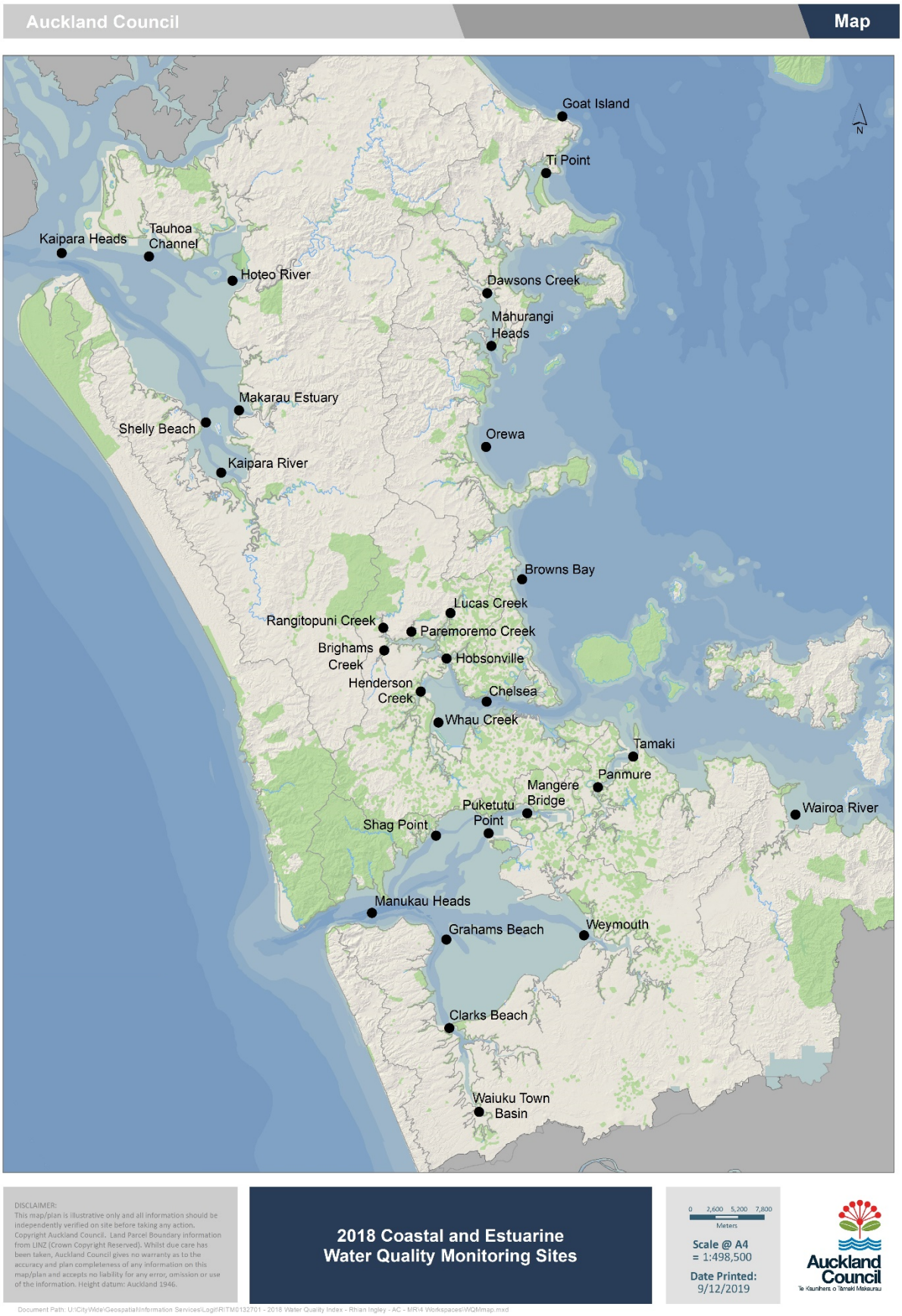


Figure 2-1: Location of the 31 coastal and estuarine water quality monitoring sites

## 2.3 Data collection

Sample collection was undertaken by council staff on a monthly basis. The quality of coastal water around the region is determined by measuring 16 parameters. A summary of all parameters monitored is provided in Table 6-19 in Appendix B.

Six parameters are determined in the field using an EXO Sonde portable water quality meter (Xylem Analytics), and the remainder are determined by laboratory analysis (see Appendix B). At each site, water samples were collected from the surface (top 1m) by lowering a two litre plastic bottle into the water.

All field measurements collected in 2018 were consistent with equipment accuracy specifications and were operated in accordance with inhouse procedures and calibration requirements (see Appendix B).

Samples were analysed under contract by Hill Laboratories Ltd (Hills), an IANZ accredited laboratory. Analytical methods follow the "Standard Methods for the Examination of Water and Wastewater" 22nd Edition (APHA, 2012). It is noted that not all methods for all parameters are IANZ accredited, however this is a common issue across service providers and Hills are actively working towards achieving accreditation.

All field and laboratory data were stored in Auckland Council's archiving database, HYDSTRA (Kisters Pty Ltd) compliant with ISO 9001:2008 certifications.

## 2.4 Data processing

Quality control was undertaken in accordance with Auckland Council's internal standards, including procedures for the collection, transport and storage of samples, and methods for data verification and quality assurance to ensure consistency across the monitoring programme. Draft National Environmental Monitoring Standards (NEMS) (Part 4 – Coastal Waters) were released in April 2019 and therefore data collected prior to this date are not directly comparable with these standards.

Data collected for each variable are analysed for each site and initially compared to data previously collected over a ten-year period. These data are used to obtain the 5$^{th}$ and 95$^{th}$ percentiles and if any new data falls outside of these boundaries, it is flagged. This allows the processor to check for erroneous data and repair (if data is incorrect) or comment as appropriate. Prior to any analysis, any data points that were assigned a quality assurance code of questionable quality were removed from the dataset.

### 2.4.1 Censored data and substituted values

For some water quality parameters censored values are reported when true values are too low or too high to be measured with precision by the analytical method being used by the laboratory. For very low values of a specific water quality parameter, the minimum acceptable precision corresponds to the analytical method "detection limit" for that parameter; for very high values, the minimum acceptable precision corresponds to the analytical method "reporting limit" for that variable.

Censored values that were below the detection limit were substituted with a value of half the detection limit prior to any analysis being undertaken. There were no instances of data reported above the high end "reporting limit".

## 2.5 Data analysis

The data summary section presents the variability of the data across all the parameters measured during 2018. Data from 2018 are presented in box plots (section 3.1) to display the ranges over marine water quality parameter results were recorded. Sites are grouped by location and then listed based on increasing median salinity. These summary statistics are also provided in data tables in Appendix A.

- Box plots were produced using the software package SigmaPlot version 14.0, using the default percentile functions. The boxes represent the inter-quartile range ($25^{th}$ and $75^{th}$ percentiles) and the whiskers represent the $10^{th}$ and $90^{th}$ percentiles. The median is shown as a line within each box.
- Summary tables which provide a statistical analysis for each parameter at each site have been produced using Sigmaplot version 14.0.

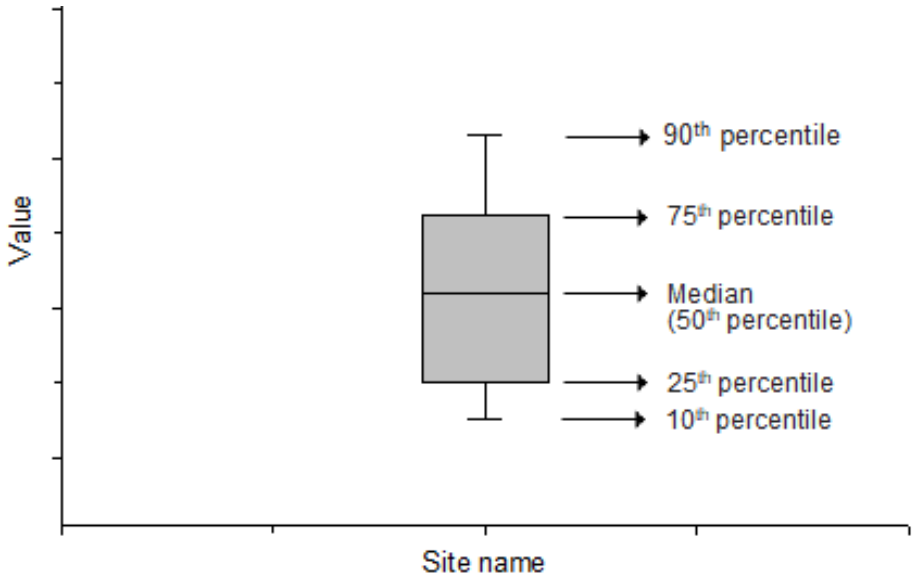


Figure 2-2: The different statistical measures shown within a box plot

### 2.5.1 Water Quality Index

A Water Quality Index (WQI) is used to simplify how we communicate the state of complex water quality data by incorporating multiple factors (parameters) into a single number or score and overall water quality class (Table 2-3). The WQI used in this report is based on that developed by the Canadian Council of Ministers for the Environment (CCME, 2001) with some modifications. The CCME index framework has been utilised by other regional councils (e.g. Greater Wellington Regional Council and Northland Regional Council) in New Zealand and is used internationally in both freshwater and saline water quality reporting (Ballantine 2012).

Our approach is based on exceedances of defined water quality guidelines derived from the 80th percentile of 10 years of data (2007-2016) or ANZECC guidelines, for a subset of six parameters, at reference sites within the Auckland region (Table 2-2). Separate guidelines have been defined for open coast, and estuarine sites resulting from expected differences in water quality due to hydrodynamics and flushing times.

For open coastal water quality sites, the least modified or reference sites were Ti Point and Goat Island. For estuary and tidal creek sites, reference sites were selected from predominantly urban catchments, subject to greater mixing and dilution which consequently represent guidelines that are regionally achievable and where water quality is high enough to support healthy coastal ecosystems (Chelsea, Hobsonville, and Manukau Heads).

Significant modifications were made to the application of the WQI methodology in 2018 including: alteration of parameters included, separate coastal and estuarine guidelines, setting static guidelines, and using a rolling three-year average value to calculate scores (Foley, 2018). This report follows Foley (2018) with the exception of using rolling median, not average values. This has been adopted to resolve the effects of skew on average values caused by anomalous events within a single year and is consistent with ANZECC recommendations and other regional councils' application of the method (ANZECC 2000; Perrie, 2007; Griffiths, 2016). Consequently, previous WQI scores are not directly comparable. Three-year median values moderate major inter-annual variation due to natural environmental changes (e.g. heavy rainfall and storms) or human impacts such as development. Exceedances are consequently indicative of sustained high concentrations (chronic effects) at that site. See Appendix C for further detail on Auckland Council's application of the CCME WQI methodology.

A three-year rolling median was used to calculate the final 2018 WQI score (monthly median values from 2016 to 2018). Three-year rolling medians and associated WQI scores were also calculated for 2016 and 2017 (monthly medians from 2014 to 2016 and 2015 to 2017 respectively) for direct comparison.

Table 2-2: WQI guidelines for the Auckland region

| Parameter | Open Coast Guideline | Estuary Guideline |
|---|---|---|
| Dissolved oxygen (% saturation) | 90-100% | 90-100% |
| Turbidity (NTU)* | <1 | <10 |
| Chlorophyll α (mg/L) | <0.0023 | <0.0031 |
| Soluble reactive phosphorus (mg/L) | 0.012 | 0.021 |
| Nitrate + nitrite nitrogen (mg/L) | 0.027 | 0.029 |
| Ammoniacal nitrogen (mg/L)** | 0.0150 | 0.0150 |

** Based on ANZECC guidelines, not 80$^{th}$ percentile of reference sites from Auckland region.*

*** Based on ANZECC guideline for ammonium (NH4+) not ammoniacal nitrogen (NH3+NH4). At the average pH of seawater, approximately 95% of ammoniacal nitrogen is in the ammonium form.*

Table 2-3: WQI categories and scoring ranges used by Auckland Council (CCME, 2001)

| Score range | WQI Class | Meaning |
|---|---|---|
| 95-100 | Excellent | Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within guidelines all the time. |
| 80-94 | Good | Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels or water quality guidelines. |
| 65-79 | Fair | Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels or water quality guidelines. |
| 45-64 | Marginal | Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels or water quality guidelines. |
| 0-44 | Poor | Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels or water quality guidelines. |

## 2.6 Programme changes

The number of sites within the programme has varied over time primarily to improve the regional coverage. Some sites have also been discontinued due to budget and resources constraints.

The number and type of water quality parameters measured has varied since the programme's inception as new technology has become more affordable, instrument sensitivity has improved, and the programme objectives modified. Refer to Appendix D for a detailed programme history of changes over time.

## 2.7 Limitations

### 2.7.1 Data continuity

Baseline monitoring aims to build a consistent dataset to improve the confidence in state and trend assessments over time, to better assist our understanding of management outcomes. Due to logistical requirements, changing priorities, and improvements to methodologies, some discontinuities exist within the dataset.

The service provider for laboratory analysis changed in July 2017 from Watercare Services Ltd to Hill Laboratories Ltd (Hills). This changeover coincided with some minor changes to analytical methodologies, and detection limits for select parameters. All samples collected in 2018 were analysed by Hills and are comparable between sites within year.

Some discrepancies have been observed in a recent review of long-term trends particularly for:

- Ammoniacal nitrogen, where a step increase (of approximately 0.008 mg/L) was observed coinciding with the change in service provider.
- Total nitrogen, where a series of step increases has been observed dating to January 2016 and July 2017 (second step of approximately 0.08 mg/L).
- Chlorophyll α, where an increase in detection limit between July 2017 and June 2018 resulted in poor resolution of the data and a high percentage of censored values (e.g. 71% censored values from January to May 2018 compared to 4% censored values from June to December 2018). This has since been resolved by substitution to a method with a more sensitive detection limit.

## 2.8 Rainfall and hydrology comparison

Regular monitoring is undertaken at monthly intervals and is not targeted to episodic rainfall events, such as floods, which may deliver high quantities of contaminants to the coastal environment over a relatively short duration. An understanding of the flow events sampled within 2018 is important to enable interpretation and comparisons of water quality, particularly at tidal creek and estuary mouth sites. Sampling higher river flow events in 2018 than typical, may explain anomalies in the data such as very high concentrations of sediment or other contaminants delivered by freshwater inputs to our estuaries.

Flow duration curves were produced for a range of hydrology monitoring stations located upstream in the contributing catchments. These long-term flow conditions were compared to the flow conditions experienced at that river hydrology monitoring station

on the days that we undertook the coastal and estuarine water quality monitoring in 2018.

The water that we have sampled in 2018 was generally representative of median rainfall conditions (approximately 20th to 60th per cent of flows) and was not representative of very high or very low flow conditions that can be experienced over the longer term. Between tidal creek estuarine monitoring sites, and between different years, we expect some variation in the range of flows experienced; that is shifts left or right on the flow duration curve indicating that higher or lower flows were sampled. An example of the 2018 river flow data compared to the longer-term dataset is provided below in Figure 2-3.

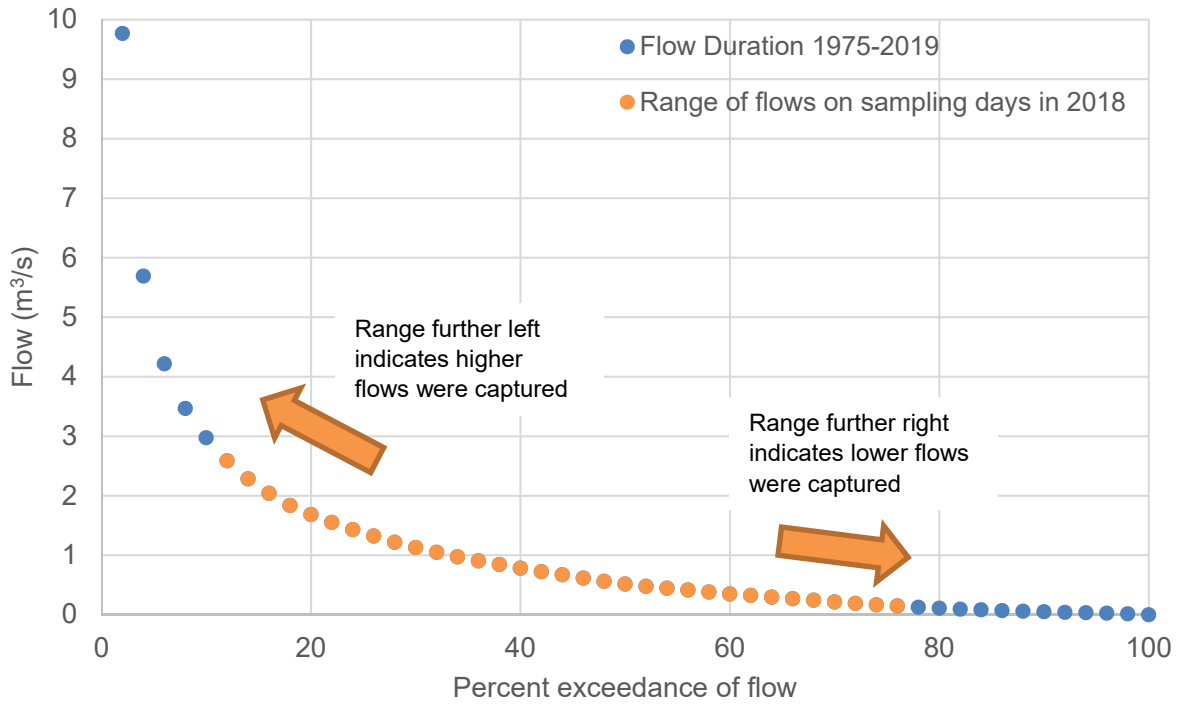


Figure 2-3: Example of flow duration analysis based on the long-term record for the Rangitopuni River @ Walkers hydrology site compared to flow conditions experienced at that site on the 2018 monthly coastal water quality sample days at the tidal Rangitopuni Creek site.

# 3.0 Results

## 3.1 2018 annual data summary

New Zealand's climate varies significantly from year to year and long-term, associated with decadal circulation and climate variations such as the Interdecadal Pacific Oscillation (IPO) and El Niño Southern Oscillation (ENSO). These cycles affect average sea surface temperature, prevailing winds, and rainfall patterns, which drive differences in nutrients and sedimentation (such as through changes to oceanic upwelling of nutrient rich waters and soil erosion and nutrient leaching). Scarsbrook (2008) has previously found that within the Manukau Harbour, temperature, nitrate, and ammoniacal nitrogen all tend to be higher during La Niña phases and lower during El Niño phases. ENSO typically accounts for less than 25 per cent of variance in seasonal rainfall and temperature patterns at most sites in New Zealand (NIWA, nd) and accounted for <15 per cent of the variance in nitrogen concentrations within the Manukau (Scarsbrook, 2008).

In 2018, the early part of the year commenced in weak La Niña conditions reverting to normal (April to August) and transitioned to weak El Niño in spring (September) (NIWA, 2018 to 2019) (Figure 3-1). There was little evidence to support full El Niño phenomena occurring in late 2018 to 2019 (NIWA, 2019).

Anomalously warm ocean waters or a 'marine heatwave' persisted around the country for the duration of 2018, peaking in November 2017 to February 2018 (1°C warmer than average for the time of the year) (NIWA, 2018; MfE and Stats NZ, 2019). Marine heatwave conditions are defined by comparison to a 30-year baseline. Warmer sea surface temperatures were discernible in the 2017/18 summer season at the coastal and estuarine water quality monitoring sites, particularly within the Hauraki Gulf.

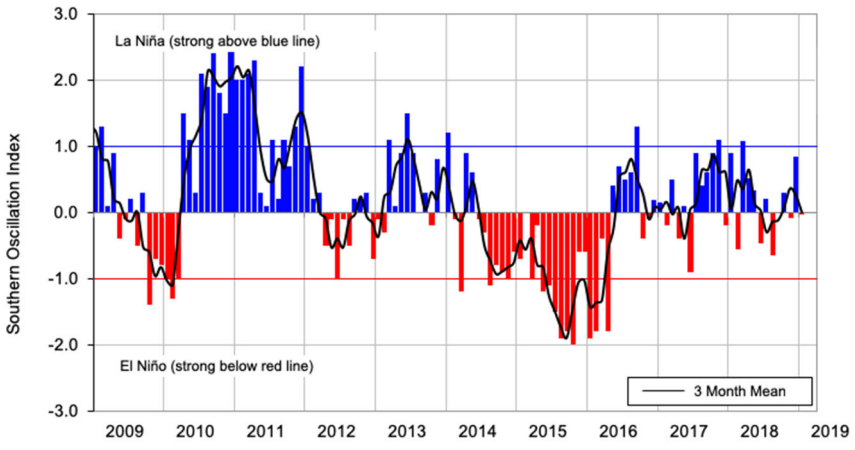


Figure 3-1: Monthly values of the Southern Oscillation Index and three-month mean (black line) (Image from NIWA, 2019).

Sites within the coastal and estuarine water quality programme are representative of a range of physical conditions ranging from open coast to estuaries/harbours and upper tidal creeks. Salinity (and conductivity) is reflective of these conditions with open coastal sites close to oceanic values of 35ppt (Figure 3-3). River mouth sites are typically more variable due to varying freshwater inflows; this is further exacerbated in upper tidal creeks (such as Rangitopuni Creek) where, following heavy rain events, surface waters can be very fresh.

The range of values recorded for each parameter at each site is similar to what has been previously reported, see Figure 3-2 to Figure 3-7 and associated data tables in Appendix A. Anomalous events recorded in 2018 included:

- Lucas Creek – high rainfall event in January (highest 2% of flows on record) associated with low pH and salinity/conductivity, colder water temperature than expected for January, and the highest turbidity and total suspended solids observed in the past five years (Figure 3-4). Elevated total nitrogen and total phosphorus concentrations were also recorded for this date; however, these were within range of previous observations for this site.
- Hoteo River – high rainfall event in June (highest 4% of flows on record) associated with the highest maximum nitrate, total nitrogen, total phosphorus and turbidity concentrations observed in the past five years. It was interesting to note that total suspended solids were not similarly elevated during this event. Elevated nitrate concentrations were also recorded in June at other Kaipara and Manukau harbour sites.
- Wairoa River – the highest maximum total phosphorus observed in the past five years was recorded in July 2018 (Figure 3-7). This was not associated with a notable rain event.

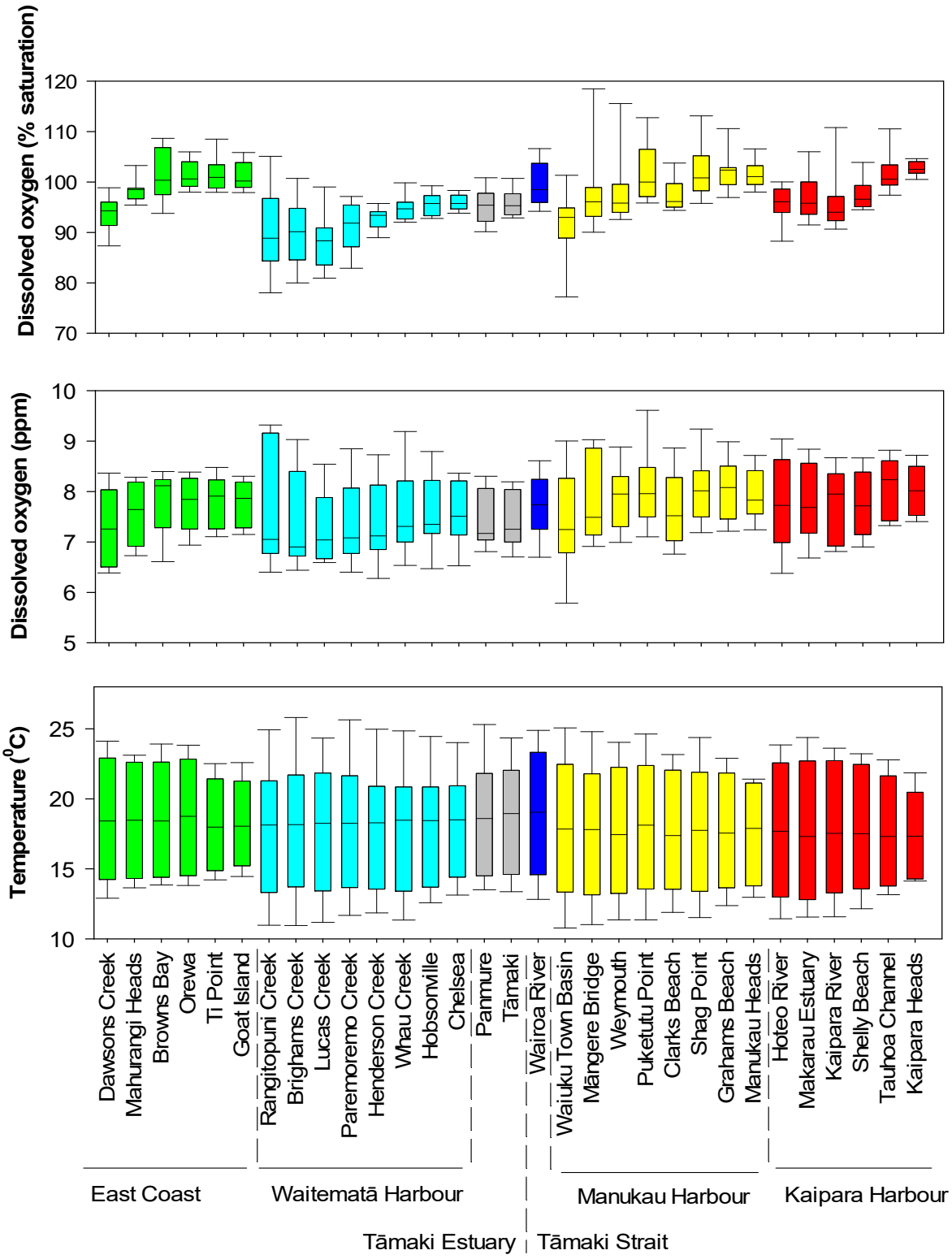


Figure 3-2: Spatial patterns in two indices of dissolved oxygen (ppm and % saturation) and sea surface temperature.

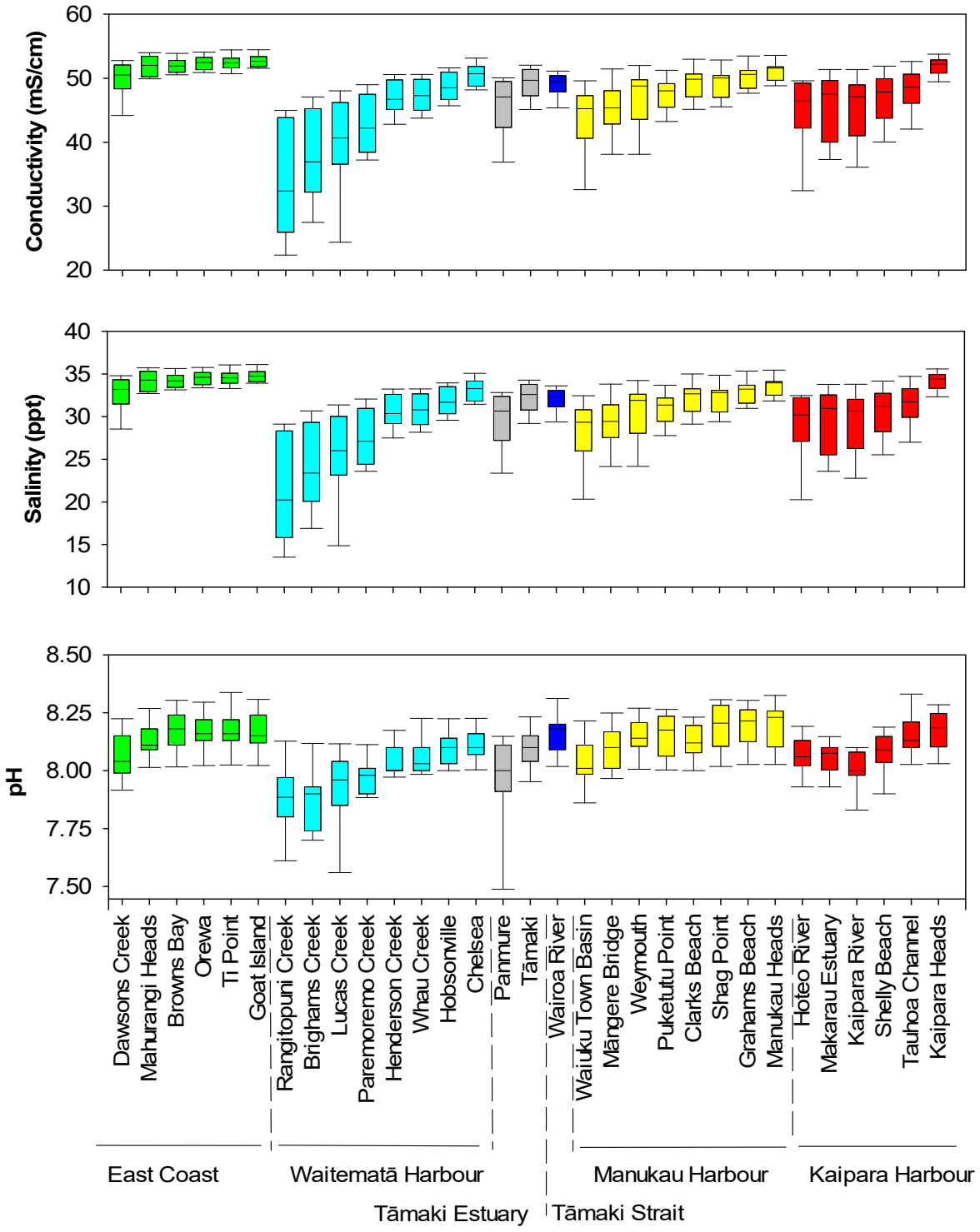


Figure 3-3: Spatial patterns in conductivity, salinity and pH.

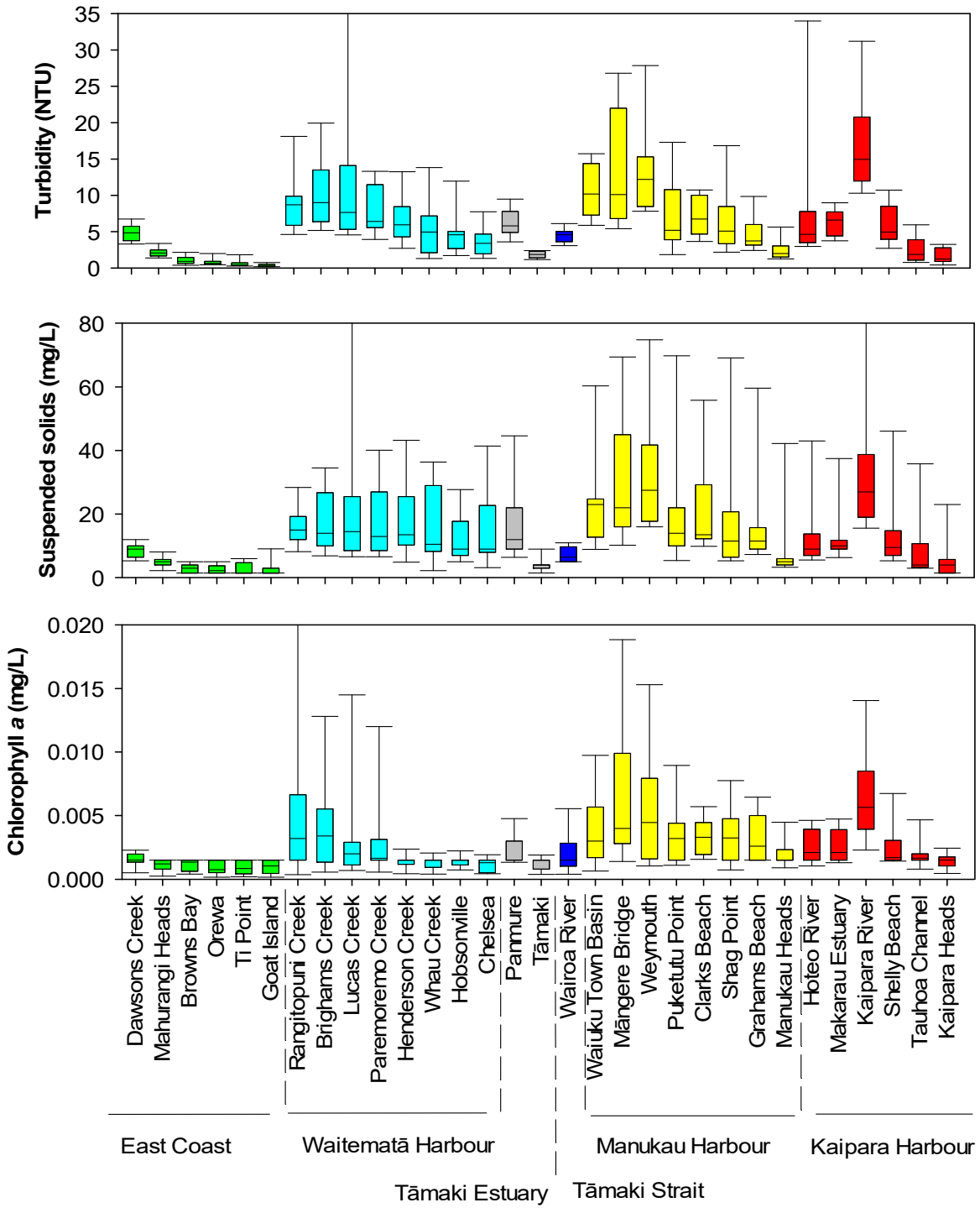


Figure 3-4: Spatial patterns in turbidity, suspended sediment, and chlorophyll α.
90th percentile values not shown: Turbidity at Lucas Creek – 85.5 NTU, Suspended solids at Lucas Creek and Kaipara River – 114.9 mg/L, and 83.2 mg/L, and Chlorophyll *a* at Rangitopuni Creek – 0.0294 mg/L.

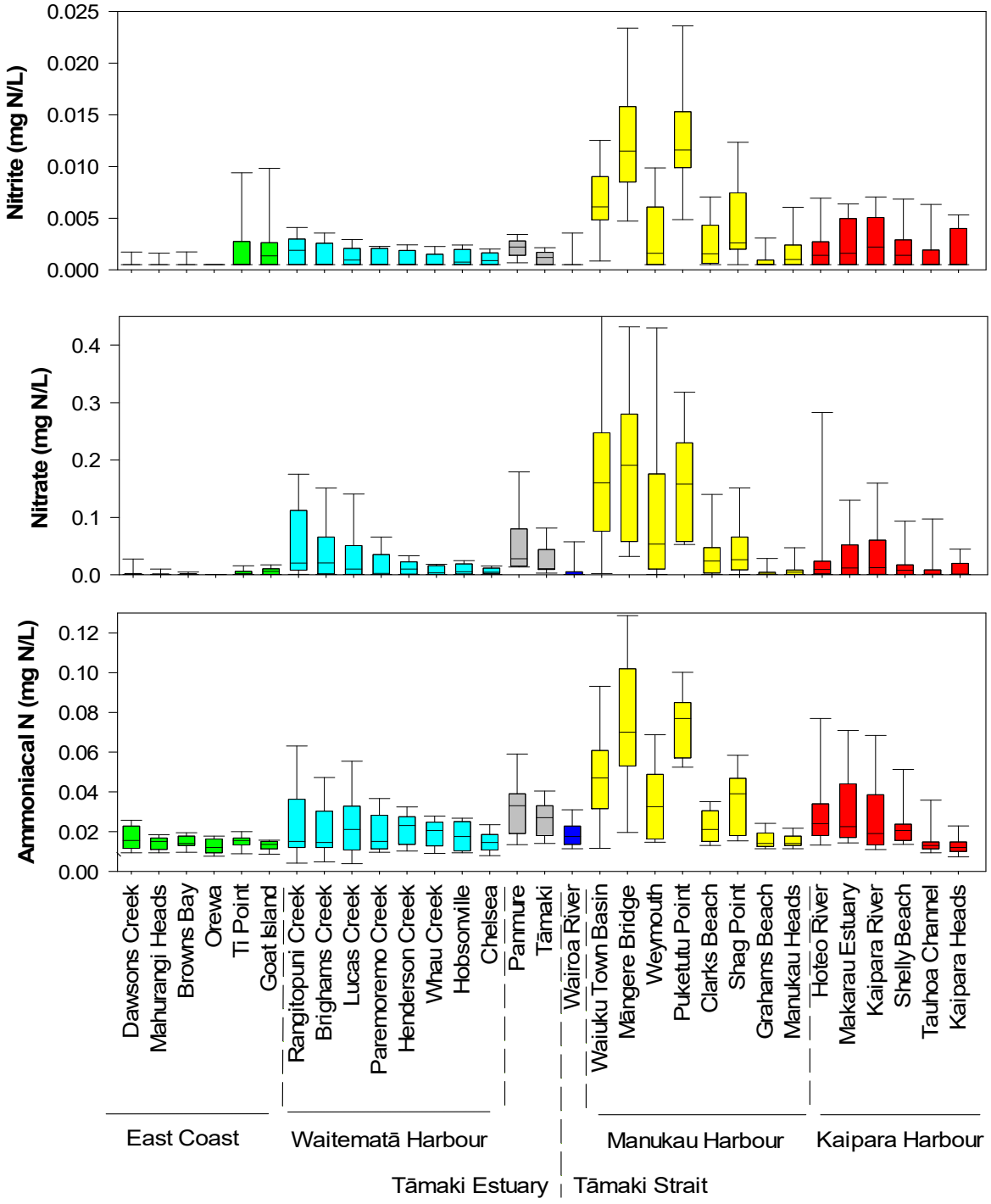


Figure 3-5: Spatial patterns in nitrite, nitrate and ammonia.
90th percentile values not shown: Nitrate at Waiuku Town Basin – 0.787 mg N/L.

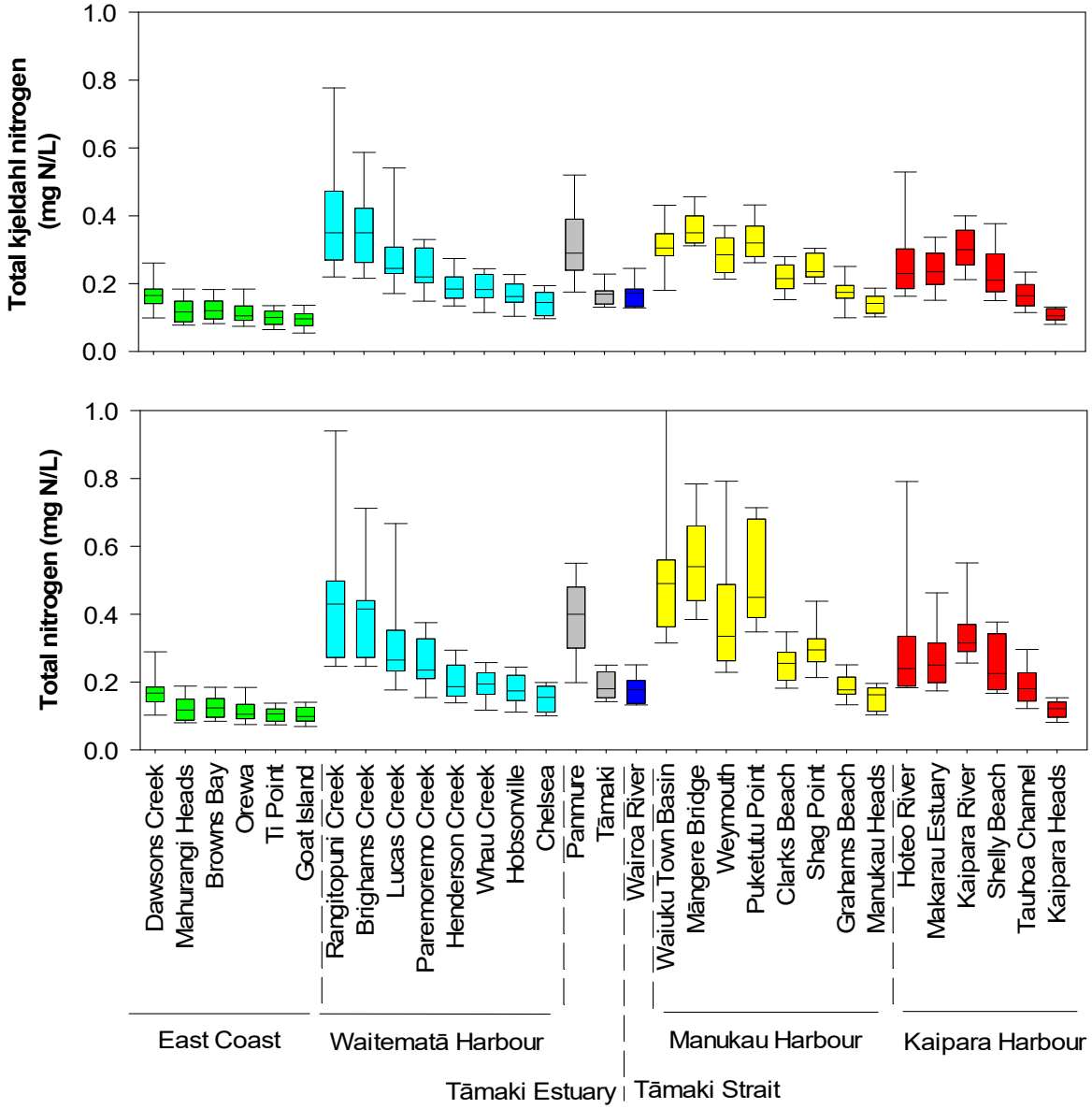


Figure 3-6: Spatial patterns in total kjedahl nitrogen and total nitrogen.
90th percentile values not shown: Total nitrogen at Waiuku Town Basin – 1.1 mg N/L.

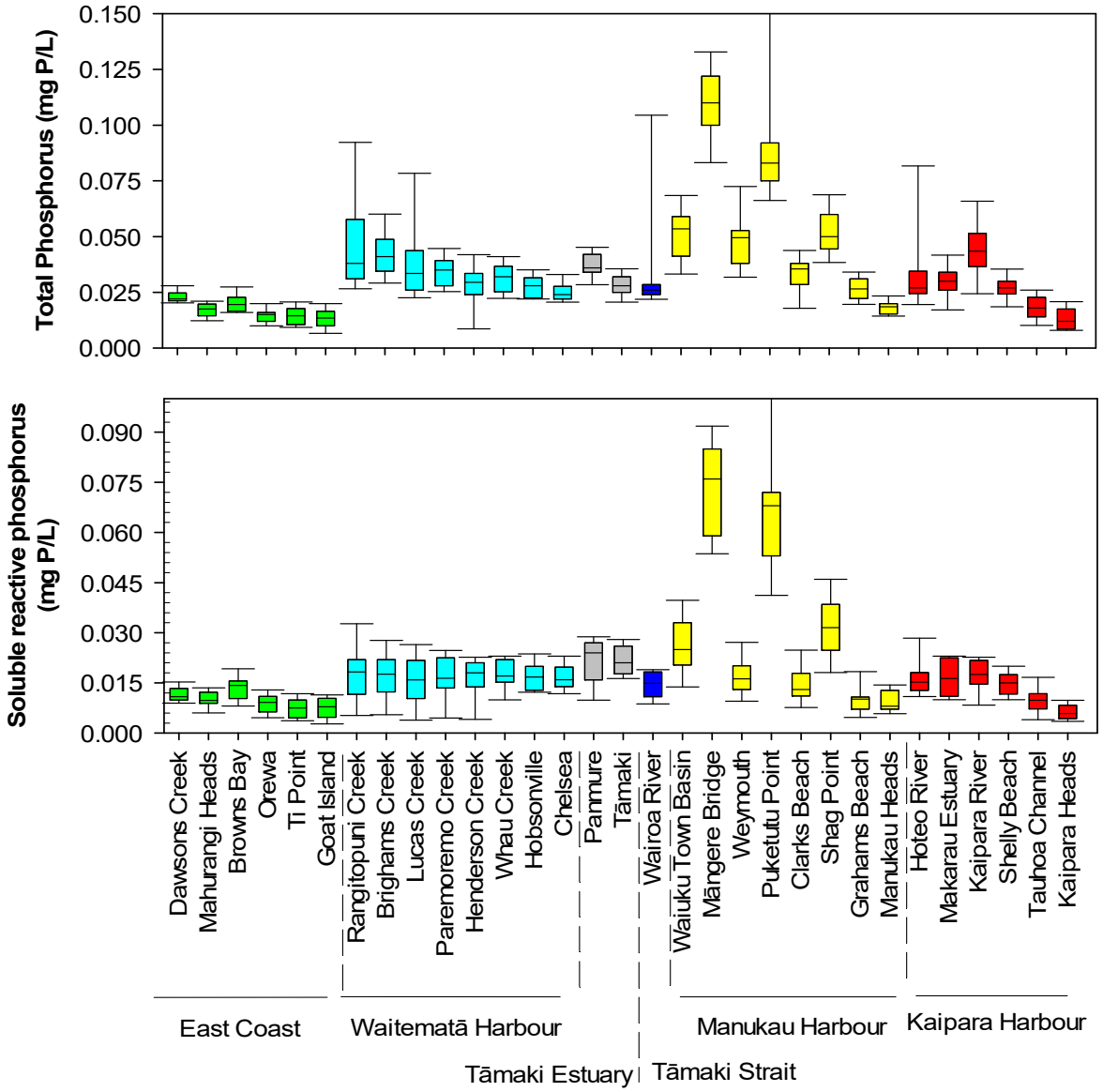


Figure 3-7: Spatial patterns in total phosphorus and soluble reactive phosphorus.
90th percentile values not shown: Total and soluble phosphorus at Puketutu Point – 0.196 mg P/L, 0.161 P/L.

## 3.2 Water Quality Index

A Water Quality Index (WQI) represents the deviation from “natural” marine or estuarine conditions in the Auckland region, rather than indicating whether the water quality is suitable for a particular purpose or activity.

Median monthly values from 2016-2018 are summarised in the water quality index. This includes an overview of water quality status across the region, key differences between areas within the region, and changes in state over time.

### 3.2.1 Regional water quality

Water quality across the region appears to have improved over the past five years with 35 per cent of sites improving by at least one water quality class (e.g. from marginal to fair) between 2014 to 2016 and 2016 to 2018 medians (Figure 3-8; Table 6-1 in Appendix A). Changes in the WQI scores over time do not necessarily indicate statistically valid trends, however these patterns are consistent with the most recent trend analysis (2007-2016) that showed improving coastal and estuarine water quality across the region (Foley, *et al*., 2018).

Improvements in water quality were driven by a decreasing number of exceedances of the guidelines for chlorophyll α (chl a), soluble reactive phosphorus, dissolved oxygen, and turbidity (Figure 3-9). An increasing number of exceedances were observed for ammoniacal nitrogen.

It is noted that variations associated with a change in laboratory services provider in 2017 may have influenced the number of exceedances, particularly for chlorophyll α (underestimate), and ammoniacal nitrogen (overestimate) (see section 2.7.1 for further information). Both parameters showed mixed trends across the region (increasing, decreasing, and no discernible trend) in the most recent ten-year trend analysis from 2007 to 2016 (Foley, *et al*., 2018). Therefore, these patterns should be treated with caution. Trend analysis to be undertaken in 2020, will include 2017 data.

Only one site (Mahurangi Heads) had a lower water quality grade than previously reported. One low magnitude exceedance of a single parameter will reduce the WQI grade from ‘excellent’ to ‘good’. For Mahurangi Heads, the change in score is associated with a single exceedance of ammoniacal nitrogen which is likely due to the noted laboratory issue.

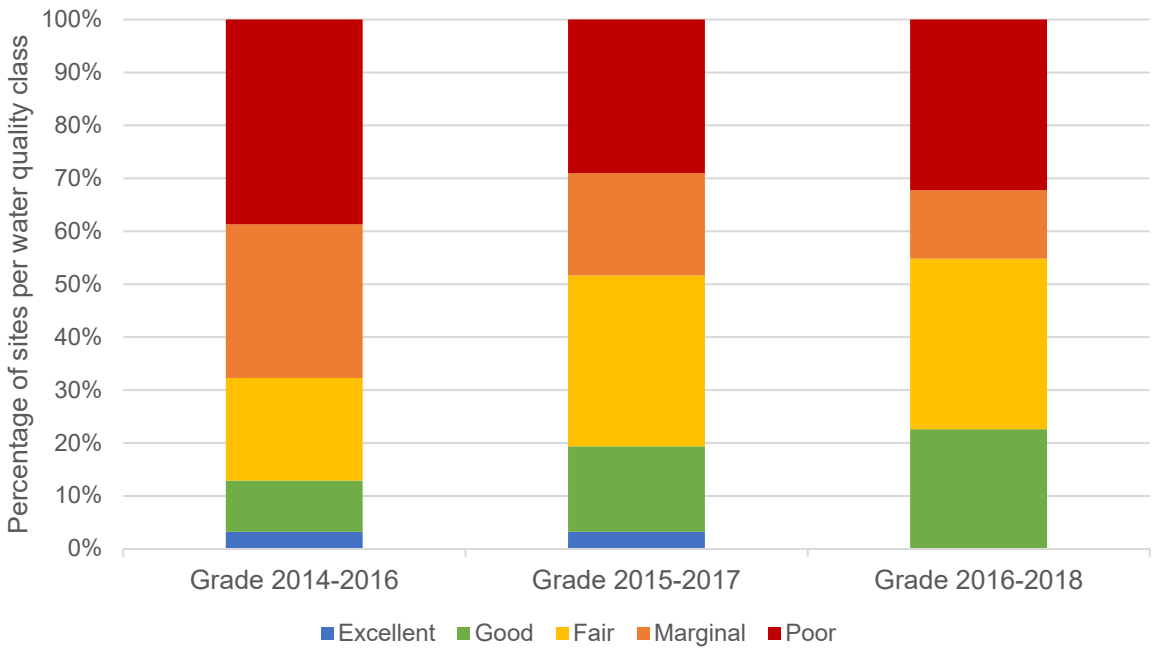


Figure 3-8: Percentage of sites per water quality class from 2014 to 2018.
WQI are presented as three year rolling medians

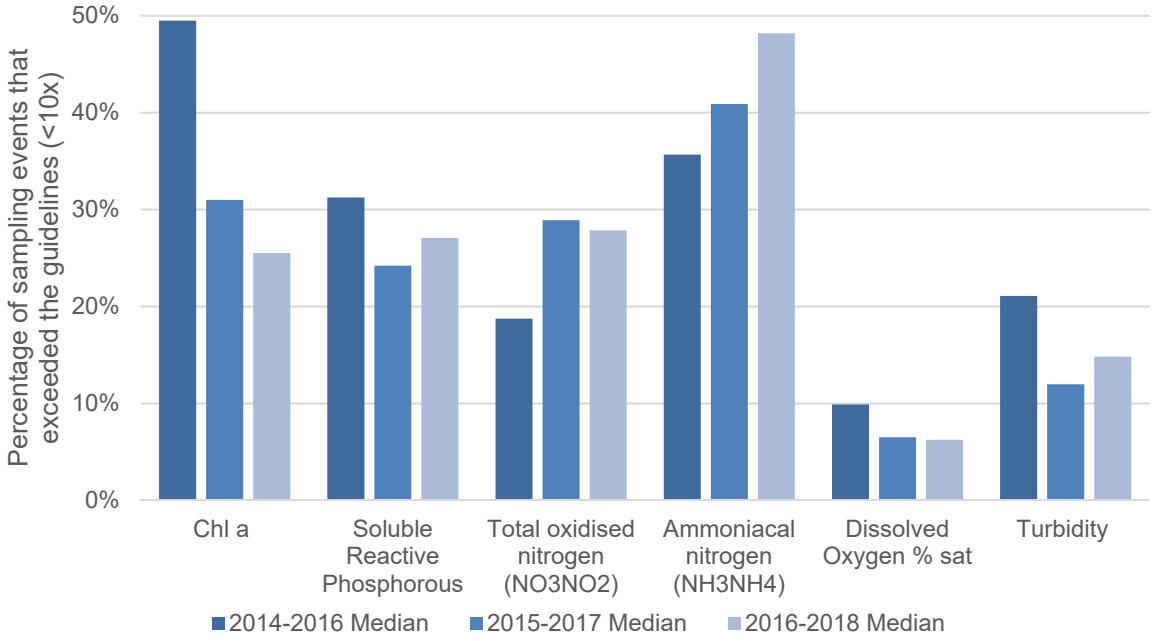


Figure 3-9: Percentage of sampling events that exceeded the relevant water quality guideline by <10 times (n=384) **Note possible lab induced changes in exceedances for Chlorophyll α (chl a) and ammoniacal nitrogen ($NH_3NH_4$)*

The overall distribution of water quality scores shows a strong relationship with median salinity at each site (Figure 3-10). A similar relationship has been demonstrated in previous state and trend analysis where salinity was compared to an average water quality ranking across Auckland state of the environment monitoring sites (Scarsbrook, 2008). This is indicative of proximity to freshwater input and associated contaminant runoff, and the subsequent effects of dilution and dispersion through increased mixing.

Open coast and harbour mouth sites generally had 'good' water quality, whilst upper tidal creeks all had consistently 'poor' water quality (Figure 3-11; Figure 3-12). Therefore, values of salinity provide a useful proxy of the position of monitoring sites relative to land derived anthropogenic contaminants from riverine inputs (Scarsbrook, 2008).

Several east coast sites had generally better water quality than expected which may reflect differences in the application of separate open coast and estuarine guidelines (Figure 3-10).

Several sites within the Manukau Harbour had poorer water quality than would be expected given the salinity of the sites, most notably the sites closest to the Mangere Wastewater Treatment Plant (Mangere Bridge, Puketutu Point, and Shag Point) and Waiuku Town Basin (Figure 3-10), as well as Weymouth, and Clarks Beach. Other sites that generally had poorer water quality than expected for the salinity of the site include the Kaipara River, and Panmure (Figure 3-10).

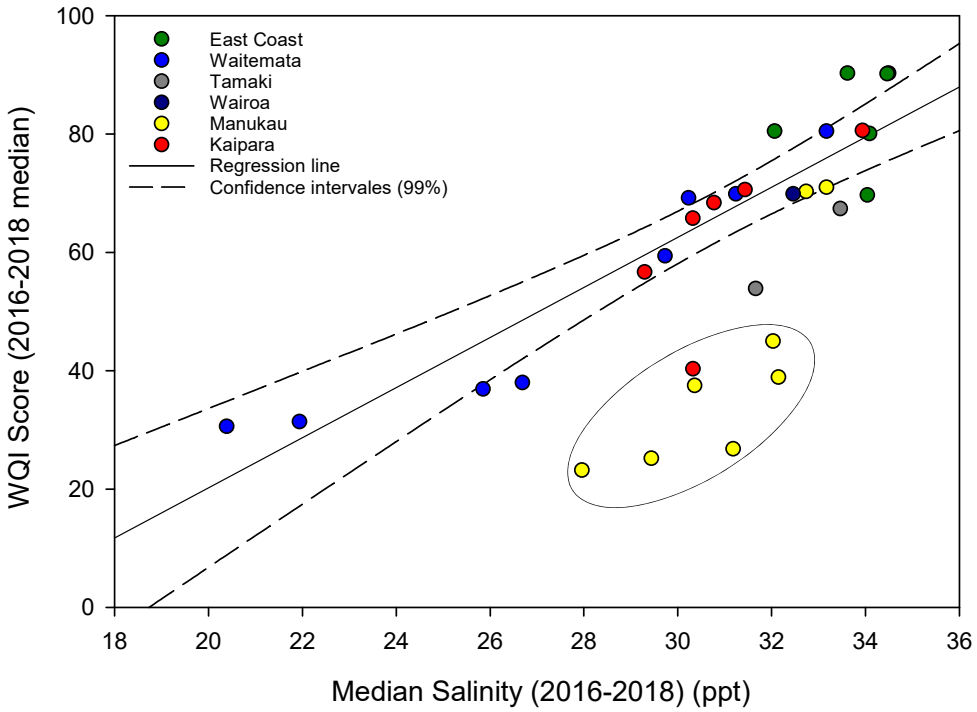


Figure 3-10: Relationship between salinity and WQI score. Regression line ($r^2$=0.83) and confidence intervals plotted excluding circled sites (Mangere Bridge, Puketutu Point, Shag Point, Waiuku Town Basin, Clarks Beach and Weymouth, Kaipara River).

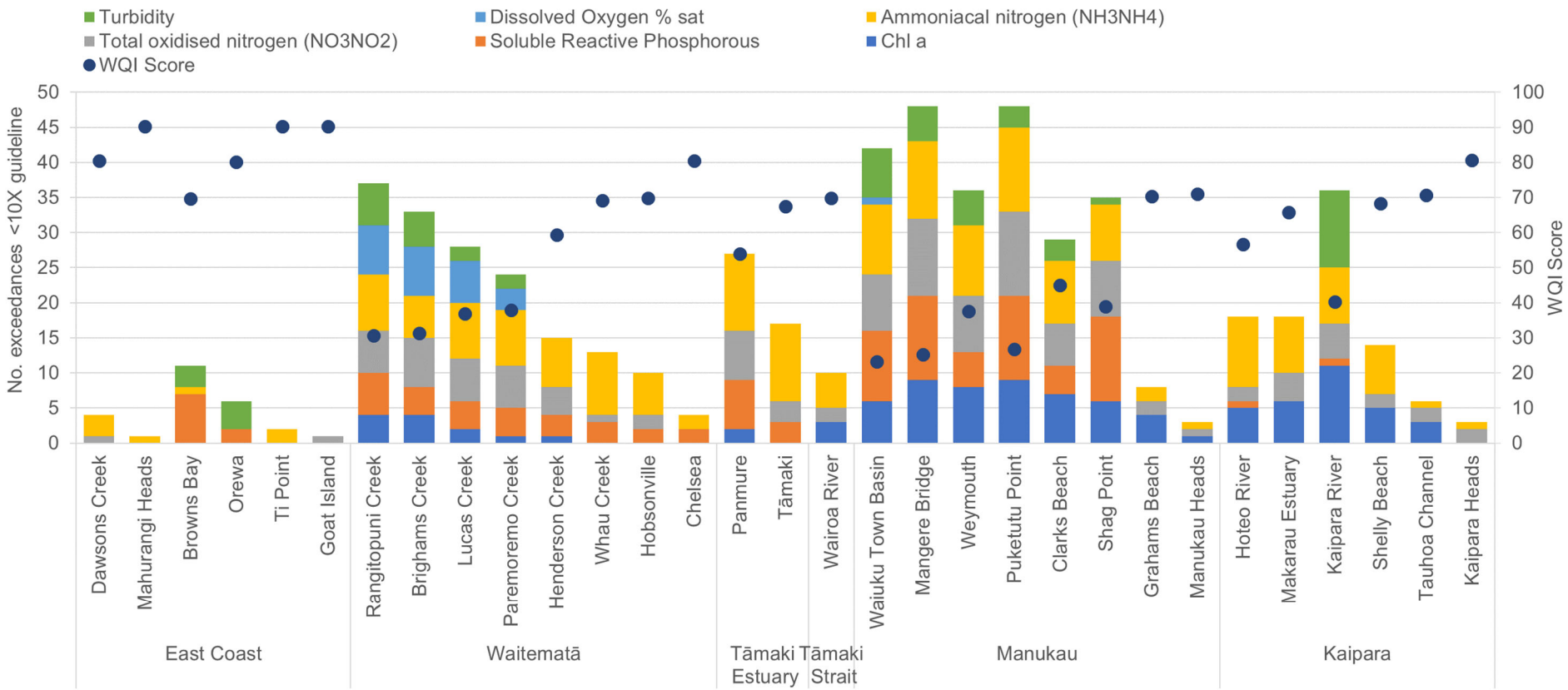


Figure 3-11: Water Quality Index score and summary of number of exceedances <10x the relevant guideline value per site (2016-2018 median values).

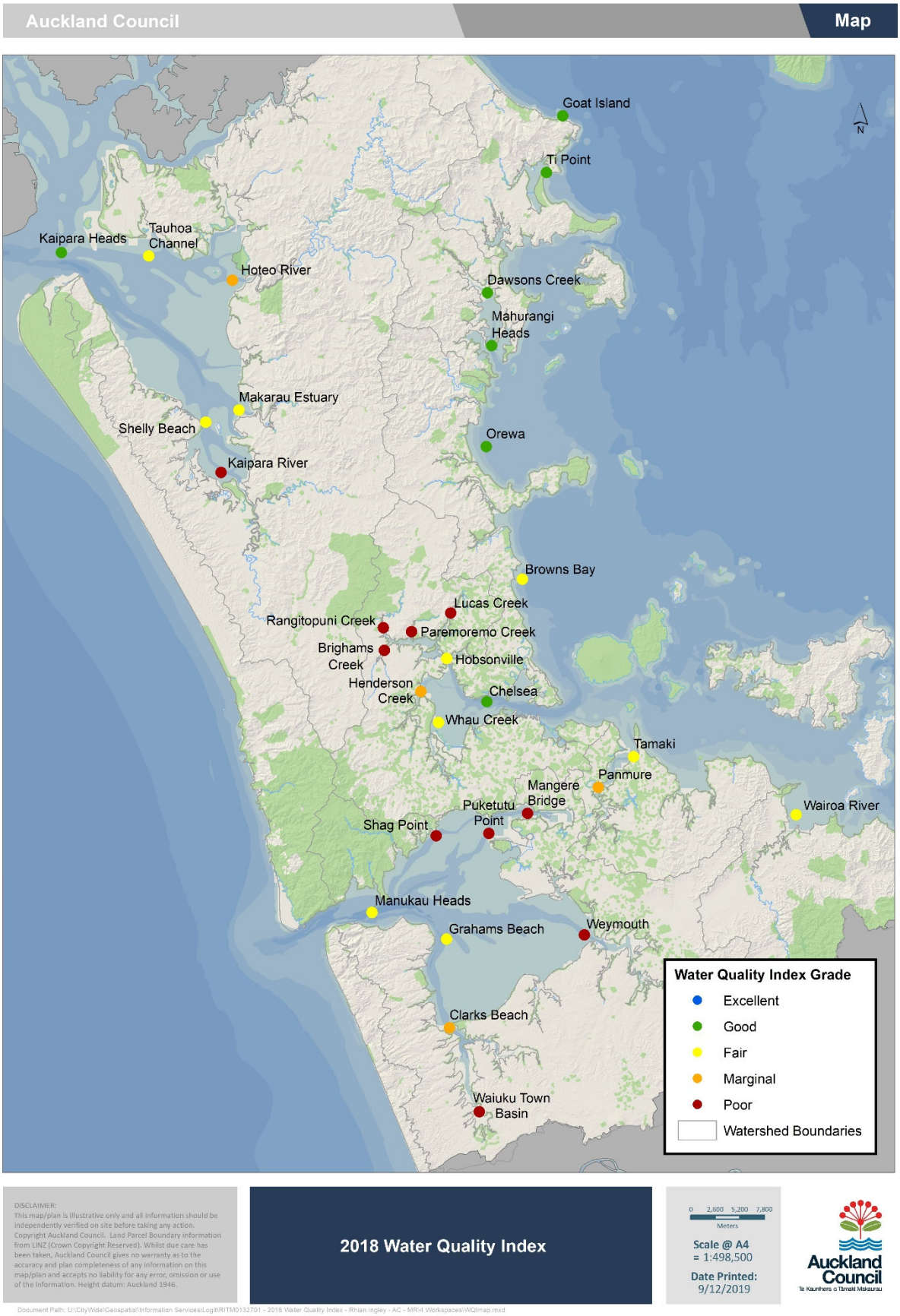


Figure 3-12: Overall water quality grade at coastal and estuarine water quality sites

### 3.2.2 Area water quality

Exceedances greater than 10 times the guideline value were only observed within the Manukau Harbour. The vast majority of exceedances of the relevant water quality guidelines were less than 10 times the guideline value and the discussion below is in relation to this level of exceedance unless expressly specified.

#### 3.2.2.1 East Coast

The northern east coast sites, Goat Island, Ti Point, and Mahurangi, were all 'good' to 'excellent'. Note that Mahurangi Heads and Dawsons Creek are compared to the estuarine guideline whilst all other sites are compared to the open coast guideline. These northern sites had a low frequency of exceedances for total oxidised nitrogen and ammoniacal nitrogen however the latter is anomalous for the 2016 to 2018 period and is likely laboratory induced (see section 2.7.1 and Figure 3-13). The previous two years of rolling median values also had a low frequency of exceedances of chlorophyll α, the lack of exceedances in the most recent period is also likely a laboratory artefact.

Orewa and Browns Bay sites had low to moderate frequency of exceedances of turbidity and soluble reactive phosphorus respectively. It is noted that the open coast guideline for turbidity is very low. Maximum turbidity at these sites was <2.5 NTU which is well below the lower interquartile range for open coast sites across New Zealand (Dudley *et al*., 2018). The lower total water quality class at Browns Bay is therefore primarily associated with elevated soluble reactive phosphorus.

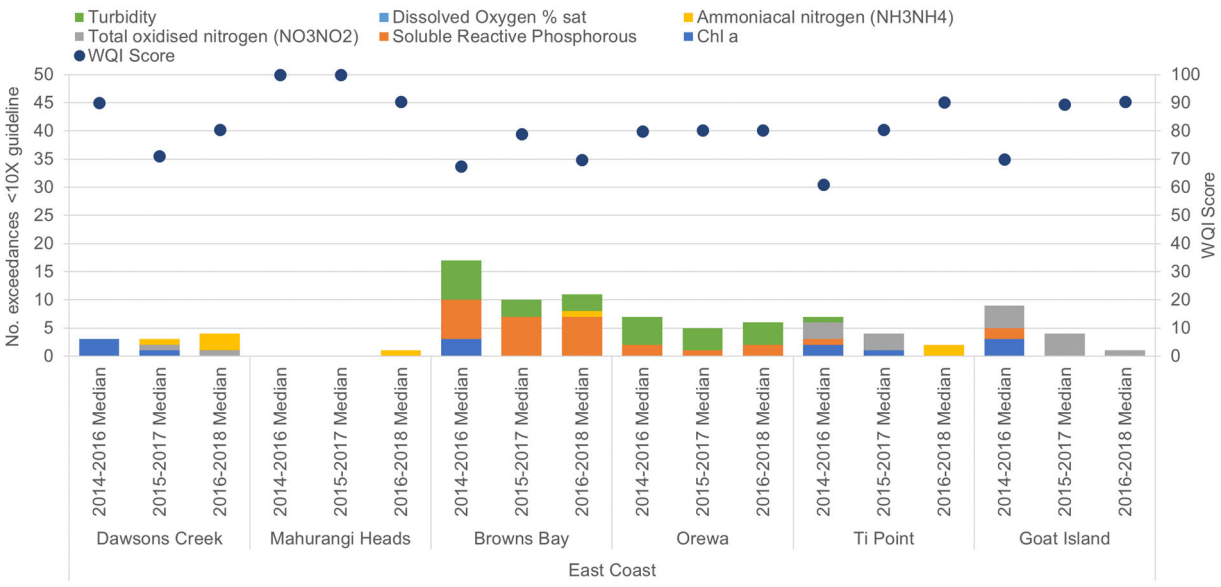


Figure 3-13:Variation in number of exceedances (<10x guideline value) over time for sites within the East Coast based on rolling three year median values.

### 3.2.2.2 Waitematā Harbour

The central and upper Waitematā Harbour sites show an obvious distinction in overall water quality scores and associated exceedances (Figure 3-14).

Central Waitematā sites had a low frequency of exceedances across all nutrient and chlorophyll parameters suggesting moderate nutrient enrichment at these sites.

The upper tidal creeks had a moderate frequency of exceedances across all six parameters resulting in 'poor' water quality. These four sites are the only locations in the 2016 to 2018 period that exceeded dissolved oxygen guidelines (primarily due to low DO%).

Moderate frequency of exceedances of ammoniacal nitrogen occurred at all sites within the Waitematā across the rolling five-year period, suggesting that this is a real exceedance, not associated with the laboratory change issue1.

No obvious patterns were observed in changes to these exceedances over time. Tidal creek environments are subject to greater freshwater influences and are poorly flushed, particularly with regard to the well mixed harbour mouth reference conditions that the estuarine guidelines are based on.

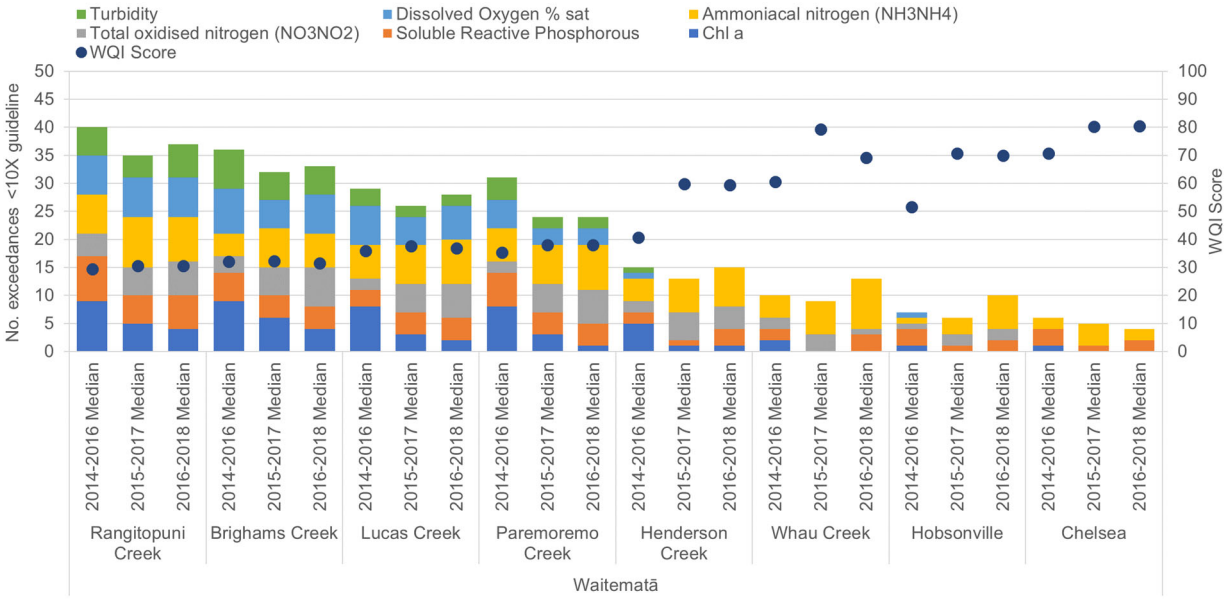


Figure 3-14:Variation in number of exceedances (<10x guideline value) over time for sites within the Waitematā based on rolling three year median values.

[1] It is noted that all concentrations of ammoniacal nitrogen were well below the ANZECC trigger value for total ammoniacal nitrogen (pH adjusted) in relation to chronic ammonia ($NH_3$) toxicity (ANZECC 2000).

### 3.2.2.3 Tāmaki Estuary and Tāmaki Strait

Exceedances for soluble reactive phosphorus and total oxidised nitrogen were moderately frequent at Panmure with fewer exceedances at the downstream Tāmaki site. While concentrations of ammoniacal nitrogen also decrease from Panmure to Tāmaki, they remain above the WQI guideline value and both sites exhibited a moderate frequency of exceedances of ammoniacal nitrogen[1]. Consistency in the frequency of exceedances over time (pre and post lab change) suggest that elevated ammoniacal nitrogen at these sites are not a laboratory artefact (Figure 3-15).

The surrounding catchments draining to these sites are predominantly urban (>60 per cent of the entire Tāmaki watershed, and approximately >85 per cent upstream of Panmure). In urban environments, most contaminants enter water bodies through stormwater and wastewater networks such as through sewage overflows, illegal connections, and leaky pipes and connections (MfE, 2017).

In addition to elevated nutrients, the Panmure site also had a low frequency of exceedances for chlorophyll α, turbidity, and dissolved oxygen. As noted above, this resulted in an overall lower water quality score at this site than anticipated relative to salinity. It appears that turbidity and dissolved oxygen have improved over time with no exceedances for these parameters in the 2016 to 2018 period.

Wairoa River had 'fair' water quality. The most common exceedances at this site were for ammoniacal nitrogen, with low frequency exceedances of total oxidised nitrogen, and chlorophyll α. It appears that there have also been improvements in turbidity over time at this site (Figure 3-15).

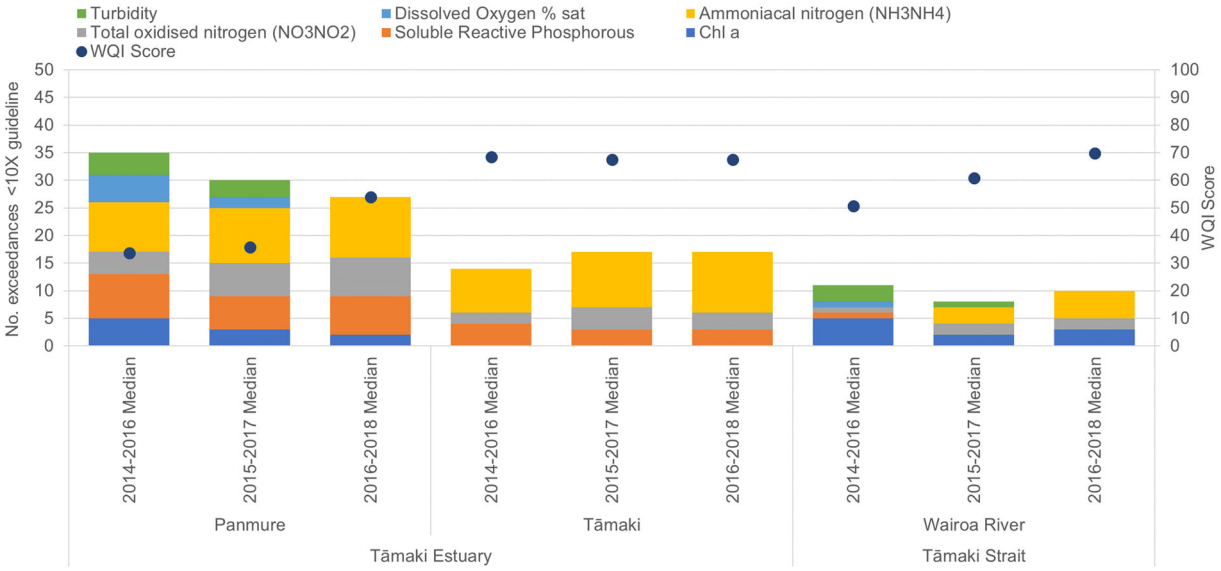


Figure 3-15:Variation in number of exceedances (<10x guideline value) over time for sites within the Tāmaki Estuary and at Wairoa based on rolling three year median values.

#### 3.2.2.4 Manukau Harbour

Chronic high concentrations of all nutrient parameters and chlorophyll α (frequent <10x magnitude exceedances) occur at five of the eight sites monitored within the Manukau Harbour (Figure 3-16).

Four of these sites, Mangere Bridge, Waiuku Town Basin, Puketutu Point, and Weymouth, also had very high magnitude exceedances (*greater* than 10 times the guideline values) for total oxidised nitrogen, and one very high magnitude exceedance of ammoniacal nitrogen[1] (at Mangere Bridge) (not shown in Figure 3-16). The most frequent high magnitude exceedances were for total oxidised nitrogen at Mangere Bridge and at Waiuku Town Basin. The number of high magnitude exceedances increased between the 2014 to 2016 and 2015 to 2017 rolling periods and generally occurred within the winter months (June to August).

Whilst the high nutrient conditions appear to be relatively diluted or mixed at the more central harbour site (Grahams Beach), and harbour mouth site (Manukau Heads), a low to moderate frequency of exceedances (<10X) for chlorophyll was still observed at these sites which is likely associated with uptake of the high nutrient inputs (Figure 3-16).

As noted above six of the sites within the Manukau Harbour had poorer water quality than expected given the salinity (and anticipated degree of mixing) at these sites. This included all ‘poor’ sites with chronic high concentrations and very high magnitude exceedances, as well as Clarks Beach which had a moderate frequency of exceedances across all nutrient and chlorophyll parameters resulting in a ‘marginal’ classification.

Three of these sites (Mangere Bridge, Puketutu Point, Shag Point) are located adjacent to the Mangere Wastewater Treatment Plant which services 76 per cent of Auckland’s population (Watercare Services Ltd, 2018). The Weymouth site is located at the mouth of the Pahurehure Inlet and integrates inputs from both highly urban catchments, and high intensity rural catchments including the dominant market gardening region in Auckland (AssureQuality, 2018). It is noted that the Waiuku Wastewater Treatment Plant discharge is located downstream of the town basin monitoring site and there are three significant stream inflows to the estuary from both urban and rural catchments (Mills, 2014). The Clarks Beach site is located at the mouth of the Waiuku and Taihiki Estuaries which include the small urban area of Waiuku town and high intensity rural land use including dairy, beef farming, and extensive market gardening (AssureQuality, 2018). The small Clarks Beach treatment plant also discharges to the mouth of the Waiuku Estuary. Resource consent has been granted for a new wastewater treatment plant that will service Waiuku, Clarks Beach and

Kingseat and replace the existing plants under Watercare Services Ltd 2018-2038 Asset Management Plan (collectively servicing <1% of Auckland's population) (Watercare Services Ltd 2018).

A comprehensive hydrodynamic and water quality model is currently being developed for the Manukau Harbour by Watercare to clarify potential reasons for the poor water quality at these six sites (Watercare Services Ltd 2019).

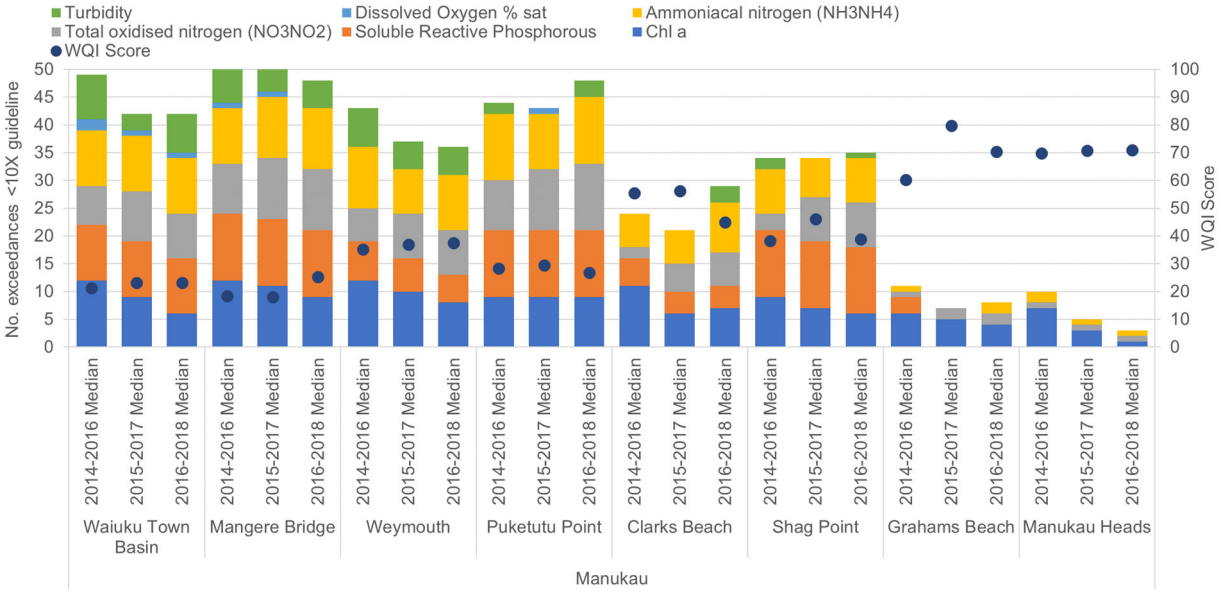


Figure 3-16:Variation in number of exceedances (<10x guideline value) over time for sites within the Manukau Harbour based on rolling three year median values.

### 3.2.2.5 Kaipara Harbour

In contrast to the Waitematā and Manukau Harbours, Kaipara Harbour had no to minimal exceedances of soluble reactive phosphorus. The Kaipara Harbour had fewer exceedances of total oxidised nitrogen than the Waitematā but a higher frequency of chlorophyll α exceedances. Exceedances in ammoniacal nitrogen were consistent across the rolling five-year period suggesting that concentrations are chronically high within the Kaipara (Figure 3-17).

The effects of dilution and dispersion are also evident with water quality improving from the river mouth sites to Tauhoa Channel and returning to 'good' at the Kaipara Heads.

The Kaipara River site was noted to have poorer water quality than expected given the median salinity at the site. This appears to be primarily driven by a high frequency of turbidity exceedances. Turbidity was much more strongly correlated with total suspended solids ($r$=0.93) at this site than for other sites within the Kaipara Harbour ($r$<0.7) and poorly correlated with chlorophyll α concentrations (similar to regional pairwise correlations, Scarsbrook (2008)). This suggests that the poor clarity at this

site is associated with high inorganic sediment concentrations. The Kaipara and Kaukapakapa rivers are the main local source of sediment to the southern Kaipara Harbour. Dispersion patterns indicate this sediment is generally deposited close to the source, and nitrogen and carbon signatures suggest the sediment input is predominantly from land based rather than marine sources (Gibbs, *et al*., 2012; Green and Daigneault 2018).

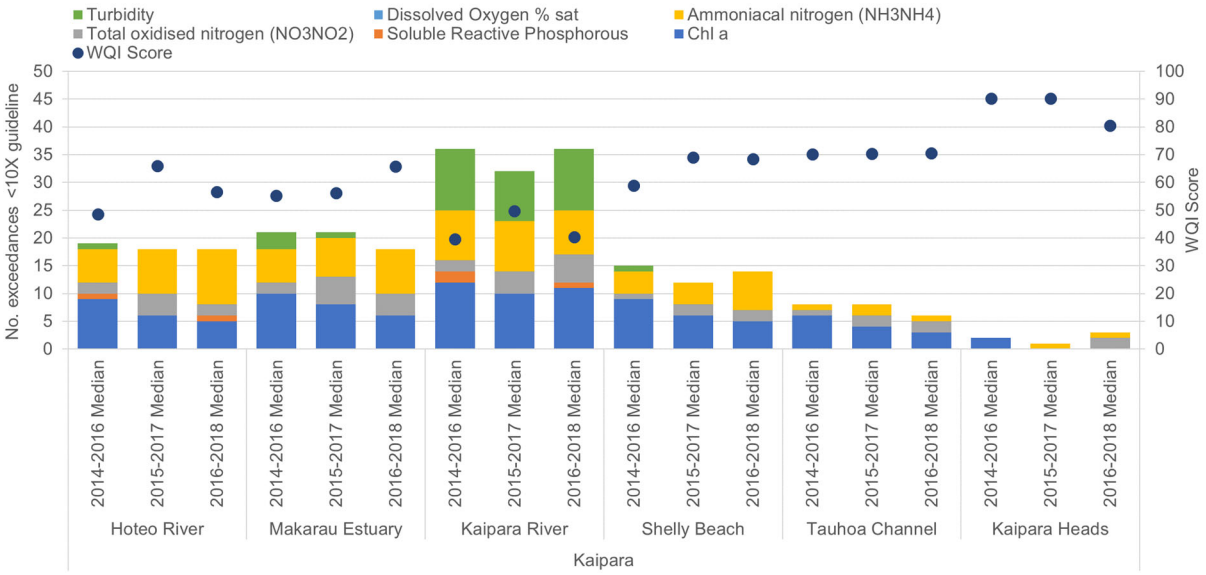


Figure 3-17:Variation in number of exceedances (<10x guideline value) over time for sites within the Kaipara Harbour based on rolling three year median values

# 4.0 Summary

Coastal and estuarine water quality has been monitored at sites across the Auckland region since 1987. Long-term monitoring is important for identifying trends in water quality parameters that are naturally highly variable between seasons and years, allowing better understanding of human induced change.

The most recent detailed state and trends report focused on trends occurring between 2007 and 2016. This showed that water quality was generally improving across the region, although many parameters still exceeded water quality guidelines (Foley, *et al*., 2018). Guideline values were exceeded most frequently in the Manukau and Kaipara harbours, particularly for total suspended sediment, total oxidised nitrogen, and total nitrogen concentrations (Foley, *et al.,* 2018). Sites in the upper Waitematā Harbour were generally found to have declining water quality due to increases in nutrients and suspended sediments (Foley, *et al.,* 2018).

The results of the 2018 annual data analysis are broadly consistent with this previous water quality trend analysis. It was found that water quality state has improved over the past five years with 35 per cent of sites improving by one water quality index class between the 2014-2016 and 2016-2018 periods. The parameters most frequently exceeded in the 2016 to 2018 period were ammoniacal nitrogen, total oxidised nitrogen, and soluble reactive phosphorus (note suspended sediments and total nitrogen were excluded from the WQI calculations in this analysis). Improvements in water quality were driven by a decreasing number of exceedances of guidelines for chlorophyll α, soluble reactive phosphorus, dissolved oxygen, and turbidity. Recent changes in chlorophyll α and ammoniacal nitrogen appear to be influenced by changes in laboratory analysis methodology.

Water quality state across the region is strongly related to median salinity, which is indicative of the proximity of a coastal or estuarine site to freshwater inputs, and the extent of flushing and dilution at the site. Several sites within the Manukau Harbour (including Mangere Bridge, Puketutu Point, Shag Point, Waiuku Town Basin, Clarks Beach and Weymouth), and one site in the Kaipara Harbour (Kaipara River) had poorer water quality than expected for the salinity of the site. In the Manukau Harbour this was primarily due to chronic, high concentrations of nutrients and chlorophyll α. At the Kaipara River, this was due to poor water clarity (turbidity).

Our WQI guidelines are not regulatory triggers or thresholds and are only used to enable comparison between sites and to identify potential directions for further investigation. Several of the parameters assessed show a seasonality to the incidence of exceedances, such as chlorophyll α in summer in the Waitematā Harbour, and total oxidised nitrogen (nitrite+nitrate) in winter (regionally). In the Hauraki Gulf, prevalent upwelling of nitrate and phosphorus is seen in spring and summer driving off the shelf from the north-east of the gulf (Zeldis *et al.,* 2013). This usually ceases in autumn (Zeldis *et al.,* 2013). Lower oceanic nitrate

concentrations over spring and summer are associated with thermal stratification and maximum uptake by phytoplankton. Nitrate concentrations therefore peak in winter associated with mixing from winter storms and low biological uptake.

The WQI provides a useful tool to summarise complex and interactive water quality variables into a single narrative statement. The strong influence of salinity on water quality state in the Auckland region suggests that further work should be undertaken to identify water quality guidelines that are relevant to more freshwater influenced environments such as the approach adopted by Northland Regional Council including open coast, estuary, and upper tidal creeks (Griffiths, 2016). It is also recommended that guidelines are reviewed with consideration of natural fluctuations (such as seasonality). The Manukau Harbour had several sites where water quality was poorer than expected. More detailed investigation of the causes of this will be enabled through analysis of the upcoming hydrodynamic and water quality model.

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# 6.0 Acknowledgements

The Auckland Council coastal water quality monitoring programme has benefitted from the efforts of numerous people since its inception in 1987. During the 2018 sampling season, special thanks to Peter Dal Ferro, Luke Stanley, Hamish Allen, and Nick Holwerda for organising and undertaking the sampling, and to Vanitha Pradeep and Jade Khin for data management and quality assurance processes.

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Thanks to Hill Laboratories for their services in laboratory analysis of these samples.

Thank you to Laura Buckthought and Coral Grant (Auckland Council), and Richard Griffiths (Northland Regional Council) for discussion and providing comments that improved this report.

# Appendix A Data tables

Table 6-1: Water Quality Index calculations over the past three years based on rolling three year median values.
Blue = Excellent, Green = Good, Yellow = Fair, Orange = Marginal, Red = Poor.

| Area | Site | WQI Score (2014-2016) | WQI Score (2015-2017) | WQI Score (2016-2018) |
|---|---|---|---|---|
| East Coast | Goat Island | 70 | 89.5 | 90.3 |
| | Ti Point | 61 | 80.4 | 90.2 |
| | Dawsons Creek | 89.9 | 71 | 80.5 |
| | Mahurangi Heads | 100 | 100 | 90.3 |
| | Orewa | 79.9 | 80.3 | 80.1 |
| | Browns Bay | 67.5 | 79 | 69.7 |
| Waitematā | Chelsea | 80.3 | 80.3 | 80.5 |
| | Whau Creek | 60.6 | 79.4 | 69.2 |
| | Henderson Creek | 40.7 | 59.8 | 59.4 |
| | Hobsonville | 51.5 | 70.7 | 69.9 |
| | Lucas Creek | 35.9 | 37.7 | 36.9 |
| | Paremoremo Creek | 35.4 | 38 | 38 |
| | Brighams Creek | 32 | 32.2 | 31.4 |
| | Rangitopuni Creek | 29.5 | 30.5 | 30.6 |
| Tāmaki Estuary | Tāmaki | 68.5 | 67.5 | 67.4 |
| | Panmure | 33.6 | 35.7 | 53.9 |
| Tāmaki Strait | Wairoa River | 50.6 | 60.7 | 69.9 |
| Manukau | Mangere Bridge | 18.3 | 18 | 25.2 |
| | Puketutu Point | 28.3 | 29.5 | 26.8 |
| | Weymouth | 35.3 | 37 | 37.5 |
| | Waiuku Town Basin | 21.2 | 23.2 | 23.2 |
| | Clarks Beach | 55.5 | 56.3 | 45 |
| | Grahams Beach | 60.2 | 79.7 | 70.3 |
| | Shag Point | 38.2 | 46 | 38.9 |
| | Manukau Heads | 69.8 | 70.8 | 71 |
| Kaipara | Kaipara Heads | 90.2 | 90.3 | 80.6 |
| | Tauhoa Channel | 70.2 | 70.4 | 70.6 |
| | Hoteo River | 48.7 | 66 | 56.7 |
| | Makarau Estuary | 55.3 | 56.3 | 65.8 |
| | Shelly Beach | 59 | 68.9 | 68.4 |
| | Kaipara River | 39.6 | 49.8 | 40.3 |

Table 6-2: Dissolved oxygen (% saturation) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 86.6 | 99.6 | 91.4 | 94.3 | 96.1 |
| | Mahurangi Heads | 12 | 95.4 | 104.4 | 96.7 | 98.5 | 98.8 |
| | Browns Bay | 12 | 93.3 | 108.9 | 97.5 | 100.4 | 106.8 |
| | Orewa | 12 | 97.6 | 106.2 | 99.2 | 100.6 | 104.1 |
| | Ti Point | 12 | 97.9 | 110 | 98.8 | 101 | 103.4 |
| | Goat Island | 12 | 97.8 | 106.3 | 98.9 | 100.2 | 103.9 |
| Waitematā | Rangitopuni Creek | 12 | 77.2 | 107 | 84.4 | 88.9 | 96.8 |
| | Brighams Creek | 12 | 79.4 | 102.6 | 84.6 | 90.2 | 94.8 |
| | Lucas Creek | 12 | 80 | 101.8 | 83.6 | 88.4 | 90.9 |
| | Paremoremo Creek | 12 | 82.4 | 97.8 | 87.2 | 91.9 | 95.4 |
| | Henderson Creek | 12 | 88.9 | 96.4 | 91.1 | 93.4 | 94.1 |
| | Whau Creek | 12 | 91.9 | 101.1 | 92.7 | 94.7 | 96 |
| | Hobsonville | 12 | 92.7 | 99.9 | 93.3 | 95.8 | 97.3 |
| | Chelsea | 12 | 93.6 | 98.6 | 94.7 | 95.8 | 97.4 |
| Tāmaki | Panmure | 11 | 90.1 | 101.2 | 92.2 | 95.4 | 97.8 |
| | Tāmaki | 11 | 92.9 | 101.1 | 93.5 | 95.3 | 97.7 |
| | Wairoa River | 12 | 94.1 | 107.3 | 96 | 98.5 | 103.7 |
| Manukau | Waiuku Town Basin | 12 | 74.3 | 101.8 | 88.9 | 93 | 94.9 |
| | Mangere Bridge | 11 | 89.3 | 122.7 | 93.2 | 96.1 | 98.9 |
| | Weymouth | 12 | 92.1 | 116.2 | 94 | 95.9 | 99.6 |
| | Puketutu Point | 11 | 95.8 | 113.5 | 97.1 | 100 | 106.5 |
| | Clarks Beach | 12 | 94.3 | 104.6 | 95 | 96.2 | 99.7 |
| | Shag Point | 12 | 95 | 115.3 | 98.3 | 100.9 | 105.2 |
| | Grahams Beach | 12 | 96.3 | 112 | 99.5 | 102.4 | 102.9 |
| | Manukau Heads | 12 | 97.5 | 107.5 | 99.5 | 101.1 | 103.3 |
| Kaipara | Hoteo River | 12 | 86.4 | 100.1 | 94 | 96.1 | 98.6 |
| | Makarau Estuary | 12 | 91.2 | 108.3 | 93.6 | 95.8 | 100 |
| | Kaipara River | 12 | 90.2 | 115.8 | 92.3 | 94 | 97.1 |
| | Shelly Beach | 12 | 94.5 | 105.2 | 95.1 | 96.6 | 99.4 |
| | Tauhoa Channel | 12 | 96.9 | 113.2 | 99.4 | 100.6 | 103.4 |
| | Kaipara Heads | 12 | 100.2 | 104.8 | 101.8 | 102.6 | 104.1 |

Table 6-3: Dissolved oxygen (ppm) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 6.36 | 8.46 | 6.51 | 7.26 | 8.04 |
| | Mahurangi Heads | 12 | 6.66 | 8.3 | 6.91 | 7.65 | 8.19 |
| | Browns Bay | 12 | 6.56 | 8.43 | 7.28 | 8.12 | 8.24 |
| | Orewa | 12 | 6.84 | 8.4 | 7.26 | 7.85 | 8.26 |
| | Ti Point | 12 | 7.05 | 8.54 | 7.26 | 7.91 | 8.23 |
| | Goat Island | 12 | 7.14 | 8.31 | 7.28 | 7.87 | 8.19 |
| Waitematā | Rangitopuni Creek | 11 | 6.37 | 9.35 | 6.77 | 7.05 | 9.16 |
| | Brighams Creek | 11 | 6.4 | 9.09 | 6.72 | 6.9 | 8.4 |
| | Lucas Creek | 11 | 6.57 | 8.65 | 6.67 | 7.04 | 7.88 |
| | Paremoremo Creek | 11 | 6.31 | 8.95 | 6.77 | 7.08 | 8.07 |
| | Henderson Creek | 11 | 6.27 | 8.86 | 6.85 | 7.12 | 8.13 |
| | Whau Creek | 11 | 6.51 | 9.32 | 7 | 7.31 | 8.21 |
| | Hobsonville | 11 | 6.47 | 8.9 | 7.17 | 7.35 | 8.22 |
| | Chelsea | 11 | 6.51 | 8.4 | 7.14 | 7.51 | 8.21 |
| Tāmaki | Panmure | 11 | 6.76 | 8.34 | 7.04 | 7.17 | 8.06 |
| | Tāmaki | 11 | 6.69 | 8.21 | 7 | 7.25 | 8.04 |
| | Wairoa River | 12 | 6.61 | 8.7 | 7.25 | 7.74 | 8.24 |
| Manukau | Waiuku Town Basin | 12 | 5.48 | 9.06 | 6.79 | 7.25 | 8.26 |
| | Mangere Bridge | 11 | 6.88 | 9.05 | 7.14 | 7.49 | 8.86 |
| | Weymouth | 12 | 6.96 | 8.9 | 7.31 | 7.95 | 8.3 |
| | Puketutu Point | 12 | 7.02 | 9.94 | 7.5 | 7.96 | 8.48 |
| | Clarks Beach | 12 | 6.68 | 8.96 | 7.03 | 7.52 | 8.28 |
| | Shag Point | 12 | 7.18 | 9.38 | 7.5 | 8.02 | 8.41 |
| | Grahams Beach | 12 | 7.2 | 9.05 | 7.46 | 8.08 | 8.51 |
| | Manukau Heads | 12 | 7.22 | 8.77 | 7.56 | 7.83 | 8.42 |
| Kaipara | Hoteo River | 12 | 6.3 | 9.12 | 6.99 | 7.73 | 8.64 |
| | Makarau Estuary | 12 | 6.58 | 8.89 | 7.18 | 7.69 | 8.56 |
| | Kaipara River | 12 | 6.81 | 8.77 | 6.92 | 7.95 | 8.35 |
| | Shelly Beach | 12 | 6.87 | 8.72 | 7.15 | 7.72 | 8.39 |
| | Tauhoa Channel | 12 | 7.31 | 8.88 | 7.42 | 8.24 | 8.61 |
| | Kaipara Heads | 12 | 7.37 | 8.75 | 7.53 | 8.02 | 8.5 |

Table 6-4: Summary table of temperature (°C) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | **Dawsons Creek** | 12 | 12.89 | 24.24 | 14.24 | 18.42 | 22.91 |
| | **Mahurangi Heads** | 12 | 13.51 | 23.14 | 14.31 | 18.47 | 22.61 |
| | **Browns Bay** | 12 | 13.76 | 23.96 | 14.39 | 18.41 | 22.62 |
| | **Orewa** | 12 | 13.76 | 23.84 | 14.5 | 18.75 | 22.83 |
| | **Ti Point** | 12 | 14.13 | 22.77 | 14.87 | 17.97 | 21.43 |
| | **Goat Island** | 12 | 14.4 | 22.97 | 15.21 | 18.04 | 21.26 |
| Waitematā | **Rangitopuni Creek** | 12 | 10.8 | 25.1 | 13.3 | 18.14 | 21.29 |
| | **Brighams Creek** | 12 | 10.89 | 26.24 | 13.71 | 18.16 | 21.7 |
| | **Lucas Creek** | 12 | 10.87 | 25.05 | 13.43 | 18.25 | 21.84 |
| | **Paremoremo Creek** | 12 | 11.53 | 25.95 | 13.66 | 18.25 | 21.64 |
| | **Henderson Creek** | 12 | 11.4 | 25.29 | 13.56 | 18.29 | 20.89 |
| | **Whau Creek** | 12 | 11.13 | 25.14 | 13.41 | 18.47 | 20.85 |
| | **Hobsonville** | 12 | 12.29 | 24.47 | 13.69 | 18.44 | 20.85 |
| | **Chelsea** | 12 | 12.94 | 24.14 | 14.4 | 18.5 | 20.93 |
| Tāmaki | **Panmure** | 11 | 13.46 | 25.42 | 14.49 | 18.59 | 21.81 |
| | **Tāmaki** | 11 | 13.29 | 24.48 | 14.6 | 18.95 | 22.03 |
| | **Wairoa River** | 12 | 12.46 | 25.23 | 14.59 | 19.04 | 23.32 |
| Manukau | **Waiuku Town Basin** | 12 | 10.49 | 25.32 | 13.33 | 17.84 | 22.47 |
| | **Mangere Bridge** | 11 | 10.85 | 25.28 | 13.14 | 17.8 | 21.79 |
| | **Weymouth** | 12 | 11.1 | 24.17 | 13.24 | 17.43 | 22.24 |
| | **Puketutu Point** | 12 | 11.13 | 24.8 | 13.56 | 18.11 | 22.39 |
| | **Clarks Beach** | 12 | 11.83 | 23.19 | 13.54 | 17.37 | 22.04 |
| | **Shag Point** | 12 | 11.31 | 24.39 | 13.4 | 17.75 | 21.9 |
| | **Grahams Beach** | 12 | 12.36 | 22.94 | 13.64 | 17.55 | 21.84 |
| | **Manukau Heads** | 12 | 12.92 | 21.42 | 13.78 | 17.89 | 21.13 |
| Kaipara | **Hoteo River** | 12 | 10.88 | 23.9 | 12.98 | 17.68 | 22.56 |
| | **Makarau Estuary** | 12 | 11.24 | 24.83 | 12.8 | 17.31 | 22.7 |
| | **Kaipara River** | 12 | 11.19 | 23.81 | 13.28 | 17.53 | 22.72 |
| | **Shelly Beach** | 12 | 11.87 | 23.23 | 13.57 | 17.5 | 22.45 |
| | **Tauhoa Channel** | 12 | 13 | 22.84 | 13.77 | 17.31 | 21.64 |
| | **Kaipara Heads** | 12 | 14.12 | 22.14 | 14.27 | 17.32 | 20.47 |

Table 6-5: Electrical conductivity (mS.cm-1) for data collected January 2018 to December 2018.

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 42.75 | 52.89 | 48.34 | 50.53 | 52.08 |
| | Mahurangi Heads | 12 | 49.78 | 54.14 | 50.23 | 52.01 | 53.43 |
| | Browns Bay | 12 | 50.5 | 54.24 | 50.93 | 51.91 | 52.77 |
| | Orewa | 12 | 50.85 | 54.24 | 51.36 | 52.45 | 53.25 |
| | Ti Point | 12 | 50.47 | 54.66 | 51.62 | 52.4 | 53.14 |
| | Goat Island | 12 | 51.5 | 54.68 | 51.8 | 52.65 | 53.39 |
| Waitematā | Rangitopuni Creek | 12 | 21.16 | 45.05 | 25.92 | 32.38 | 43.83 |
| | Brighams Creek | 12 | 26.28 | 47.28 | 32.19 | 36.93 | 45.25 |
| | Lucas Creek | 12 | 19.95 | 48.19 | 36.56 | 40.65 | 46.21 |
| | Paremoremo Creek | 12 | 37.19 | 49.37 | 38.44 | 42.2 | 47.5 |
| | Henderson Creek | 12 | 42.68 | 50.59 | 45.13 | 46.7 | 49.76 |
| | Whau Creek | 12 | 43.56 | 50.7 | 45 | 47.3 | 49.84 |
| | Hobsonville | 12 | 45.39 | 51.79 | 46.69 | 48.51 | 50.96 |
| | Chelsea | 12 | 48.06 | 53.53 | 48.76 | 50.7 | 51.85 |
| Tāmaki | Panmure | 11 | 36.36 | 50.08 | 42.3 | 47.07 | 49.48 |
| | Tāmaki | 11 | 44.61 | 52.1 | 47.28 | 49.69 | 51.39 |
| | Wairoa River | 12 | 45.11 | 51.31 | 47.84 | 49.46 | 50.4 |
| Manukau | Waiuku Town Basin | 12 | 31.31 | 50.32 | 40.61 | 45.24 | 47.29 |
| | Mangere Bridge | 11 | 37.28 | 52.07 | 42.85 | 45.37 | 48.07 |
| | Weymouth | 12 | 36.65 | 52.27 | 43.58 | 48.77 | 49.78 |
| | Puketutu Point | 12 | 42.89 | 51.52 | 45.47 | 48.04 | 49.16 |
| | Shag Point | 12 | 45.1 | 53.35 | 47 | 50.03 | 50.43 |
| | Clarks Beach | 12 | 45.04 | 53.54 | 47.09 | 49.85 | 50.66 |
| | Manukau Heads | 12 | 48.61 | 53.79 | 49.7 | 51.58 | 51.79 |
| | Grahams Beach | 12 | 47.62 | 53.92 | 48.43 | 50.61 | 51.22 |
| Kaipara | Hoteo River | 12 | 29.58 | 49.62 | 42.21 | 46.45 | 49.25 |
| | Makarau Estuary | 12 | 36.78 | 51.93 | 40.02 | 47.52 | 49.67 |
| | Kaipara River | 12 | 34.97 | 51.95 | 41.02 | 47.11 | 48.97 |
| | Shelly Beach | 12 | 39.6 | 52.52 | 43.77 | 47.85 | 49.94 |
| | Tauhoa Channel | 12 | 41.3 | 53.35 | 46.1 | 48.6 | 50.65 |
| | Kaipara Heads | 12 | 49.39 | 54.07 | 50.81 | 52.18 | 52.89 |

Table 6-6: Salinity (ppt) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | **Dawsons Creek** | 12 | 27.55 | 34.89 | 31.5 | 33.18 | 34.32 |
| | **Mahurangi Heads** | 12 | 32.64 | 35.84 | 32.92 | 34.28 | 35.32 |
| | **Browns Bay** | 12 | 33.09 | 35.91 | 33.42 | 34.19 | 34.84 |
| | **Orewa** | 12 | 33.35 | 35.91 | 33.75 | 34.61 | 35.19 |
| | **Ti Point** | 12 | 33.13 | 36.24 | 33.93 | 34.56 | 35.11 |
| | **Goat Island** | 12 | 33.9 | 36.26 | 34.09 | 34.75 | 35.29 |
| Waitematā | **Rangitopuni Creek** | 12 | 12.73 | 29.19 | 15.83 | 20.23 | 28.33 |
| | **Brighams Creek** | 12 | 16.08 | 30.81 | 20.08 | 23.39 | 29.32 |
| | **Lucas Creek** | 12 | 11.91 | 31.47 | 23.16 | 26.03 | 30.02 |
| | **Paremoremo Creek** | 12 | 23.6 | 32.34 | 24.42 | 27.1 | 30.97 |
| | **Henderson Creek** | 12 | 27.38 | 33.24 | 29.19 | 30.37 | 32.62 |
| | **Whau Creek** | 12 | 27.99 | 33.32 | 29.08 | 30.81 | 32.67 |
| | **Hobsonville** | 12 | 29.34 | 34.07 | 30.36 | 31.69 | 33.51 |
| | **Chelsea** | 12 | 31.39 | 35.37 | 31.83 | 33.29 | 34.17 |
| Tāmaki | **Panmure** | 11 | 23 | 32.86 | 27.23 | 30.66 | 32.38 |
| | **Tāmaki** | 11 | 28.82 | 34.34 | 30.77 | 32.58 | 33.77 |
| | **Wairoa River** | 12 | 29.22 | 33.76 | 31.16 | 32.41 | 33.06 |
| Manukau | **Waiuku Town Basin** | 12 | 19.44 | 32.96 | 25.99 | 29.34 | 30.82 |
| | **Mangere Bridge** | 11 | 23.56 | 34.26 | 27.55 | 29.44 | 31.4 |
| | **Weymouth** | 12 | 23.13 | 34.43 | 28.05 | 31.9 | 32.64 |
| | **Puketutu Point** | 12 | 27.51 | 33.86 | 29.45 | 31.35 | 32.19 |
| | **Clarks Beach** | 12 | 29.07 | 35.39 | 30.62 | 32.69 | 33.27 |
| | **Shag Point** | 12 | 29.09 | 35.22 | 30.55 | 32.82 | 33.08 |
| | **Grahams Beach** | 12 | 30.95 | 35.67 | 31.59 | 33.24 | 33.68 |
| | **Manukau Heads** | 12 | 31.69 | 35.6 | 32.51 | 33.96 | 34.12 |
| Kaipara | **Hoteo River** | 12 | 18.29 | 32.48 | 27.11 | 30.18 | 32.22 |
| | **Makarau Estuary** | 12 | 23.23 | 34.16 | 25.54 | 30.98 | 32.54 |
| | **Kaipara River** | 12 | 21.97 | 34.2 | 26.26 | 30.67 | 32.03 |
| | **Shelly Beach** | 12 | 25.22 | 34.63 | 28.23 | 31.22 | 32.74 |
| | **Tauhoa Channel** | 12 | 26.45 | 35.26 | 29.92 | 31.74 | 33.29 |
| | **Kaipara Heads** | 12 | 32.3 | 35.81 | 33.34 | 34.4 | 34.93 |

Table 6-7: pH (pH units) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 11 | 7.9 | 8.24 | 7.99 | 8.04 | 8.15 |
| | Mahurangi Heads | 11 | 8 | 8.28 | 8.09 | 8.11 | 8.18 |
| | Browns Bay | 11 | 8 | 8.32 | 8.11 | 8.18 | 8.24 |
| | Orewa | 11 | 8 | 8.31 | 8.13 | 8.16 | 8.22 |
| | Ti Point | 11 | 8 | 8.34 | 8.13 | 8.16 | 8.22 |
| | Goat Island | 11 | 8 | 8.32 | 8.12 | 8.15 | 8.24 |
| Waitematā | Rangitopuni Creek | 12 | 7.56 | 8.13 | 7.8 | 7.89 | 7.97 |
| | Brighams Creek | 11 | 7.7 | 8.14 | 7.74 | 7.9 | 7.93 |
| | Lucas Creek | 11 | 7.5 | 8.13 | 7.85 | 7.96 | 8.04 |
| | Paremoremo Creek | 11 | 7.88 | 8.12 | 7.9 | 7.98 | 8.01 |
| | Henderson Creek | 11 | 7.97 | 8.19 | 8 | 8 | 8.1 |
| | Whau Creek | 11 | 7.98 | 8.25 | 8 | 8.03 | 8.1 |
| | Hobsonville | 11 | 8 | 8.23 | 8.03 | 8.1 | 8.14 |
| | Chelsea | 11 | 8 | 8.23 | 8.07 | 8.1 | 8.16 |
| Tāmaki | Panmure | 11 | 7.41 | 8.15 | 7.91 | 8 | 8.11 |
| | Tāmaki | 11 | 7.94 | 8.24 | 8.04 | 8.1 | 8.15 |
| | Wairoa River | 11 | 8 | 8.33 | 8.09 | 8.18 | 8.2 |
| Manukau | Waiuku Town Basin | 12 | 7.84 | 8.23 | 7.99 | 8.01 | 8.11 |
| | Mangere Bridge | 12 | 7.96 | 8.27 | 8.01 | 8.1 | 8.17 |
| | Weymouth | 12 | 8 | 8.27 | 8.11 | 8.14 | 8.21 |
| | Puketutu Point | 12 | 8 | 8.27 | 8.06 | 8.18 | 8.24 |
| | Clarks Beach | 12 | 8 | 8.24 | 8.08 | 8.12 | 8.2 |
| | Shag Point | 12 | 8 | 8.31 | 8.11 | 8.21 | 8.28 |
| | Grahams Beach | 12 | 8 | 8.31 | 8.13 | 8.22 | 8.26 |
| | Manukau Heads | 12 | 8 | 8.34 | 8.1 | 8.23 | 8.26 |
| Kaipara | Hoteo River | 12 | 7.9 | 8.2 | 8.02 | 8.06 | 8.13 |
| | Makarau Estuary | 12 | 7.9 | 8.15 | 8 | 8.08 | 8.1 |
| | Kaipara River | 12 | 7.8 | 8.1 | 7.98 | 8 | 8.08 |
| | Shelly Beach | 12 | 7.9 | 8.2 | 8.04 | 8.09 | 8.15 |
| | Tauhoa Channel | 12 | 8 | 8.37 | 8.1 | 8.13 | 8.21 |
| | Kaipara Heads | 12 | 8 | 8.3 | 8.1 | 8.19 | 8.25 |

Table 6-8: Turbidity (NTU) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 3.2 | 6.8 | 3.78 | 4.85 | 5.75 |
| | Mahurangi Heads | 12 | 1.3 | 3.6 | 1.66 | 2.08 | 2.5 |
| | Browns Bay | 12 | 0.36 | 2.4 | 0.64 | 0.94 | 1.46 |
| | Orewa | 12 | 0.45 | 2.4 | 0.49 | 0.67 | 0.94 |
| | Ti Point | 12 | 0.24 | 2.2 | 0.36 | 0.42 | 0.72 |
| | Goat Island | 12 | 0.18 | 0.82 | 0.2 | 0.3 | 0.5 |
| Waitematā | Rangitopuni Creek | 12 | 4.6 | 21 | 5.88 | 8.7 | 9.9 |
| | Brighams Creek | 12 | 5.1 | 22 | 6.38 | 9 | 13.5 |
| | Lucas Creek | 12 | 4.4 | 115 | 5.33 | 7.65 | 14.1 |
| | Paremoremo Creek | 12 | 3.4 | 13.7 | 5.58 | 6.4 | 11.48 |
| | Henderson Creek | 12 | 2.4 | 14.9 | 4.3 | 5.95 | 8.45 |
| | Whau Creek | 12 | 1.11 | 16.4 | 2.12 | 4.95 | 7.18 |
| | Hobsonville | 12 | 1.5 | 13.1 | 2.68 | 4.6 | 5.05 |
| | Chelsea | 12 | 1.28 | 8.4 | 1.97 | 3.4 | 4.68 |
| Tāmaki | Panmure | 11 | 3.6 | 9.5 | 4.9 | 5.8 | 7.8 |
| | Tāmaki | 11 | 1.11 | 2.4 | 1.41 | 1.88 | 2.3 |
| | Wairoa River | 12 | 2.9 | 6.3 | 3.63 | 4.6 | 5.05 |
| Manukau | Waiuku Town Basin | 12 | 5.6 | 16 | 7.28 | 10.2 | 14.38 |
| | Mangere Bridge | 11 | 5.4 | 28 | 6.8 | 10.1 | 22 |
| | Weymouth | 12 | 7.7 | 33 | 8.48 | 12.2 | 15.3 |
| | Puketutu Point | 11 | 1.64 | 18.9 | 3.9 | 5.2 | 10.8 |
| | Clarks Beach | 12 | 3.4 | 10.8 | 4.68 | 6.75 | 10.03 |
| | Shag Point | 12 | 1.92 | 20 | 3.35 | 5.1 | 8.48 |
| | Grahams Beach | 12 | 2.4 | 11.2 | 3.15 | 3.75 | 6 |
| | Manukau Heads | 12 | 1.15 | 6.7 | 1.52 | 2 | 3.05 |
| Kaipara | Hoteo River | 12 | 2.8 | 45 | 3.5 | 4.65 | 7.78 |
| | Makarau Estuary | 12 | 3.7 | 9.2 | 4.43 | 6.6 | 7.73 |
| | Kaipara River | 12 | 10 | 33 | 11.98 | 14.95 | 20.78 |
| | Shelly Beach | 12 | 2.6 | 11.2 | 3.95 | 4.95 | 8.5 |
| | Tauhoa Channel | 12 | 0.66 | 6.7 | 1.1 | 1.88 | 3.9 |
| | Kaipara Heads | 12 | 0.36 | 3.3 | 0.92 | 1.23 | 2.8 |

Table 6-9: Suspended sediment (mg/L) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 5 | 12 | 6.5 | 9 | 10 |
| | Mahurangi Heads | 12 | 1.5 | 9 | 4 | 5 | 5.75 |
| | Browns Bay | 12 | 1.5 | 5 | 1.5 | 3 | 4 |
| | Orewa | 12 | 1.5 | 5 | 1.5 | 2.25 | 3.75 |
| | Ti Point | 12 | 1.5 | 6 | 1.5 | 1.5 | 4.75 |
| | Goat Island | 12 | 1.5 | 10 | 1.5 | 1.5 | 3 |
| Waitematā | Rangitopuni Creek | 12 | 7 | 32 | 12 | 15 | 19.25 |
| | Brighams Creek | 12 | 6 | 36 | 10 | 14 | 26.75 |
| | Lucas Creek | 12 | 6 | 150 | 8.5 | 14.5 | 25.5 |
| | Paremoremo Creek | 12 | 6 | 41 | 8.5 | 13 | 27 |
| | Henderson Creek | 12 | 4 | 48 | 10.25 | 13.5 | 25.5 |
| | Whau Creek | 12 | 1.5 | 37 | 8.25 | 10.5 | 29 |
| | Hobsonville | 12 | 5 | 31 | 7 | 9 | 17.75 |
| | Chelsea | 12 | 1.5 | 42 | 8 | 9 | 22.75 |
| Tāmaki | Panmure | 11 | 6 | 49 | 9 | 12 | 22 |
| | Tāmaki | 11 | 1.5 | 10 | 3 | 4 | 4 |
| | Wairoa River | 12 | 5 | 11 | 5 | 6.5 | 9.75 |
| Manukau | Waiuku Town Basin | 12 | 8 | 63 | 12.75 | 23 | 24.75 |
| | Mangere Bridge | 11 | 10 | 70 | 16 | 22 | 45 |
| | Weymouth | 12 | 16 | 79 | 17.75 | 27.5 | 41.75 |
| | Puketutu Point | 11 | 5 | 73 | 10 | 14 | 22 |
| | Clarks Beach | 12 | 9 | 57 | 12.25 | 13.5 | 29.25 |
| | Shag Point | 12 | 5 | 76 | 6.5 | 11.5 | 20.75 |
| | Grahams Beach | 12 | 7 | 65 | 9 | 11.5 | 15.75 |
| | Manukau Heads | 12 | 3 | 44 | 4 | 5 | 6 |
| Kaipara | Hoteo River | 12 | 5 | 43 | 7 | 9 | 13.75 |
| | Makarau Estuary | 12 | 6 | 48 | 9 | 10 | 11.75 |
| | Kaipara River | 12 | 15 | 97 | 19 | 27 | 38.75 |
| | Shelly Beach | 12 | 5 | 59 | 7 | 9.5 | 14.75 |
| | Tauhoa Channel | 12 | 3 | 46 | 3.25 | 4 | 10.75 |
| | Kaipara Heads | 12 | 1.5 | 29 | 1.5 | 4 | 5.75 |

Table 6-10: Chlorophyll α (mg/L) for data collected from January 2018 to December 2018 **Note for the East Coast, max and 75$^{th}$ile values half of detection limit of 0.003.*

| Area | Site | Count | Min | Max | 25$^{th}$ %ile | Median | 75$^{th}$ %ile |
|---|---|---|---|---|---|---|---|
| East Coast | **Dawsons Creek** | 12 | 0.0003 | 0.0024 | 0.0014 | 0.0015 | 0.002 |
| | **Mahurangi Heads** | 12 | 0.0001 | 0.0015 | 0.0008 | 0.0012 | 0.0015 |
| | **Browns Bay** | 12 | 0.0004 | 0.0015 | 0.0006 | 0.0014 | 0.0015 |
| | **Orewa** | 12 | 0.0001 | 0.0015 | 0.0005 | 0.0008 | 0.0015 |
| | **Ti Point** | 12 | 0.0001 | 0.0015 | 0.0004 | 0.0009 | 0.0015 |
| | **Goat Island** | 12 | 0.0001 | 0.0015 | 0.0005 | 0.0011 | 0.0015 |
| Waitematā | **Rangitopuni Creek** | 12 | 0.0003 | 0.036 | 0.0015 | 0.0032 | 0.0067 |
| | **Brighams Creek** | 12 | 0.0005 | 0.014 | 0.0014 | 0.0034 | 0.0055 |
| | **Lucas Creek** | 12 | 0.0006 | 0.019 | 0.0011 | 0.002 | 0.0029 |
| | **Paremoremo Creek** | 12 | 0.0005 | 0.015 | 0.0015 | 0.0017 | 0.0031 |
| | **Henderson Creek** | 12 | 0.0004 | 0.0026 | 0.0012 | 0.0015 | 0.0015 |
| | **Whau Creek** | 12 | 0.0004 | 0.0023 | 0.0009 | 0.0015 | 0.0015 |
| | **Hobsonville** | 12 | 0.0007 | 0.0025 | 0.0011 | 0.0015 | 0.0015 |
| | **Chelsea** | 12 | 0.0004 | 0.0021 | 0.0005 | 0.0013 | 0.0015 |
| Tāmaki | **Panmure** | 11 | 0.0013 | 0.005 | 0.0015 | 0.0015 | 0.003 |
| | **Tāmaki** | 11 | 0.0003 | 0.002 | 0.0008 | 0.0015 | 0.0015 |
| | **Wairoa River** | 12 | 0.0003 | 0.0062 | 0.001 | 0.0015 | 0.0028 |
| Manukau | **Waiuku Town Basin** | 12 | 0.0004 | 0.011 | 0.0017 | 0.003 | 0.0057 |
| | **Mangere Bridge** | 11 | 0.0011 | 0.021 | 0.0028 | 0.004 | 0.0099 |
| | **Weymouth** | 12 | 0.0009 | 0.018 | 0.0016 | 0.0045 | 0.0079 |
| | **Puketutu Point** | 11 | 0.001 | 0.01 | 0.0015 | 0.0032 | 0.0044 |
| | **Clarks Beach** | 12 | 0.0015 | 0.006 | 0.002 | 0.0033 | 0.0045 |
| | **Shag Point** | 12 | 0.0004 | 0.0083 | 0.0015 | 0.0033 | 0.0048 |
| | **Grahams Beach** | 12 | 0.0015 | 0.0066 | 0.0015 | 0.0026 | 0.005 |
| | **Manukau Heads** | 12 | 0.0009 | 0.0048 | 0.0015 | 0.0015 | 0.0023 |
| Kaipara | **Hoteo River** | 12 | 0.0009 | 0.0049 | 0.0015 | 0.0021 | 0.0039 |
| | **Makarau Estuary** | 12 | 0.0013 | 0.005 | 0.0015 | 0.0021 | 0.0039 |
| | **Kaipara River** | 12 | 0.0019 | 0.016 | 0.0039 | 0.0057 | 0.0085 |
| | **Shelly Beach** | 12 | 0.0014 | 0.008 | 0.0015 | 0.0017 | 0.0031 |
| | **Tauhoa Channel** | 12 | 0.0005 | 0.005 | 0.0015 | 0.0017 | 0.002 |
| | **Kaipara Heads** | 12 | 0.0003 | 0.0025 | 0.0011 | 0.0015 | 0.0018 |

Table 6-11: Nitrite (mg N/L) for data collected from January 2018 to December 2018 **Note min (and 25th %ile) values half of detection limit of 0.001*

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | **Dawsons Creek** | 12 | 0.0005 | 0.0019 | 0.0005 | 0.0005 | 0.0005 |
| | **Mahurangi Heads** | 12 | 0.0005 | 0.0018 | 0.0005 | 0.0005 | 0.0005 |
| | **Browns Bay** | 12 | 0.0005 | 0.002 | 0.0005 | 0.0005 | 0.0005 |
| | **Orewa** | 12 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | **Ti Point** | 12 | 0.0005 | 0.0099 | 0.0005 | 0.0005 | 0.0028 |
| | **Goat Island** | 12 | 0.0005 | 0.0103 | 0.0005 | 0.0014 | 0.0026 |
| Waitematā | **Rangitopuni Creek** | 12 | 0.0005 | 0.0043 | 0.0005 | 0.0019 | 0.003 |
| | **Brighams Creek** | 12 | 0.0005 | 0.0038 | 0.0005 | 0.0005 | 0.0026 |
| | **Lucas Creek** | 12 | 0.0005 | 0.0032 | 0.0005 | 0.001 | 0.0021 |
| | **Paremoremo Creek** | 12 | 0.0005 | 0.0023 | 0.0005 | 0.0005 | 0.0021 |
| | **Henderson Creek** | 12 | 0.0005 | 0.0026 | 0.0005 | 0.0005 | 0.0019 |
| | **Whau Creek** | 12 | 0.0005 | 0.0024 | 0.0005 | 0.0005 | 0.0015 |
| | **Hobsonville** | 12 | 0.0005 | 0.0025 | 0.0005 | 0.0008 | 0.002 |
| | **Chelsea** | 12 | 0.0005 | 0.0021 | 0.0005 | 0.0009 | 0.0017 |
| Tāmaki | **Panmure** | 11 | 0.0005 | 0.0036 | 0.0014 | 0.0022 | 0.0028 |
| | **Tāmaki** | 11 | 0.0005 | 0.0022 | 0.0005 | 0.0012 | 0.0017 |
| | **Wairoa River** | 12 | 0.0005 | 0.0044 | 0.0005 | 0.0005 | 0.0005 |
| Manukau | **Waiuku Town Basin** | 12 | 0.0005 | 0.0136 | 0.0048 | 0.0061 | 0.009 |
| | **Mangere Bridge** | 11 | 0.0044 | 0.024 | 0.0085 | 0.0115 | 0.0158 |
| | **Weymouth** | 12 | 0.0005 | 0.0107 | 0.0005 | 0.0016 | 0.0061 |
| | **Puketutu Point** | 11 | 0.0041 | 0.025 | 0.0099 | 0.0116 | 0.0153 |
| | **Clarks Beach** | 12 | 0.0005 | 0.0075 | 0.0006 | 0.0016 | 0.0043 |
| | **Shag Point** | 12 | 0.0005 | 0.0137 | 0.002 | 0.0026 | 0.0075 |
| | **Grahams Beach** | 12 | 0.0005 | 0.0038 | 0.0005 | 0.0005 | 0.001 |
| | **Manukau Heads** | 12 | 0.0005 | 0.0068 | 0.0005 | 0.001 | 0.0024 |
| Kaipara | **Hoteo River** | 12 | 0.0005 | 0.0079 | 0.0005 | 0.0014 | 0.0027 |
| | **Makarau Estuary** | 12 | 0.0005 | 0.0068 | 0.0005 | 0.0016 | 0.005 |
| | **Kaipara River** | 12 | 0.0005 | 0.0075 | 0.0005 | 0.0022 | 0.0051 |
| | **Shelly Beach** | 12 | 0.0005 | 0.0073 | 0.0005 | 0.0014 | 0.0029 |
| | **Tauhoa Channel** | 12 | 0.0005 | 0.0069 | 0.0005 | 0.0005 | 0.0019 |
| | **Kaipara Heads** | 12 | 0.0005 | 0.0057 | 0.0005 | 0.0005 | 0.004 |

Table 6-12: Nitrate (mg N/L) for data collected from January 2018 to December 2018 **Note Min (and 25th %ile) values half of detection limit of 0.001*

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | **Dawsons Creek** | 12 | 0.0005 | 0.036 | 0.0007 | 0.0012 | 0.0021 |
| | **Mahurangi Heads** | 12 | 0.0005 | 0.0138 | 0.0005 | 0.0005 | 0.0013 |
| | **Browns Bay** | 12 | 0.0005 | 0.0051 | 0.0005 | 0.0005 | 0.002 |
| | **Orewa** | 12 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | **Ti Point** | 12 | 0.0005 | 0.0175 | 0.0005 | 0.0019 | 0.0061 |
| | **Goat Island** | 12 | 0.0005 | 0.0193 | 0.0005 | 0.006 | 0.0107 |
| Waitematā | **Rangitopuni Creek** | 12 | 0.0005 | 0.191 | 0.0082 | 0.0205 | 0.112 |
| | **Brighams Creek** | 12 | 0.0005 | 0.161 | 0.0014 | 0.0208 | 0.066 |
| | **Lucas Creek** | 12 | 0.0005 | 0.178 | 0.0009 | 0.0099 | 0.0507 |
| | **Paremoremo Creek** | 12 | 0.0005 | 0.069 | 0.0005 | 0.0024 | 0.0352 |
| | **Henderson Creek** | 12 | 0.0005 | 0.036 | 0.0011 | 0.0099 | 0.0225 |
| | **Whau Creek** | 12 | 0.0005 | 0.019 | 0.0005 | 0.0035 | 0.016 |
| | **Hobsonville** | 12 | 0.0005 | 0.026 | 0.0013 | 0.0055 | 0.019 |
| | **Chelsea** | 12 | 0.0005 | 0.0161 | 0.0024 | 0.0046 | 0.0117 |
| Tāmaki | **Panmure** | 11 | 0.0135 | 0.185 | 0.0153 | 0.028 | 0.08 |
| | **Tāmaki** | 11 | 0.0017 | 0.085 | 0.0093 | 0.0108 | 0.044 |
| | **Wairoa River** | 12 | 0.0005 | 0.059 | 0.0005 | 0.0005 | 0.0054 |
| Manukau | **Waiuku Town Basin** | 12 | 0.0005 | 0.91 | 0.076 | 0.16 | 0.248 |
| | **Mangere Bridge** | 11 | 0.026 | 0.46 | 0.058 | 0.191 | 0.28 |
| | **Weymouth** | 12 | 0.0005 | 0.49 | 0.0103 | 0.0535 | 0.176 |
| | **Puketutu Point** | 11 | 0.052 | 0.33 | 0.058 | 0.158 | 0.23 |
| | **Clarks Beach** | 12 | 0.0005 | 0.167 | 0.003 | 0.024 | 0.0475 |
| | **Shag Point** | 12 | 0.0005 | 0.175 | 0.0085 | 0.0265 | 0.066 |
| | **Grahams Beach** | 12 | 0.0005 | 0.037 | 0.0005 | 0.0012 | 0.0045 |
| | **Manukau Heads** | 12 | 0.0005 | 0.057 | 0.0006 | 0.0047 | 0.0084 |
| Kaipara | **Hoteo River** | 12 | 0.0005 | 0.36 | 0.0014 | 0.0094 | 0.0239 |
| | **Makarau Estuary** | 12 | 0.0005 | 0.145 | 0.0007 | 0.0119 | 0.0522 |
| | **Kaipara River** | 12 | 0.0005 | 0.178 | 0.0009 | 0.0124 | 0.0605 |
| | **Shelly Beach** | 12 | 0.0005 | 0.095 | 0.0005 | 0.008 | 0.0176 |
| | **Tauhoa Channel** | 12 | 0.0005 | 0.108 | 0.0005 | 0.001 | 0.0086 |
| | **Kaipara Heads** | 12 | 0.0005 | 0.046 | 0.0005 | 0.0013 | 0.02 |

Table 6-13: Ammoniacal N (mg N/L) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 0.009 | 0.026 | 0.012 | 0.016 | 0.023 |
| | Mahurangi Heads | 12 | 0.009 | 0.019 | 0.011 | 0.015 | 0.017 |
| | Browns Bay | 12 | 0.009 | 0.02 | 0.013 | 0.014 | 0.018 |
| | Orewa | 12 | 0.007 | 0.018 | 0.009 | 0.012 | 0.016 |
| | Ti Point | 12 | 0.007 | 0.02 | 0.013 | 0.016 | 0.017 |
| | Goat Island | 12 | 0.008 | 0.016 | 0.011 | 0.014 | 0.015 |
| Waitematā | Rangitopuni Creek | 12 | 0.003 | 0.072 | 0.012 | 0.015 | 0.036 |
| | Brighams Creek | 12 | 0.003 | 0.049 | 0.012 | 0.015 | 0.03 |
| | Lucas Creek | 12 | 0.003 | 0.059 | 0.011 | 0.021 | 0.033 |
| | Paremoremo Creek | 12 | 0.009 | 0.039 | 0.011 | 0.015 | 0.028 |
| | Henderson Creek | 12 | 0.009 | 0.033 | 0.014 | 0.023 | 0.028 |
| | Whau Creek | 12 | 0.009 | 0.029 | 0.013 | 0.021 | 0.025 |
| | Hobsonville | 12 | 0.009 | 0.027 | 0.01 | 0.018 | 0.025 |
| | Chelsea | 12 | 0.007 | 0.024 | 0.011 | 0.015 | 0.019 |
| Tāmaki | Panmure | 11 | 0.012 | 0.062 | 0.019 | 0.033 | 0.039 |
| | Tāmaki | 11 | 0.013 | 0.042 | 0.018 | 0.027 | 0.033 |
| | Wairoa River | 12 | 0.011 | 0.033 | 0.014 | 0.018 | 0.023 |
| Manukau | Waiuku Town Basin | 12 | 0.011 | 0.101 | 0.032 | 0.047 | 0.061 |
| | Mangere Bridge | 11 | 0.015 | 0.132 | 0.053 | 0.07 | 0.102 |
| | Weymouth | 12 | 0.014 | 0.075 | 0.016 | 0.033 | 0.049 |
| | Puketutu Point | 11 | 0.052 | 0.104 | 0.057 | 0.077 | 0.085 |
| | Clarks Beach | 12 | 0.013 | 0.035 | 0.015 | 0.021 | 0.031 |
| | Shag Point | 12 | 0.015 | 0.059 | 0.018 | 0.039 | 0.047 |
| | Grahams Beach | 12 | 0.011 | 0.025 | 0.013 | 0.014 | 0.019 |
| | Manukau Heads | 12 | 0.011 | 0.022 | 0.013 | 0.014 | 0.018 |
| Kaipara | Hoteo River | 12 | 0.012 | 0.08 | 0.018 | 0.024 | 0.034 |
| | Makarau Estuary | 12 | 0.014 | 0.073 | 0.017 | 0.023 | 0.044 |
| | Kaipara River | 12 | 0.01 | 0.072 | 0.013 | 0.019 | 0.039 |
| | Shelly Beach | 12 | 0.013 | 0.054 | 0.016 | 0.021 | 0.024 |
| | Tauhoa Channel | 12 | 0.009 | 0.04 | 0.011 | 0.013 | 0.015 |
| | Kaipara Heads | 12 | 0.006 | 0.024 | 0.01 | 0.012 | 0.015 |

Table 6-14: Total kjeldahl nitrogen (mg N/L) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | **Dawsons Creek** | 12 | 0.098 | 0.27 | 0.141 | 0.166 | 0.184 |
| | **Mahurangi Heads** | 12 | 0.076 | 0.191 | 0.088 | 0.116 | 0.148 |
| | **Browns Bay** | 12 | 0.081 | 0.186 | 0.096 | 0.12 | 0.149 |
| | **Orewa** | 12 | 0.071 | 0.197 | 0.092 | 0.105 | 0.134 |
| | **Ti Point** | 12 | 0.064 | 0.137 | 0.08 | 0.101 | 0.119 |
| | **Goat Island** | 12 | 0.049 | 0.145 | 0.076 | 0.097 | 0.111 |
| Waitematā | **Rangitopuni Creek** | 12 | 0.22 | 0.9 | 0.27 | 0.35 | 0.472 |
| | **Brighams Creek** | 12 | 0.197 | 0.65 | 0.263 | 0.35 | 0.422 |
| | **Lucas Creek** | 12 | 0.15 | 0.61 | 0.23 | 0.245 | 0.307 |
| | **Paremoremo Creek** | 12 | 0.128 | 0.33 | 0.203 | 0.22 | 0.305 |
| | **Henderson Creek** | 12 | 0.128 | 0.28 | 0.157 | 0.185 | 0.22 |
| | **Whau Creek** | 12 | 0.112 | 0.25 | 0.159 | 0.183 | 0.227 |
| | **Hobsonville** | 12 | 0.096 | 0.23 | 0.145 | 0.162 | 0.199 |
| | **Chelsea** | 12 | 0.095 | 0.197 | 0.106 | 0.145 | 0.175 |
| Tāmaki | **Panmure** | 11 | 0.167 | 0.53 | 0.24 | 0.29 | 0.39 |
| | **Tāmaki** | 11 | 0.129 | 0.24 | 0.14 | 0.169 | 0.179 |
| | **Wairoa River** | 12 | 0.128 | 0.26 | 0.132 | 0.171 | 0.184 |
| Manukau | **Waiuku Town Basin** | 12 | 0.175 | 0.44 | 0.283 | 0.305 | 0.347 |
| | **Mangere Bridge** | 11 | 0.31 | 0.47 | 0.32 | 0.35 | 0.4 |
| | **Weymouth** | 12 | 0.21 | 0.38 | 0.233 | 0.285 | 0.335 |
| | **Puketutu Point** | 11 | 0.26 | 0.44 | 0.28 | 0.32 | 0.37 |
| | **Clarks Beach** | 12 | 0.144 | 0.28 | 0.186 | 0.215 | 0.255 |
| | **Shag Point** | 12 | 0.2 | 0.31 | 0.22 | 0.235 | 0.29 |
| | **Grahams Beach** | 12 | 0.09 | 0.26 | 0.157 | 0.174 | 0.195 |
| | **Manukau Heads** | 12 | 0.102 | 0.195 | 0.113 | 0.142 | 0.163 |
| Kaipara | **Hoteo River** | 12 | 0.156 | 0.61 | 0.186 | 0.23 | 0.302 |
| | **Makarau Estuary** | 12 | 0.148 | 0.34 | 0.198 | 0.235 | 0.29 |
| | **Kaipara River** | 12 | 0.2 | 0.4 | 0.255 | 0.3 | 0.357 |
| | **Shelly Beach** | 12 | 0.149 | 0.38 | 0.176 | 0.21 | 0.287 |
| | **Tauhoa Channel** | 12 | 0.109 | 0.24 | 0.135 | 0.164 | 0.198 |
| | **Kaipara Heads** | 12 | 0.079 | 0.133 | 0.093 | 0.105 | 0.127 |

Table 6-15: Total nitrogen (mg N/L) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 0.099 | 0.31 | 0.142 | 0.167 | 0.185 |
| | Mahurangi Heads | 12 | 0.079 | 0.191 | 0.088 | 0.117 | 0.15 |
| | Browns Bay | 12 | 0.084 | 0.186 | 0.096 | 0.124 | 0.151 |
| | Orewa | 12 | 0.071 | 0.197 | 0.092 | 0.105 | 0.135 |
| | Ti Point | 12 | 0.071 | 0.141 | 0.085 | 0.106 | 0.121 |
| | Goat Island | 12 | 0.067 | 0.146 | 0.085 | 0.099 | 0.126 |
| Waitematā | Rangitopuni Creek | 12 | 0.24 | 1.09 | 0.273 | 0.43 | 0.498 |
| | Brighams Creek | 12 | 0.24 | 0.82 | 0.273 | 0.415 | 0.44 |
| | Lucas Creek | 12 | 0.158 | 0.79 | 0.233 | 0.265 | 0.352 |
| | Paremoremo Creek | 12 | 0.136 | 0.39 | 0.21 | 0.235 | 0.328 |
| | Henderson Creek | 12 | 0.134 | 0.3 | 0.159 | 0.187 | 0.25 |
| | Whau Creek | 12 | 0.112 | 0.26 | 0.163 | 0.194 | 0.227 |
| | Hobsonville | 12 | 0.098 | 0.25 | 0.145 | 0.174 | 0.22 |
| | Chelsea | 12 | 0.098 | 0.2 | 0.111 | 0.155 | 0.188 |
| Tāmaki | Panmure | 11 | 0.183 | 0.56 | 0.3 | 0.4 | 0.48 |
| | Tāmaki | 11 | 0.14 | 0.25 | 0.154 | 0.18 | 0.23 |
| | Wairoa River | 12 | 0.132 | 0.26 | 0.137 | 0.177 | 0.204 |
| Manukau | Waiuku Town Basin | 12 | 0.3 | 1.22 | 0.362 | 0.49 | 0.56 |
| | Mangere Bridge | 11 | 0.38 | 0.81 | 0.44 | 0.54 | 0.66 |
| | Weymouth | 12 | 0.22 | 0.84 | 0.263 | 0.335 | 0.487 |
| | Puketutu Point | 11 | 0.34 | 0.72 | 0.39 | 0.45 | 0.68 |
| | Clarks Beach | 12 | 0.18 | 0.36 | 0.205 | 0.255 | 0.287 |
| | Shag Point | 12 | 0.21 | 0.48 | 0.26 | 0.295 | 0.328 |
| | Grahams Beach | 12 | 0.124 | 0.26 | 0.164 | 0.177 | 0.214 |
| | Manukau Heads | 12 | 0.102 | 0.2 | 0.114 | 0.163 | 0.183 |
| Kaipara | Hoteo River | 12 | 0.183 | 0.98 | 0.188 | 0.24 | 0.335 |
| | Makarau Estuary | 12 | 0.171 | 0.49 | 0.199 | 0.25 | 0.315 |
| | Kaipara River | 12 | 0.25 | 0.59 | 0.29 | 0.315 | 0.37 |
| | Shelly Beach | 12 | 0.166 | 0.38 | 0.177 | 0.225 | 0.342 |
| | Tauhoa Channel | 12 | 0.117 | 0.32 | 0.144 | 0.18 | 0.227 |
| | Kaipara Heads | 12 | 0.08 | 0.154 | 0.096 | 0.122 | 0.141 |

Table 6-16: Total phosphorus (mg P/L) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 0.02 | 0.028 | 0.021 | 0.022 | 0.025 |
| | Mahurangi Heads | 12 | 0.012 | 0.021 | 0.015 | 0.018 | 0.02 |
| | Browns Bay | 12 | 0.016 | 0.028 | 0.017 | 0.02 | 0.023 |
| | Orewa | 12 | 0.01 | 0.02 | 0.012 | 0.015 | 0.016 |
| | Ti Point | 12 | 0.009 | 0.021 | 0.011 | 0.015 | 0.018 |
| | Goat Island | 12 | 0.006 | 0.02 | 0.01 | 0.014 | 0.017 |
| Waitematā | Rangitopuni Creek | 12 | 0.026 | 0.098 | 0.031 | 0.038 | 0.058 |
| | Brighams Creek | 12 | 0.028 | 0.064 | 0.035 | 0.041 | 0.049 |
| | Lucas Creek | 12 | 0.022 | 0.091 | 0.026 | 0.034 | 0.044 |
| | Paremoremo Creek | 12 | 0.025 | 0.045 | 0.028 | 0.035 | 0.039 |
| | Henderson Creek | 12 | 0.002 | 0.044 | 0.024 | 0.03 | 0.034 |
| | Whau Creek | 12 | 0.022 | 0.041 | 0.025 | 0.032 | 0.037 |
| | Hobsonville | 12 | 0.022 | 0.036 | 0.023 | 0.028 | 0.032 |
| | Chelsea | 12 | 0.02 | 0.033 | 0.022 | 0.024 | 0.028 |
| Tāmaki | Panmure | 11 | 0.028 | 0.046 | 0.034 | 0.036 | 0.042 |
| | Tāmaki | 11 | 0.02 | 0.036 | 0.025 | 0.028 | 0.032 |
| | Wairoa River | 12 | 0.021 | 0.136 | 0.024 | 0.026 | 0.029 |
| Manukau | Waiuku Town Basin | 12 | 0.032 | 0.072 | 0.041 | 0.054 | 0.059 |
| | Mangere Bridge | 11 | 0.082 | 0.133 | 0.1 | 0.11 | 0.122 |
| | Weymouth | 12 | 0.03 | 0.08 | 0.038 | 0.05 | 0.053 |
| | Puketutu Point | 11 | 0.064 | 0.22 | 0.075 | 0.083 | 0.092 |
| | Clarks Beach | 12 | 0.017 | 0.045 | 0.029 | 0.036 | 0.038 |
| | Shag Point | 12 | 0.036 | 0.07 | 0.045 | 0.05 | 0.06 |
| | Grahams Beach | 12 | 0.019 | 0.035 | 0.022 | 0.027 | 0.031 |
| | Manukau Heads | 12 | 0.014 | 0.024 | 0.015 | 0.019 | 0.02 |
| Kaipara | Hoteo River | 12 | 0.018 | 0.1 | 0.025 | 0.027 | 0.035 |
| | Makarau Estuary | 12 | 0.015 | 0.045 | 0.026 | 0.03 | 0.034 |
| | Kaipara River | 12 | 0.022 | 0.068 | 0.037 | 0.044 | 0.052 |
| | Shelly Beach | 12 | 0.017 | 0.036 | 0.024 | 0.027 | 0.03 |
| | Tauhoa Channel | 12 | 0.009 | 0.026 | 0.014 | 0.018 | 0.023 |
| | Kaipara Heads | 12 | 0.008 | 0.022 | 0.009 | 0.012 | 0.018 |

Table 6-17: Soluble reactive phosphorus (mg P/L) for data collected from January 2018 to December 2018

| Area | Site | Count | Min | Max | 25th %ile | Median | 75th %ile |
|---|---|---|---|---|---|---|---|
| East Coast | Dawsons Creek | 12 | 0.0087 | 0.0161 | 0.0099 | 0.0109 | 0.0134 |
| | Mahurangi Heads | 12 | 0.0056 | 0.0136 | 0.0089 | 0.0098 | 0.0122 |
| | Browns Bay | 12 | 0.0081 | 0.0198 | 0.0104 | 0.0142 | 0.0156 |
| | Orewa | 12 | 0.0045 | 0.0135 | 0.0064 | 0.0092 | 0.011 |
| | Ti Point | 12 | 0.0037 | 0.0121 | 0.0046 | 0.0075 | 0.0099 |
| | Goat Island | 12 | 0.0027 | 0.0114 | 0.0047 | 0.0079 | 0.0104 |
| Waitematā | Rangitopuni Creek | 12 | 0.0039 | 0.033 | 0.0116 | 0.0183 | 0.022 |
| | Brighams Creek | 12 | 0.0032 | 0.028 | 0.0123 | 0.0176 | 0.022 |
| | Lucas Creek | 12 | 0.0022 | 0.028 | 0.0103 | 0.0159 | 0.0217 |
| | Paremoremo Creek | 12 | 0.0017 | 0.025 | 0.0135 | 0.0164 | 0.0225 |
| | Henderson Creek | 12 | 0.001 | 0.023 | 0.0138 | 0.018 | 0.021 |
| | Whau Creek | 12 | 0.0097 | 0.023 | 0.0152 | 0.0171 | 0.022 |
| | Hobsonville | 12 | 0.0121 | 0.024 | 0.0128 | 0.0168 | 0.02 |
| | Chelsea | 12 | 0.011 | 0.023 | 0.0139 | 0.0159 | 0.0197 |
| Tāmaki | Panmure | 11 | 0.0087 | 0.029 | 0.0159 | 0.024 | 0.027 |
| | Tāmaki | 11 | 0.0161 | 0.028 | 0.0177 | 0.021 | 0.026 |
| | Wairoa River | 12 | 0.0081 | 0.0191 | 0.0109 | 0.0149 | 0.0183 |
| Manukau | Waiuku Town Basin | 12 | 0.0131 | 0.04 | 0.0204 | 0.025 | 0.033 |
| | Mangere Bridge | 11 | 0.053 | 0.093 | 0.059 | 0.076 | 0.085 |
| | Weymouth | 12 | 0.0084 | 0.028 | 0.013 | 0.0163 | 0.0201 |
| | Puketutu Point | 11 | 0.04 | 0.181 | 0.053 | 0.068 | 0.072 |
| | Clarks Beach | 12 | 0.0074 | 0.026 | 0.0111 | 0.013 | 0.0179 |
| | Shag Point | 12 | 0.016 | 0.049 | 0.0248 | 0.0315 | 0.0385 |
| | Grahams Beach | 12 | 0.0039 | 0.0191 | 0.0072 | 0.0102 | 0.0108 |
| | Manukau Heads | 12 | 0.0056 | 0.0147 | 0.0072 | 0.0081 | 0.0128 |
| Kaipara | Hoteo River | 12 | 0.0106 | 0.029 | 0.0128 | 0.0152 | 0.0181 |
| | Makarau Estuary | 12 | 0.0099 | 0.023 | 0.011 | 0.0163 | 0.0225 |
| | Kaipara River | 12 | 0.007 | 0.023 | 0.0147 | 0.0175 | 0.0217 |
| | Shelly Beach | 12 | 0.0093 | 0.021 | 0.0117 | 0.015 | 0.0175 |
| | Tauhoa Channel | 12 | 0.0034 | 0.0186 | 0.0073 | 0.0098 | 0.0118 |
| | Kaipara Heads | 12 | 0.0033 | 0.0102 | 0.0043 | 0.0059 | 0.0083 |

# Appendix B Physical-chemical Parameters

Table 6-18: Summary of marine water quality parameters, detection limits, analytical methods and two sources of data collection

| Parameter | Unit | Detection Limit | Method | Source |
|---|---|---|---|---|
| **Dissolved oxygen** | ppm | 0.1 | EXO2 Sonde (Xylem Analytics) | Field |
| **Dissolved oxygen saturation** | % sat | 0.01 | EXO2 Sonde (Xylem Analytics) | Field |
| **Temperature** | °C | 0.01 | EXO2 Sonde (Xylem Analytics) | Field |
| **Conductivity** | mS cm | 0.01 | EXO2 Sonde (Xylem Analytics) | Field |
| **Salinity** | ppt | 0.2 | EXO2 Sonde (Xylem Analytics) | Field |
| **pH** | pH units | 0.01 | EXO2 Sonde (Xylem Analytics) | Field |
| **Total suspended solids** | mg/L | 3 | APHA (2012) 2540 D | Lab |
| **Turbidity** | NTU | 0.05 | APHA (2012) 2130 B (modified) | Lab |
| **Chlorophyll α** | mg/L | 0.0002 | APHA (2012) 10200 H (modified) | Lab |
| **Nitrate nitrogen ($NO_3N$)** | mg/L | 0.001 | Calculation ((NO3N+NO2N) – NO2) | Lab |
| **Nitrite nitrogen ($NO_2$ N)** | mg/L | 0.001 | APHA (2012) 4500-NO2 I (modified) | Lab |
| **Total oxidised nitrogen (NO2N + NO3N)** | mg/L | 0.001 | APHA (2012) 4500-NO3 I (modified) | |
| **Ammoniacal nitrogen ($NH_4$-N)** | mg/L | 0.005 | APHA (2012) 4500-NH3 H (modified) | Lab |
| **Total Kjedahl nitrogen (TKN)** | mg N/L | 0.01 | Calculation: TN – (NO3N + NO2N) | Lab |
| **Total nitrogen (TN)*** | mg N/L | 0.01 | APHA (2012) 4500-N C & 4500 NO3 I (modified) | Lab |
| **Soluble reactive phosphorus** | mg/L | 0.001 | APHA (2012) 4500-P G | Lab |
| **Total phosphorus*** | mg/L | 0.004 | APHA (2012) 4500-P B & E (modified) | Lab |

** Note: analysis methods have changed from July 2017*

Table 6-19: Summary of parameters assessed

| Parameter | Description |
|---|---|
| Salinity and Chloride | Salinity and chloride levels decrease as the influence of freshwater increases. Consequently, levels tend to be lower and more variable in estuaries. Salinity levels affect the toxicity of some contaminants. |
| Temperature | Sea surface temperature is driven by seasonal changes in solar radiation and climatic conditions (e.g. El Niño or La Niña weather patterns). The level of deep-water upwelling, which is driven by offshore winds, has a large influence on interannual variations in sea surface temperature. Shallower tidal creek sites are typically more variable associated with the extent of freshwater inputs and warming of water from exposed intertidal sediments on the incoming tide. Temperature affects biological processes and moderates the toxicity of contaminants. |
| pH | pH is a measure of acidity/alkalinity. Seawater is highly buffered and tends to have relatively stable pH levels between pH 7.8 and 8.3. pH is more variable in upper tidal creek areas because of greater freshwater inputs. pH affects biological processes and moderates the toxicity of contaminants. The accuracy of pH measurement methods used here are not expected to detect recent changes in ocean acidification in NZ (annual change of 0.0013 +- 0.0003 (Law *et al.,* 2018)). |
| Dissolved Oxygen (DO) | Oxygen is released by plants during photosynthesis and taken up by plants, animals and bacteria for respiration. Oxygen-scavenging compounds associated with organic matter also affect DO levels. High DO values can reflect high primary production while low DO values can reflect high rates of decomposition of organic matter. In extreme cases low DO levels due to respiration and/or chemical uptake can stress or kill aquatic organisms i.e. reduce the life-supporting capacity of the water. DO levels are diurnally and seasonally variable. DO is typically higher during the day and decreases at night. Colder waters also typically hold more oxygen than warmer water. |
| Turbidity<br>Suspended solids | Turbidity is a measure of the degree to which light is scattered in water by particles, such as sediment and algae.<br>Total suspended solids are a measure of the amount of suspended material in the water column such as plankton, non-living organic material, silica, clay and silt.<br>Coastal turbidity and suspended solids are influenced by the runoff of terrestrial sediments and resuspension of marine sediments. High turbidity and suspended solids levels reduce the aesthetic quality of seawater and inhibit photosynthesis by algae and seaweeds.<br>Terrestrial sediments may also cause estuary infilling, contribute to mangrove expansion, smother biota and habitats, clog gills and impede the feeding of aquatic organisms. These variables are usually closely correlated but can vary where tannins or other coloured compounds can increase turbidity but are not associated with solid particles. Estuarine waters are generally more turbid than marine or riverine waters due to flocculation, phytoplankton production and the resuspension of sediments.<br>Land-derived sediment loads are dominated by stormflows, which are only occasionally intercepted by our routine monthly monitoring. |

| Parameter | Description |
|---|---|
| Nitrite ($NO_2$),<br>Nitrate ($NO_3$)<br>Total Oxidised Nitrogen (TON, $NO_2$ +$NO_3$-N)<br>Ammoniacal Nitrogen ($NH_3$ + $NH_4$-N)<br>Total Kjedahl Nitrogen (TKN)<br>Total Nitrogen (TN) | Nitrite is the intermediate step in the conversion of ammonia to nitrate. It is usually short lived in the aquatic environment in the presence of oxygen and is typically an indication of a source of nitrogenous waste in the immediate vicinity of the sampling site. Ammonium-N and nitrate-nitrite-N are dissolved forms of nitrogen that are immediately available for phytoplankton and macroalgae uptake and growth, and are used as key indicators for that nutrient.<br>Ammonia is reported as a combination of un-ionised ammonia ($NH_3$) and the ammonium ion ($NH_4$), at normal pH values ammonium ($NH_4$) dominates. Un-ionised ammonia is the more toxic form to aquatic life and is highly dependent on water temperature, salinity and pH.<br>Total Kjedahl Nitrogen is the sum of ammoniacal nitrogen and organic nitrogen (amino acids and proteins).<br>Total Nitrogen includes all forms of dissolved and particulate nitrogen (TKN + TON). Particulate nitrogen consists of plants and animals, and their remains, as well as ammonia adsorbed onto mineral particles. Particulate nitrogen can be found in suspension or in the sediment. Total Nitrogen is usually higher in upper estuarine sites where particulate matter is higher.<br>Low dissolved forms of nitrogen compared to total nitrogen suggest that most of the nitrogen present is particulate matter such as plants, animals, and adsorbed to sediment particles. Organic nitrogen is usually removed in wastewater treatment as settled sludge and ammoniacal nitrogen is nitrified to nitrate. Nitrate is then removed through denitrification processes.<br>High nutrient levels cause algal blooms, nuisance plant growth and eutrophication. High concentrations of some nutrients are also toxic to aquatic organisms (e.g. ammonia). |
| Soluble Reactive Phosphorus (SRP)<br>Total Phosphorus (TP) | Phosphorus is found in water as dissolved and particulate forms. Soluble Reactive Phosphorus is immediately available for uptake and growth by phytoplankton and macroalgae. Particulate phosphorus consists of plants and animals and their remains, as well as phosphorus in minerals and adsorbed onto mineral surfaces. Total Phosphorus is a measure of both dissolved and particulate forms in a water sample. The adsorption and desorption of phosphate from mineral surfaces forms a buffering mechanism that regulates dissolved phosphate concentrations in rivers and estuaries.<br>Sources of phosphorus include sewage and animal effluent, cleaning products, fertilisers, and industrial discharges. Earthworks and forestry can also release phosphorus through soil erosion. Wetland drainage can expose buried phosphorus. |
| Chlorophyll α | Chlorophyll α is used as an indicator of phytoplankton concentration which can indicate trophic status.<br>Chlorophyll α levels vary naturally according to seasonal cycles and climatic conditions. However, excess nutrients caused by human activity can increase chlorophyll α levels to the point where water quality is affected. Effects include altered water colour and clarity, unpleasant odours, altered pH levels and lowered oxygen concentrations. |

# Appendix C Water Quality Index. Background and Methodology

The communication of water quality data is often hampered by the volume of results and the complexity of the information. In this report, a water quality index developed by the Canadian Council of Ministers for the Environment (CCME) (2001) was applied to the marine water quality data collected by Auckland Council to enable improved understanding and communication of the work.

The CCME approach uses water quality results to produce four water quality indices, and these indices can be used to assign a water quality class to each monitoring site. The four indices are;

- Scope – this represents the percentage of parameters that failed to meet the objective at least once during the time period under consideration (the lower this index, the better)
- Frequency – this represents the percentage of all individual tests that failed to meet the objective during the time period under consideration (the lower this index, the better).
- Magnitude – this represents the amount by which failed tests exceeded the objective (the lower this index, the better). This is based on the collective amount by which individual tests are out of compliance with the objectives and is scaled to be between 1 and 100. This is the most complex part of the index derivation and the reader is referred to CCME (2001) for full details.
- WQI – this represents an overall water quality index based on a combination of the three indices described above. It is calculated thus:

$$WQI = 100 - \left[\left\{\sqrt{(Scope^2 + Frequency^2 + Magnitude^2)}\right\} \div 1.732\right]$$

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the “worst” water quality and 100 represents the “best” water quality.

The WQI is used by Auckland Council to assign a water quality class to each site using the following ranges;

- Between 95 and 100 = excellent water quality
- Between 80 and 94 = good water quality
- Between 65 and 79 = fair water quality
- Between 45 and 64 = marginal water quality
- Lower than 44 = poor water quality

## Identification of objectives

Before an index can be calculated, appropriate objectives need to be defined.

A set of static objectives were defined using 10 years of data from the least modified open coastal, and estuarine sites within the programme (2007-2016). Both strong El Niño and La Niña conditions were experienced within this time frame. The ranges at these reference sites were used, as this represents the best achievable water quality in the Auckland region.

These data were also compared to the existing ANZECC default guidelines (ANZECC 2000). We used Auckland Council data when the 80$^{th}$ percentile exceeded ANZECC guidelines; and the ANZECC guidelines when they were more permissive than Auckland Council data. Defining guidelines based on sites in Auckland is reflective of conditions and represent guidelines that are achievable.

Table 6-20: Reference sites used to calculate objectives

| **Open coast sites** | **Estuary sites** |
|---|---|
| Goat Island | Chelsea |
| Ti Point | Hobsonville |
| | Manukau Heads |

## Parameters

A summary of all parameters monitored in the coastal and estuarine water quality programme is provided in Table 6-19. A subset of six of these parameters were selected for use within the Water Quality Index, Dissolved Oxygen, Turbidity, Total Oxidised Nitrogen, Soluble Reactive Phosphate, and Chlorophyll α.

These parameters were selected to minimise potential ‘double counting’ of closely related parameters (such as turbidity and total suspended solids) and are reflective of the most bioavailable form of nutrients which combined with chlorophyll α provides an indication of trophic status. Physical parameters such a temperature, pH and salinity are excluded from the water quality index however these provide important context to further interpret water quality state.

# Appendix D Programme history

The coastal and estuarine water quality programme (also known as the marine or saline water quality programme) was designed to assess water quality on a regional scale over decadal time scales.

The marine water quality program commenced in 1987 with six sites in the Manukau harbour (Table 1), following the Waitangi Tribunal decision on the Manukau Claim (Waitangi Tribunal 1985). We added additional sites to the program in the early 1990s as water quality concerns across the region began to grow. Between 1991 and 1993, the programme was expanded to include sites in the Waitematā Harbour, Hauraki Gulf, and Kaipara Harbour. This network was the status quo until an Auckland Regional Council programme review in 2008 resulted in the addition of one site in the Manukau Harbour (Manukau Heads), two sites in Tāmaki Strait and six sites in the Kaipara. An additional site in Manukau Harbour (Waiuku Town Basin) was added in 2012 based on water quality concerns voiced by the Franklin Local Board.

In June 2014, the monitoring site “Confluence” in the Upper Waitematā Harbour was dropped from the sampling programme. In July 2015 a further four sites were dropped from the sampling programme due to budget constraints, Omokiti Beacon in the Kaipara, Turanga Estuary in the Tāmaki Strait, Rarawaru and Waimarie in the Upper Waitematā Harbour. These sites were selected following an analysis of the relevance of the data that each site was providing.

## Parameters

Parameters used to determine the health of the region’s coastal waters were chosen because they are affected by human activities (e.g., land use and climate change) and can affect the growth and survival of marine plants and animals.

Faecal coliforms were removed from the list of laboratory tests in 2009 as enterococci were considered a more appropriate bacteria indicator in coastal marine waters. However, a decision was made to remove enterococci from sampling parameters in 2014 because an analysis of the results showed that the temporal variability requires a much more focused programme. For this information Auckland Council (along with Watercare, Surf Lifesaving Northern Region and Auckland Regional Public Health Service) runs Safeswim, a programme which provides water quality forecasts and up-to-date information on risks to your health and safety at 84 beaches and 8 freshwater locations around Auckland (www.safeswim.org.nz).

Total nitrogen (TN) was added to the list of chemical variables in 2009 as the current nitrogen species analysed allow for it to be calculated.

A review of the programme in 2005 resulted in the removal of the biological oxygen demand (BOD) parameter from the list of analytical laboratory tests. This was due to laboratory analysis consistently returning results at the detection limit (<2ppm) and no improved methodology was forthcoming or available.

The measurement of water clarity using a Secchi disk also ceased in July 2005 due to the difficulty of accurately estimating readings from the helicopter. Turbidity (measured in NTU) was deemed to be useful approximate parameter instead.

## Laboratory analysis

The service provider for laboratory analysis changed in July 2017 from Watercare Services Ltd to Hill Laboratories. This change over coincided with some minor changes to analytical methodologies, and detection limits for selected parameters.

## Sampling equipment

In November 2008, a hand-held multi-parameter water probe was introduced to the programme. The hand-held probe (YSI 556 MPS) was able to take in situ measures of salinity, conductivity, temperature and two dissolved oxygen readings (% saturation and concentration recorded in mg./$L^{-1}$). Previously, these parameters were measured in the lab by WLS. In December 2014, the YSI 556 MPS multi-parameter meter was upgraded to the EXO 2 multi-parameter sonde (Xylem Analytics).

**Find out more:** phone 09 301 0101, email rimu@aucklandcouncil.govt.nz or visit aucklandcouncil.govt.nz **and knowledgeauckland.org.nz**

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