Marine Water Quality Annual Report 2016

Melanie R Vaughan

December 2017 Technical Report 2017/033

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Executive summary

The Auckland Council operates a long-term, region-wide marine water quality monitoring programme. The main objective of this programme is to gather data to inform the state of the environment trends and reporting as required under section 35 of the Resource Management Act 1991 (RMA). We use the data to monitor long-term trends in water quality and to assess the efficiency of council initiatives, policies and strategies. This report documents changes to the monitoring programme and provides a summary of the data collected during 2016.

Marine water quality samples were collected monthly by helicopter, boat and from land at 31 sites around the region and 16 parameters are measured in the field and laboratory. Grouped into six geographically distinct sampling runs, the data are presented in box plots, displaying the variation in the measured parameters at each site, and in statistical summary tables for each site and parameter.

To summarise the data, Water Quality Indices (WQI) were calculated assigning a water quality class of excellent, good, fair or poor. This analysis combines water quality measures and compares against selected “reference” sites to provide a readily understood description of the water quality for 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 that 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 marine waters are influenced by the quality of surface water that runs from the land through streams, rivers, overland flow paths and the stormwater systems. The microbiological contamination of beaches after heavy rainfall and the sedimentation of harbours and estuaries (Auckland Council, 2015) illustrate the connections between inland and coastal waters as well as the sensitivity of these ecosystems.

The marine water quality programme monitors naturally occurring parameters that can become elevated in association with natural variations in ocean hydrodynamics, land erosion, and biological waste (organic material and faecal contaminants) in the water column. Along with two other monitoring programmes, benthic ecology and sediment contaminant monitoring, an integrated overview of the physical, chemical and biological condition of the region's marine environment is provided. The overall picture is strengthened further by the streams and rivers monitoring programme, which monitors similar parameters (Holland et al. 2016).

The marine water quality programmes 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 reporting.
- Contribute to the need 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.
- Provide baseline, regionally representative data to support the resource consent process and compliance monitoring.
- Answer queries from the public, and promote awareness of marine water quality issues.

1.1 Council directives

Monitoring marine water quality falls under the directives of Auckland Council policies. The programme fits under the “Environmental management and regulation” component of the 10-Year Budget, Long-term Plan 2015-2025. A key issue for the region is to deliver improved environmental outcomes, with a priority on clean waters.

Specific objectives include reducing the overall yield of suspended sediment to priority marine receiving environments from 2012 levels by 15 per cent by 2040, and facilitating action to restore the quality of Auckland’s waterways and harbours. The water quality parameters provide information on the condition of the region’s marine environment and feedback on management actions. This is necessary to confirm that Auckland Council’s management strategies are effective in sustaining ecosystem functions and uses. This helps to work towards Auckland Council’s aspiration of being:

“*For Auckland to be a world-class city*”

Information from the marine water quality programme is also used to measure the success of several strategic directives in the Auckland Plan including:

Directive 7.10 “*Manage land to support the values of waterbodies by protecting them where they are high and reviving them where they are degraded”*

and:

Directive 7.12 *“ Protect coastal areas – particularly those with high values – from the impacts of use and development, and enhance degraded areas´* (Auckland Council, 2012).

1.2 Report content

This report provides summary data for the 2016 calendar year collected from 31 monitoring sites across the Auckland region (Figure 2-1). Data from these sites are provided as summary statistics tabulated by parameter and grouped by spatial proximity along with results from WQI calculations.

2.0 Methods

2.1 Programme design

Sampling of surface waters for marine water quality monitoring is undertaken monthly by Auckland Council environmental monitoring specialists, predominantly by helicopter. This enables sites spread over a large area to be collected within a narrow time frame, reducing the effects of tidal fluctuations. Sites where water samples are not collected by helicopter include Upper Waitematā Harbour, which are sampled by boat, and the Tāmaki Estuary, which is sampled by land.

At each site, water samples were collected from the surface (top 1 m) by lowering a 2 litre plastic bottle into the water. The 2 litre plastic bottles were then sent to Watercare Laboratory Services (WLS) and analysed for a variety of parameters (see Appendix A for the full list). While bottle samples were collected, a multi-parameter sonde (EXO2-YSI) was deployed into the water to capture the field-measured parameters.

Temporal variation was avoided as much as possible by maintaining a consistent sampling time relative to tidal cycle. Samples were 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 in the same sampling order. Maintaining a consistent sample time improves the power of long-term trend detection.

2.2 Site locations

Sampling was divided into six geographically distinct runs, including thirty one sites, summarised in Table 2-1 and illustrated in Figure 2-1. The marine water quality programme sites were established in 1987 in the Manukau, following a baseline ten-year programme of sites subject to environmental pressure (Carbines et al. 2013). A list of all sites that have been included in the programme from its inception in 1987 are outlined in Table C-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:

- Water quality across a disturbance gradient from high to low
- A range of exposure levels including open coast, sheltered coast, harbours, large estuaries and tidal creeks
- The main harbours and large estuaries
- Areas with a variety of adjacent land uses, ranging from urban/industrial to rural

Table 2-1 Current marine water quality sites sorted from north to south, grouped by location. Spatial reference is in NZTM coordinates, and the year which sampling began is also listed.

Site	Location	Easting	Northing	Year initiated
Goat Island	East Coast	1761835	5984910	1993
Ti Point	East Coast	1760222	5978524	1991
Mahurangi Heads	East Coast	1754382	5959892	1993
Dawsons Creek	East Coast	1753554	5966410	1993
Orewa	East Coast	1753273	5949612	1991
Browns Bay	East Coast	1757934	5935780	1991
Shelly Beach	Kaipara Harbour	1723526	5951872	1991
Kaipara River	Kaipara Harbour	1726372	5946975	2009
Makarau Estuary	Kaipara Harbour	1728450	5953472	2009
Kaipara Heads	Kaipara Harbour	1709351	5970137	2009
Tauhoa Channel	Kaipara Harbour	1717979	5969681	2009
Hoteo River	Kaipara Harbour	1726690	5967497	2009
Chelsea	Waitematā Harbour	1753944	5922872	1991
Whau Creek	Waitematā Harbour	1748289	5920291	1991
Henderson Creek	Waitematā Harbour	1746712	5923648	1991
Hobsonville Jetty	Waitematā Harbour	1749321	5927317	1993
Paremoremo Ski Club	Waitematā Harbour	1745746	5930178	1993
Rangitopuni Creek	Waitematā Harbour	1742836	5929868	1993
Brighams Creek	Waitematā Harbour	1742758	5928019	1996
Lucas Creek	Waitematā Harbour	1750045	5932471	1993
Tāmaki	Tāmaki Estuary	1769372	5917448	1992
Panmure	Tāmaki Estuary	1765295	5913934	1992
Wairoa River	Tāmaki Strait	1786443	5909850	2009
Grahams Beach	Manukau Harbour	1749651	5888082	1987
Clarks Beach	Manukau Harbour	1748630	5897349	1987
Waiuku Town Basin	Manukau Harbour	1753690	5878187	2012
Shag Point	Manukau Harbour	1748379	5908452	1987
Puketutu Point	Manukau Harbour	1753877	5908724	1987
Weymouth	Manukau Harbour	1764925	5897672	1987
Mangere Bridge	Manukau Harbour	1758588	5910714	1987
Manukau Heads	Manukau Harbour	1708915	5970600	2009

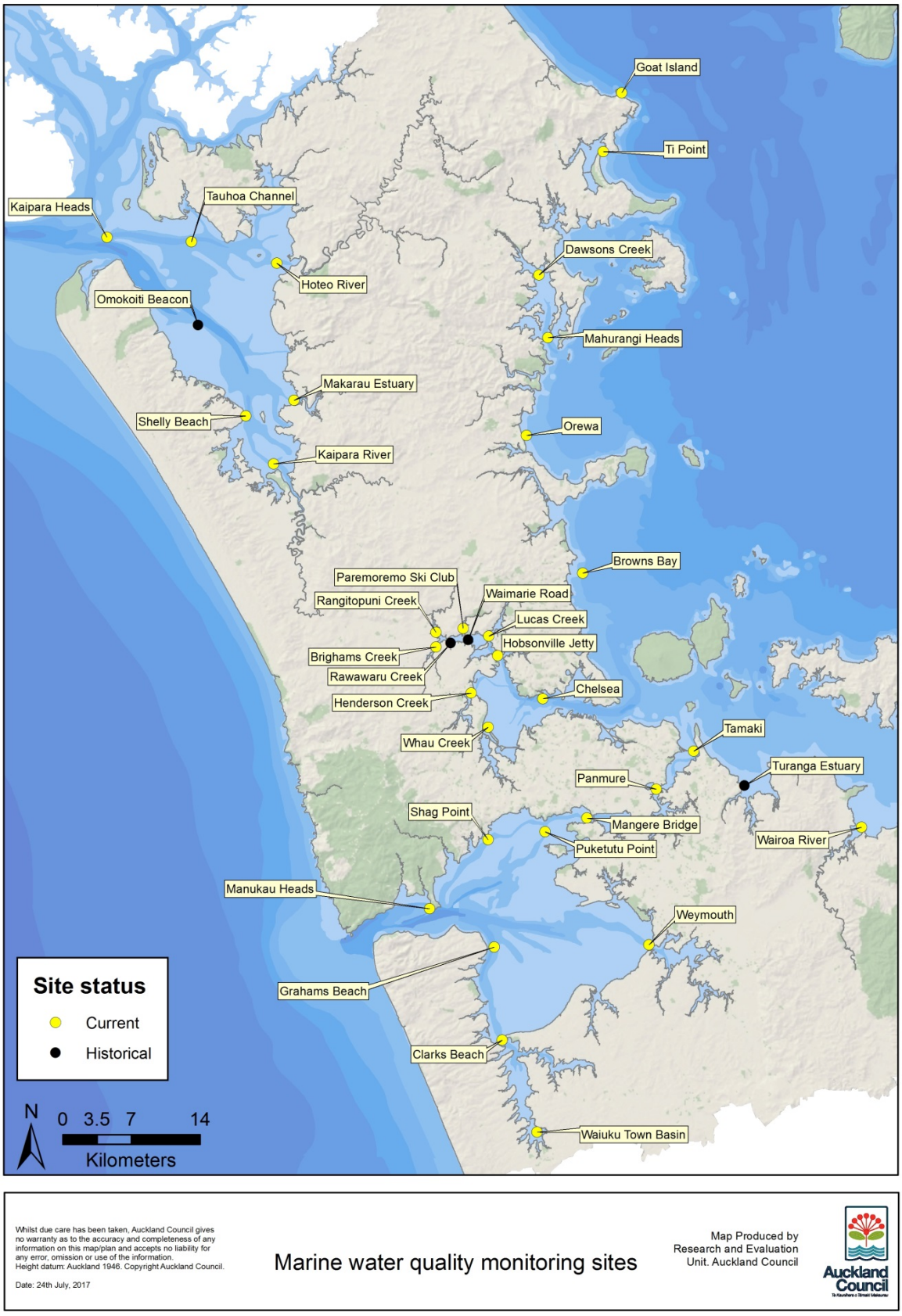

Figure 2-1 Location of the current 31 marine water quality monitoring sites and four historical sites.

2.3 Marine water quality parameters

Marine water quality around the region's coastal environment was determined by measuring 16 parameters. Some of these parameters are measured in the field using a multi-parameter sonde (YSI EXO2), but most are analysed by Watercare Laboratory Services (Table A-1). The number and type of parameters has varied since the programme's inception as new technology has become more affordable, instrument sensitivity improved, and the programme objectives modified.

The measured parameters all convey information about the ability of marine waters to support a functioning ecosystem, including humans.

Conductivity and salinity are two measures of how much salt is in the water. Salinity is a derived measurement based on the conductivity and temperature of the water. In coastal marine waters, conductivity and salinity can be used to show the timing and duration of freshwater influence in coastal waterbodies. Water temperature is another important factor that can document freshwater input, and also determines how quickly plants and animals grow, how much oxygen the water can hold, and what organisms can live in the water.

Suspended sediment and turbidity measure the clarity of the water. As the amount of sediment in the water column increases, turbidity increases and water clarity decreases. Decreased water clarity makes it more difficult for plants to photosynthesize, and excessive amounts of suspended sediment can negatively affect animals by making it difficult for them to feed and find food.

Dissolved oxygen (measured as % saturation and parts per million) is used to determine if a waterbody is producing more oxygen from photosynthesis than is being consumed by invertebrates, fish and microbes. Higher values of dissolved oxygen suggest more photosynthesis by plants than consumption by organisms. Low dissolved oxygen values suggest that oxygen is being consumed faster than it is produced: perpetual low oxygen conditions negatively affect fish and invertebrate populations. The pH of water, which is affected by dissolved oxygen concentration, is another metric that determines which organisms are able to live and thrive. Low pH values make it difficult for calcifying organisms (e.g., those with a hard shell) to make and maintain their calcified structures. Measuring pH is increasingly important in coastal seas as ocean acidification continues to occur in ocean basins around the world.

Nutrient species of nitrogen and phosphorus are all necessary for plants to photosynthesize. However, excess nutrients can cause ecological shifts in aquatic systems by increasing primary productivity and subsequently reducing dissolved

oxygen. High levels of nutrients in aquatic systems are often indicative of human based inputs or land-use change.

Finally one biological parameter, chlorophyll *a*, provides an indication how the system is responding to water quality by measuring phytoplankton. An overabundance of phytoplankton is usually indicative of a system with excess nutrients and may be described as an algal bloom.

2.4 Programme changes

2.4.1 Sites

This section briefly outlines some of the key changes that have occurred during the programme. 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, and Rarawaru and Waimarie in the Upper Waitematā Harbour. These sites were removed from the programme following an analysis of the value the site provided.

In January 2009, six new sites were established and added to the programme in the Kaipara Harbour. In addition, one site at the Manukau Heads, one site at Turanga Estuary, and one site at the mouth of the Wairoa River were also added. In August 2012, a site at Waiuku Town Basin was created in response to a request from the Franklin Local Board. These additional sites allow for greater coverage of the coastal waters within the Auckland Region.

2.4.2 Parameters

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 such as Safeswim which is run over summer at Auckland beaches (www.aucklandcouncil.govt.nz/safeswim).

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 2005 review of the programme resulted in the removal of 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.

2.4.3 Sampling gear

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}). Previous to this, 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).

2.5 Quality control, data storage and analysis

Quality control is 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. Samples were analysed under a contract between Auckland Council and WaterCare Laboratory Services, an International Accreditation New Zealand (IANZ) and ISO accredited laboratory. Analytical methods follow the "Standard Methods for the Examination of Water and Wastewater" 22nd Edition (APHA, 2012). All field and laboratory data are stored in the Auckland Council's archiving database, HYDSTRA, and comply with ISO 9001:2008 certifications.

Data collected for each variable were analysed by site and season over a ten year period in order to determine the 5th and 95th percentiles. All new data are compared to these levels and any data outside of these boundaries is flagged. This allows the data processor to check for erroneous data and repair (if data are incorrect) or comment as appropriate.

The data are collated by site to produce:

- Box plots that display variation in the measured parameters at each site. The boxplots were produced with SigmaPlot version 12.0 (Systat Software, 2013), using the default percentile functions. The boxes represent the inter-quartile range (25th and 75th percentiles) and the whiskers represent the 10th and 90th percentiles. The median is shown as a line within each box.
- Summary tables which provide a statistical analysis for each parameter at each site were produced using Statistica version 13 (Dell, 2015).

- Water Quality Index (WQI) scores were produced using the data from seven water quality parameters, allowing a water quality class to be assigned to each site. Scores are classed as Excellent, Good, Fair and Poor. These are produced using an Excel workbook developed by the Canadian Council of Ministers of the Environment (2001). The application of this method to the Auckland Council's marine water quality data is described in Appendix B.

2.6 Reports

This is the 27th data report since the inception of the monitoring programme in 1987, and it is the tenth time since 2000 that the data have been reported separately from the rivers, streams and lakes water quality monitoring programmes. Previous reports are listed in the references and can be obtained by contacting Auckland Council on (09) 301 0101, or in electronic format from Auckland Council's research information website Knowledge Auckland, www.knowledgeauckland.org.nz.

A comprehensive trend analysis is conducted periodically, the last report was published in 2008 (Scarsbrook, 2008) and a previous report published in 1998 (Vant and Lee, 1998). Recommendations are made in these reports along with analyses of long term changes for the Auckland region. Both reports are available on Knowledge Auckland.

The most recent trends analysis is currently underway. Auckland Council's 2015 state of the environment report briefly summarises marine water quality issues, the pressures facing the Auckland region, and its ecological health (Auckland Council, 2015).

A specific review of the Mahurangi Harbour, Upper Waitematā Harbour, and Tāmaki Estuary was undertaken in 2001 (Wilcock and Kemp, 2001).

3.0 Results

Data from the 2016 calendar year are presented in box plots (section 3.1) to display the ranges of marine water quality parameter results were recorded. These plots also show the variations in the parameters among sites and locations. Data tables containing summary statistics (sample size, maximum/minimum value, mean and standard error) are presented in section 5.0. For box plots and data tables, sites are grouped by location (e.g., all sites within the Manukau Harbour are grouped) and then listed from north to south. WQI scores are summarised in section 4.0.

3.1 Box plots

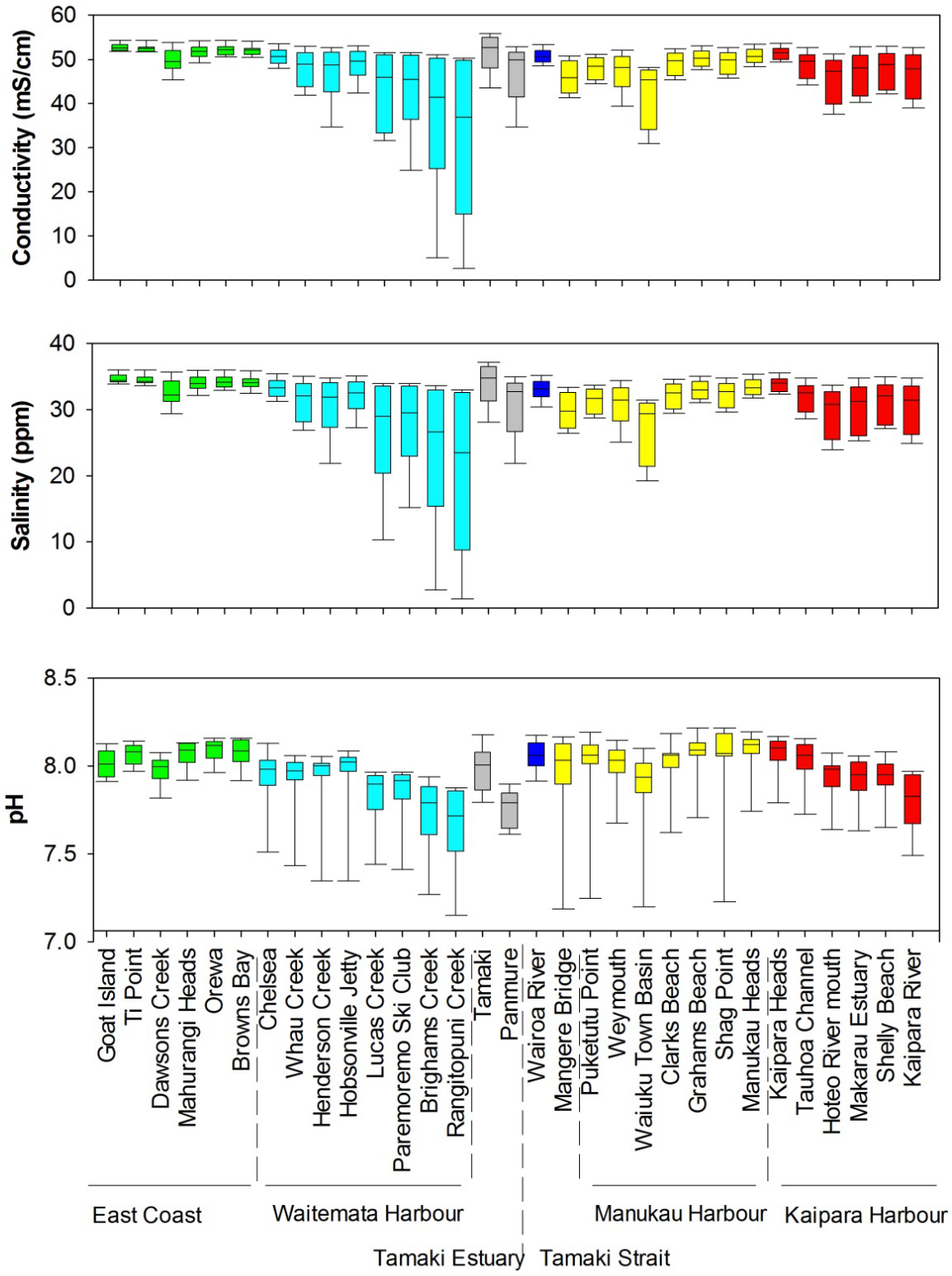

Figure 3-1 Spatial measurements of conductivity, salinity and pH. Boxes represent the median, 25th and 75th percentiles while whiskers are 10th and 90th percentiles for data collected from January 2016 to December 2016.

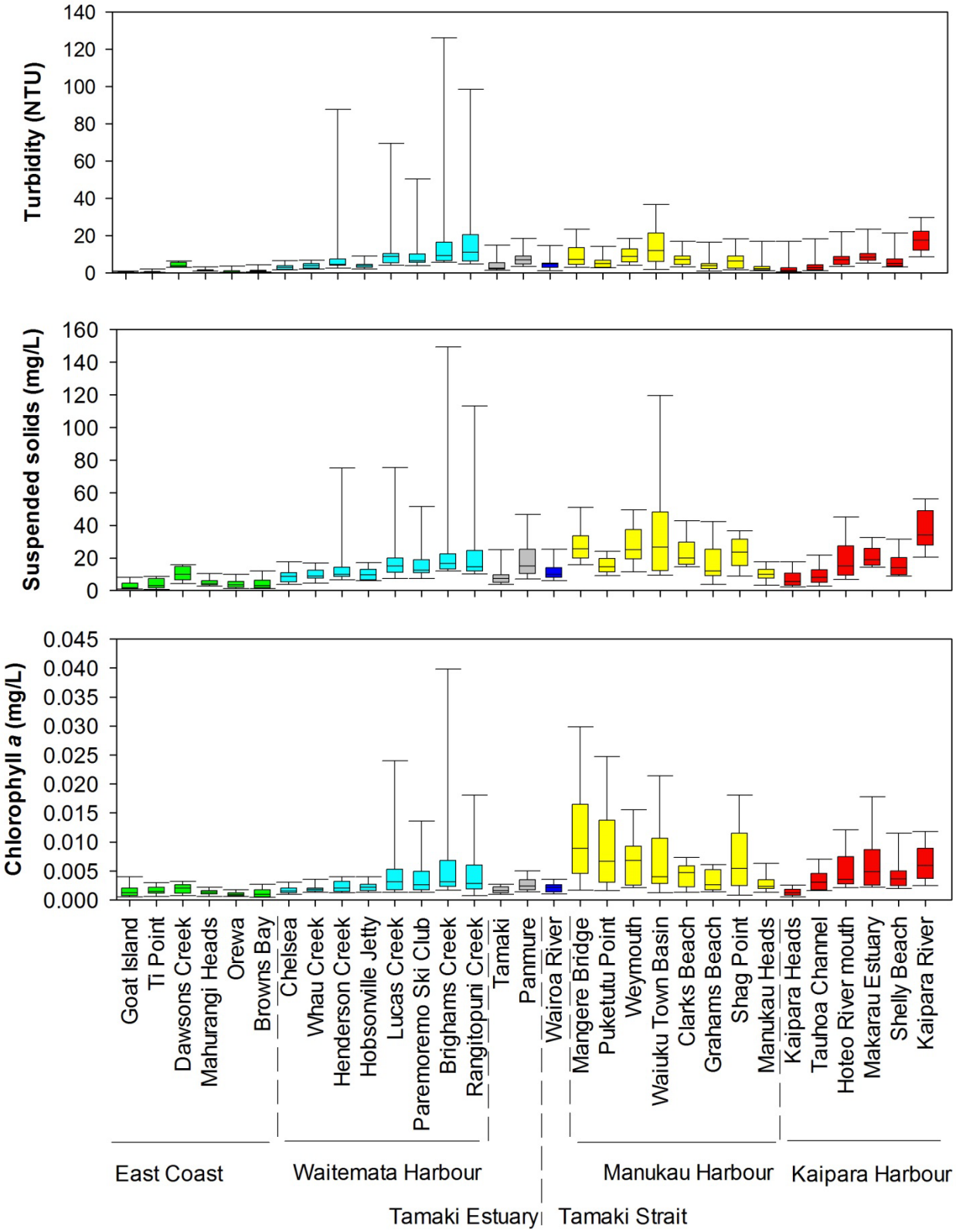

Figure 3-2 Spatial measurements of turbidity, suspended sediment, and chlorophyll *a*. Boxes represent the median, 25th and 75th percentiles while whiskers are 10th and 90th percentiles for data collected from January 2016 to December 2016.

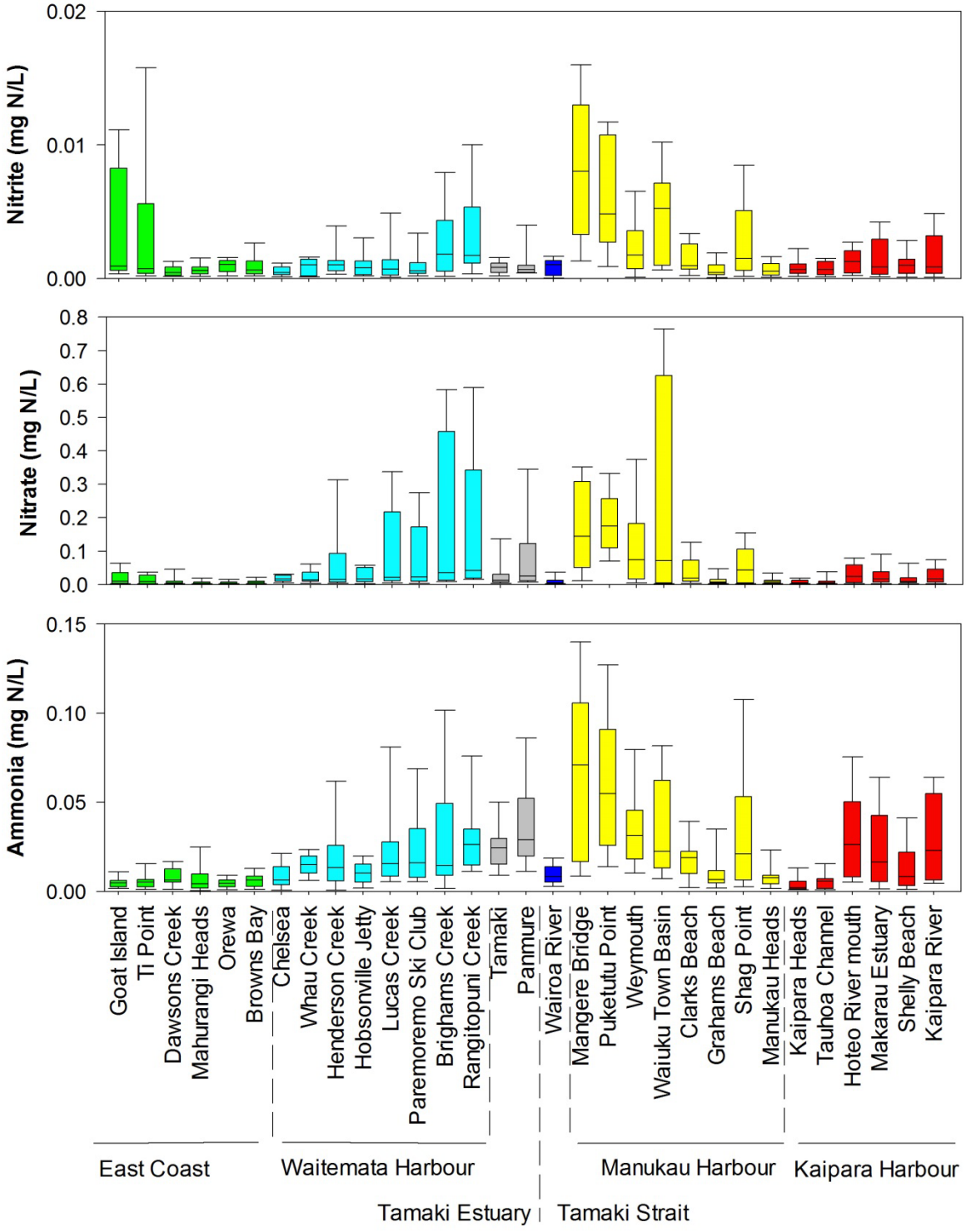

Figure 3-3 Spatial measurements of nitrite, nitrate and ammonia. Boxes represent the median, 25th and 75th percentiles while whiskers are 10th and 90th percentiles for data collected from January 2016 to December 2016.

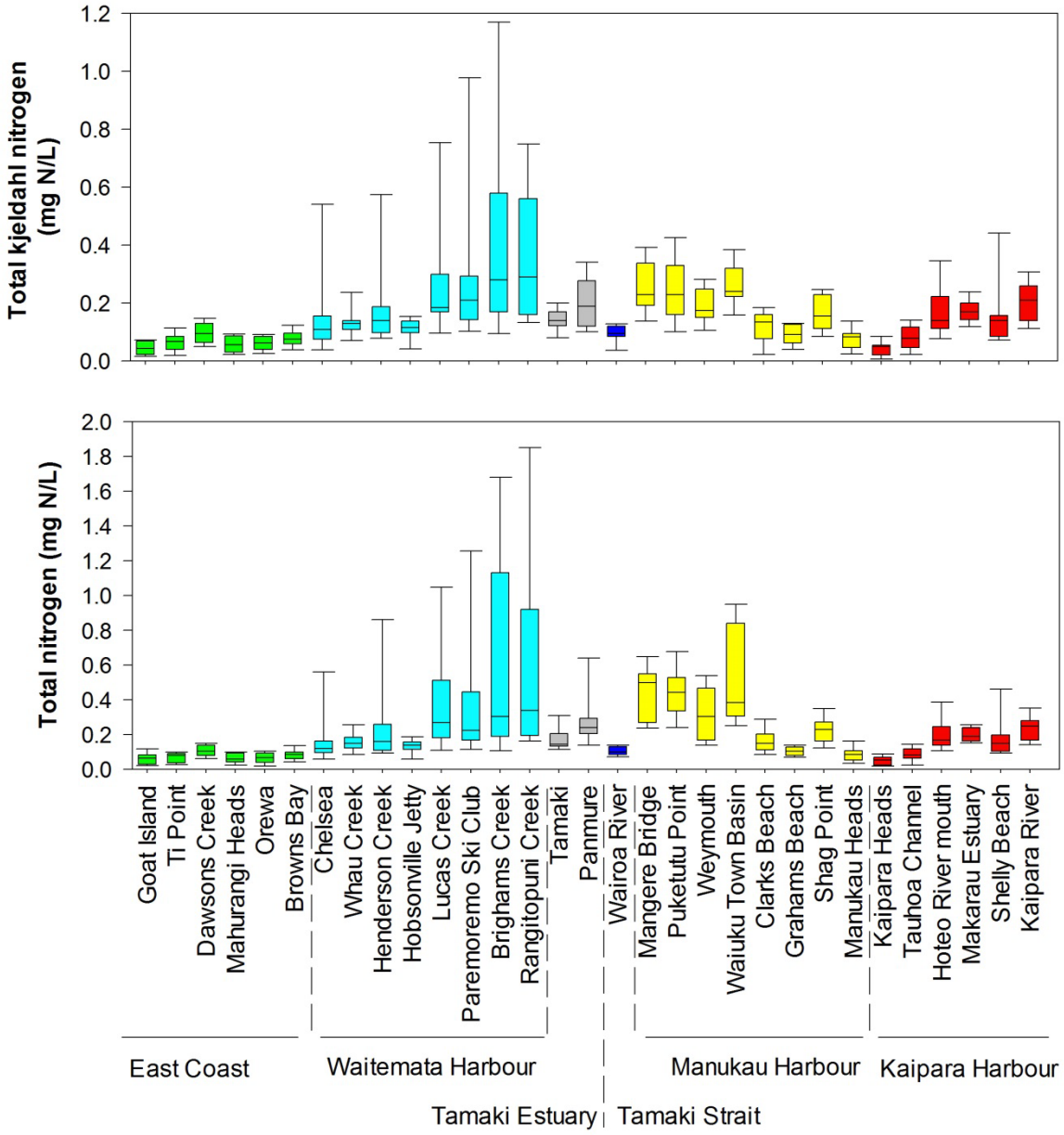

Figure 3-4 Spatial measurements of total kjedahl nitrogen and total nitrogen. Boxes represent the median, 25th and 75th percentiles while whiskers are 10th and 90th percentiles for data collected from January 2016 to December 2016.

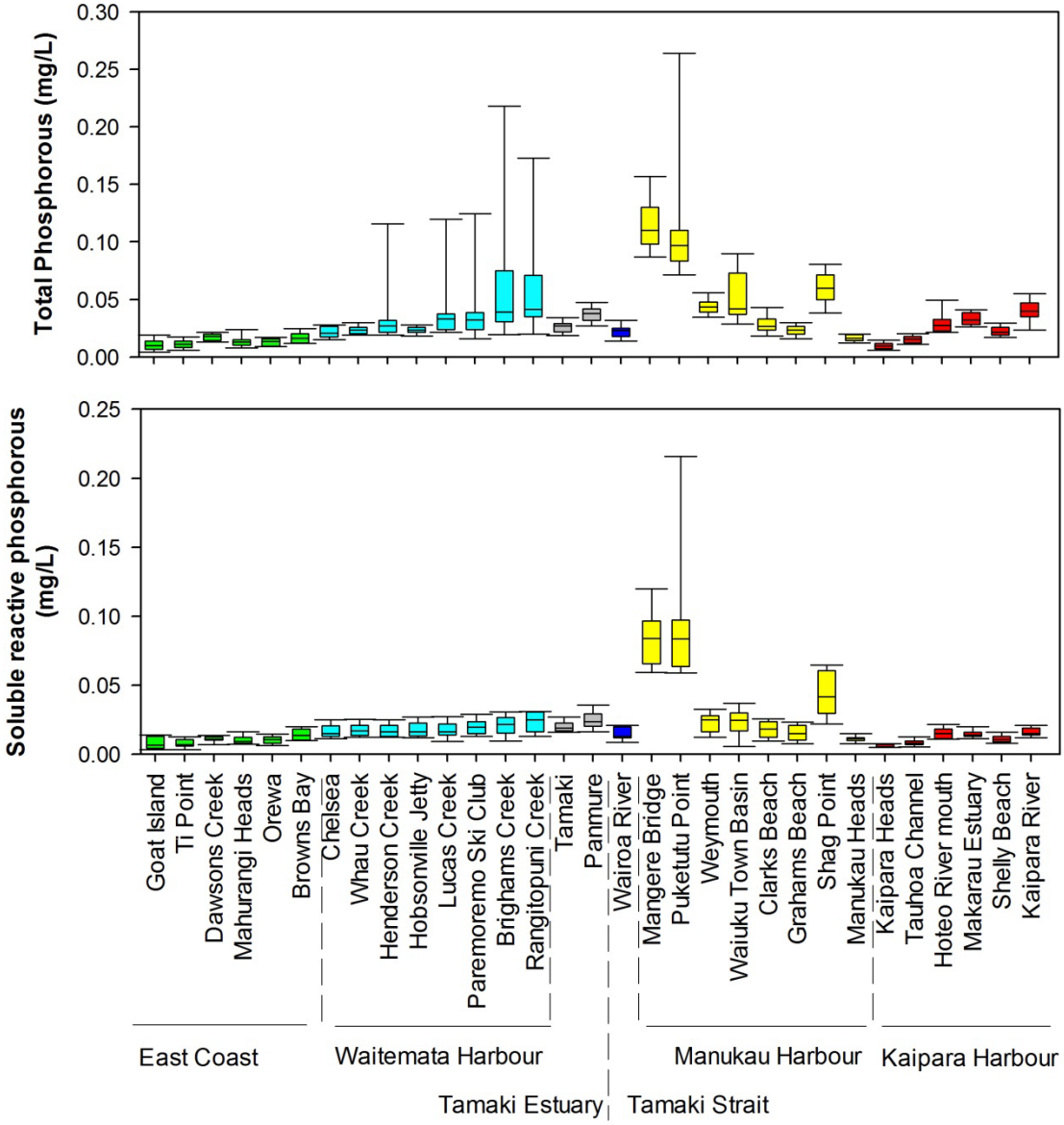

Figure 3-5 Spatial measurements of total phosphorus and soluble reactive phosphorus. Boxes represent the median, 25th and 75th percentiles while whiskers are 10th and 90th percentiles for data collected from January 2016 to December 2016.

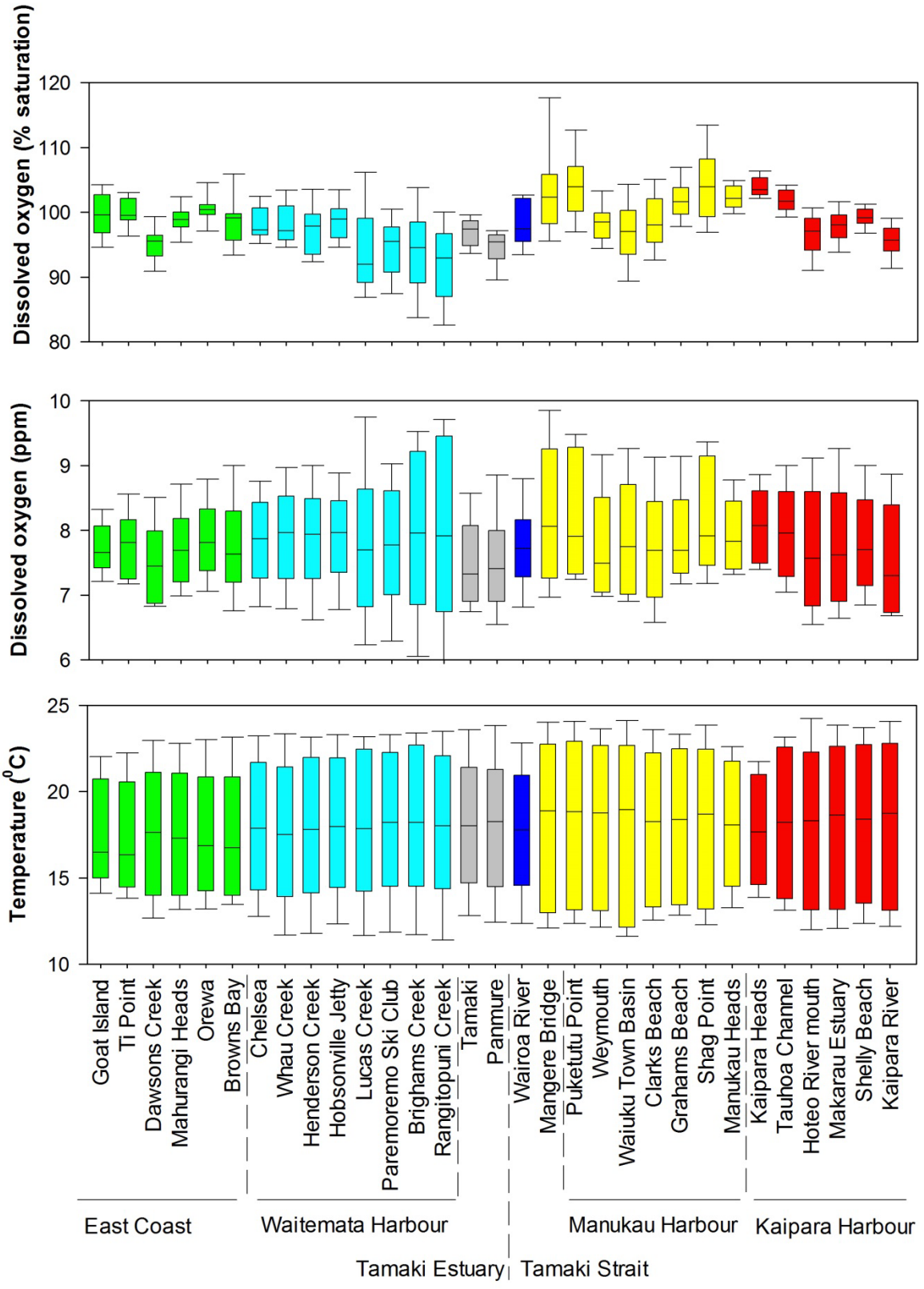

Figure 3-6 Spatial measurements of two indices of dissolved oxygen (ppm and % saturation) and sea surface temperature. Boxes represent the median, 25th and 75th percentiles while whiskers are 10th and 90th percentiles for data collected January 2016 to December 2016.

4.0 Marine Water Quality Index

Using the methodology described in Appendix A and first applied in the 2009 annual marine water quality report; marine water quality indices and classes were generated for each of the 31 sites (Figure 2-1).

Before an index could be calculated, appropriate objectives needed to be defined. Variables from reference sites were used to summarise water quality from Auckland's harbours to create objectives to be tested against because there are no water quality standards for coastal and marine waters. Prior to 2015, only East Coast sites were included as reference sites due to the lack of sufficient data from West Coast harbours. However, in 2015 two sites, Kaipara Heads and Manukau Harbour Mouth had five years of data available to calculate the state of water quality in those locations. The WQI lacked reference sites from west coast locations until this point, so they were added to the reference sites to calculate objectives. Five years of data collection at the two sites indicated that they had the 'best' water quality observed in each of the two west coast harbours.

The list of reference sites used were from the East Coast (Ti Point and Goat Island), Waitematā Harbour (Chelsea and Hobsonville Jetty), Kaipara Heads and Manukau Harbour Mouth. It should be acknowledged that the inclusion of the two West Coast sites slightly lowered the objective values, due to lower water quality results compared to the East Coast.

A three year rolling average was used to calculate the final 2016 WQI score, incorporating the WQIs from the previous two years (i.e. 2014 and 2015). This averaging eliminates any major interannual variations due to environmental changes (e.g. heavy rain fall and storms) or human impacts such as development. The decision to present a three year averaged WQI aligns with the State of Auckland marine report cards, and allows for greater consistency in the communication of marine water quality data and the relevant changes in the environment.

There was a marked increase in the number of sites classified as poor in 2016, from 31% in 2015 to 52% in 2016 (Table 4-1). This is cause for concern particularly since the declines occurred across the region. Water quality class changed at twelve sites from 2015 to 2016 (Table 4-2). Water quality increased at three sites, including Kaipara Heads and Dawsons Creek from Good to Excellent; and Wairoa from Fair to Good. Water quality declined at nine sites, including Chelsea and Hobsonville Jetty from Excellent to Good, Grahams Beach and Tāmaki from Excellent to Fair; Shelly Beach, Makarau Estuary, Hoteo River Mouth and Clarks Beach from Fair to Poor and Henderson Creek from Good to Poor.

Table 4-1 Percentage of sites per water quality class. Note that there are 31 sites in 2016, 35 sites in in 2010, 2011, 2014 and 2015 and 36 sites in 2012 and 2013.

Water Quality Class	2010	2011	2012	2013	2014	2015	2016
Excellent	11%	20%	3%	9%	20%	29%	23%
Good	17%	17%	11%	20%	26%	20%	19%
Fair	31%	29%	25%	29%	23%	20%	6%
Poor	40%	34%	61%	43%	31%	31%	52%

**WQI were presented as 3 year rolling averages in 2012, 2013, 2015 and 2016 and for a single year in 2010, 2011 and 2014.

Table 4-2 Water quality index score and water quality class for currently monitored sites. Sites are sorted according to their WQI. Previous years water quality classes are presented for inter-annual comparisons and reference. The WQI is discussed in Appendix B.

Sites	2014 Site WQI	2015 WQI	2016 Site WQ score	2016 WQI	WQI change from 2015
Browns Bay	Excellent	Excellent	100	Excellent	-
Kaipara Heads	Excellent	Good	100	Excellent	↑
Orewa	Excellent	Excellent	100	Excellent	-
Ti Point	Excellent	Excellent	100	Excellent	-
Goat Island	Good	Excellent	92.8	Excellent	-
Mahurangi Heads	Excellent	Excellent	92.8	Excellent	-
Dawsons Creek	Good	Good	92.7	Excellent	↑
Chelsea	Good	Excellent	85.5	Good	↓
Hobsonville Jetty	Good	Excellent	85.5	Good	↓
Wairoa River Mouth	Fair	Fair	85.5	Good	↑
Whau Creek	Good	Good	85.5	Good	-
Manukau Heads	Excellent	Good	78.3	Good	-
Tauhoa Channel	Good	Good	78.2	Good	-
Grahams Beach	Fair	Excellent	70.8	Fair	↓
Tamaki	Good	Excellent	63.2	Fair	↓
Shelly Beach	Fair	Fair	56.3	Poor	↓
Henderson Creek	Good	Good	46.4	Poor	↓
Makarau Estuary	Poor	Fair	46	Poor	↓
Panmure	Poor	Poor	44.6	Poor	-
Puketutu Point	Poor	Poor	43.2	Poor	-
Shag Point	Poor	Poor	41.2	Poor	-
Clarks Beach	Fair	Fair	40.3	Poor	↓
Hoteo River mouth	Fair	Fair	39.7	Poor	↓
Weymouth	Poor	Poor	39.4	Poor	-
Paremoremo Ski Club	Fair	Poor	38.5	Poor	-
Lucas Creek	Fair	Poor	36	Poor	-
Mangere Bridge	Poor	Poor	33.2	Poor	-
Kaipara River	Poor	Poor	33.1	Poor	-
Brighams Creek	Poor	Poor	31.1	Poor	-
Rangitopuni Creek	Poor	Poor	31.1	Poor	-
Waiuku Town Basin	Poor	Poor	30.2	Poor	-

5.0 Data tables

Table 5-1 Electrical conductivity (mS/cm) for data collected January 2016 to December 2016.

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	11	51.80	54.25	52.53	52.72	0.27
Ti Point	11	51.64	54.28	52.47	52.57	0.28
Dawsons Creek	12	44.30	53.92	49.49	49.80	0.81
Mahurangi Heads	12	48.80	54.27	51.80	51.70	0.46
Orewa	11	50.44	54.38	52.14	52.20	0.38
Browns Bay	11	50.27	54.10	52.04	52.06	0.36
Chelsea	11	47.67	53.56	50.63	50.72	0.59
Whau Creek	11	41.39	53.07	48.92	48.11	1.21
Henderson Creek	11	34.09	52.73	48.71	46.23	1.93
Hobsonville Jetty	11	41.51	53.10	49.55	48.83	1.10
Lucas Creek	10	31.45	51.54	45.94	42.71	2.66
Paramoremo Ski Club	11	24.62	51.53	45.45	41.80	3.01
Brighams Creek	11	4.18	51.21	41.43	34.31	5.17
Rangitopuni Creek	11	1.94	50.26	36.89	31.43	5.61
Tāmaki	12	42.36	56.03	52.67	51.59	1.23
Panmure	12	33.18	53.05	49.85	47.03	1.87
Wairoa River Mouth	10	48.48	53.39	50.49	50.63	0.49
Mangere Bridge	12	40.99	50.78	45.78	46.14	1.05
Puketutu Point	12	44.41	51.14	48.43	48.04	0.72
Weymouth	12	38.24	52.38	48.08	46.96	1.28
Waiuku Town Basin	12	29.91	48.09	45.37	42.08	1.99
Clarks Beach	12	45.03	52.47	49.67	48.98	0.77
Grahams Beach	12	47.62	53.25	50.23	50.22	0.56
Shag Point	12	45.54	53.01	49.81	49.37	0.73
Manukau Hbr @ Mouth	12	48.01	53.52	50.64	50.83	0.50
Kaipara Heads	12	49.38	54.10	51.46	51.40	0.42
Tauhoa Channel	12	43.78	53.20	49.59	48.73	0.87
Hoteo River Mouth	12	37.02	51.38	47.22	45.15	1.54
Makarau Estuary	11	40.21	53.22	47.98	47.01	1.41
Shelly Beach	12	42.11	53.30	48.82	47.74	1.17
Kaipara River	11	38.97	52.99	47.81	46.45	1.53

Table 5-2 Salinity (ppt) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	33.68	35.94	34.37	34.66	0.21
Ti Point	12	33.41	35.95	34.23	34.53	0.23
Dawsons Creek	12	28.57	35.67	32.19	32.60	0.60
Mahurangi Heads	12	31.83	35.94	33.90	33.99	0.35
Orewa	12	32.79	36.01	34.08	34.23	0.30
Browns Bay	12	32.21	35.80	34.05	34.09	0.31
Chelsea	11	31.09	35.40	33.26	33.30	0.44
Whau Creek	11	26.58	35.03	32.01	31.41	0.89
Henderson Creek	11	21.45	34.79	31.86	30.07	1.39
Hobsonville Jetty	11	26.67	35.06	32.47	31.93	0.80
Lucas Creek	11	7.93	33.92	28.94	25.79	2.48
Paramoremo Ski Club	11	15.02	33.91	29.49	26.97	2.12
Brighams Creek	11	2.23	33.68	26.61	21.99	3.49
Rangitopuni Creek	11	1.00	32.98	23.41	20.10	3.76
Tāmaki	12	27.27	37.26	34.75	33.97	0.90
Panmure	12	20.82	35.06	32.69	30.66	1.34
Wairoa River Mouth	11	30.03	35.28	33.14	32.92	0.45
Mangere Bridge	12	26.20	33.38	29.72	30.00	0.76
Puketutu Point	12	28.63	33.65	31.61	31.35	0.53
Weymouth	12	24.27	34.53	31.40	30.59	0.94
Waiuku Town Basin	12	18.53	31.41	29.36	27.11	1.41
Clarks Beach	12	29.19	34.61	32.52	32.05	0.56
Grahams Beach	12	30.95	35.18	32.94	32.95	0.41
Shag Point	12	29.45	35.00	32.67	32.31	0.54
Manukau Hbr @ Mouth	12	31.66	35.39	33.28	33.42	0.36
Kaipara Heads	12	32.31	35.83	33.96	33.82	0.31
Tauhoa Channel	12	28.29	35.14	32.48	31.86	0.64
Hoteo River Mouth	12	23.49	33.80	30.73	29.28	1.12
Makarau Estuary	12	25.06	35.16	31.18	30.17	1.05
Shelly Beach	12	27.04	35.21	32.00	31.15	0.85
Kaipara River	11	24.86	34.98	31.42	30.24	1.12

Table 5-3 pH (pH units) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	7.91	8.14	8.01	8.01	0.02
Ti Point	12	7.96	8.14	8.08	8.07	0.02
Dawsons Creek	12	7.78	8.08	8.00	7.98	0.02
Mahurangi Heads	12	7.90	8.13	8.09	8.06	0.02
Orewa	12	7.94	8.16	8.12	8.09	0.02
Browns Bay	12	7.87	8.16	8.09	8.07	0.02
Chelsea	12	7.42	8.14	7.98	7.93	0.06
Whau Creek	12	7.37	8.06	7.97	7.90	0.06
Henderson Creek	12	7.26	8.06	8.00	7.90	0.07
Hobsonville Jetty	12	7.23	8.09	8.02	7.93	0.07
Lucas Creek	12	7.39	7.97	7.90	7.82	0.05
Paramoremo Ski Club	12	7.37	7.97	7.92	7.83	0.06
Brighams Creek	12	7.21	7.94	7.79	7.73	0.07
Rangitopuni Creek	12	7.05	7.88	7.72	7.66	0.07
Tāmaki	12	7.78	8.21	8.01	7.99	0.04
Panmure	12	7.60	7.91	7.79	7.76	0.03
Wairoa River Mouth	11	7.89	8.18	8.06	8.06	0.03
Mangere Bridge	12	7.01	8.17	8.03	7.93	0.09
Puketutu Point	12	7.08	8.20	8.06	7.97	0.09
Weymouth	11	7.60	8.15	8.03	8.00	0.04
Waiuku Town Basin	12	7.08	8.10	7.94	7.85	0.08
Clarks Beach	11	7.53	8.20	8.06	8.02	0.05
Grahams Beach	11	7.63	8.23	8.09	8.06	0.05
Shag Point	12	7.02	8.22	8.07	8.00	0.10
Manukau Hbr @ Mouth	11	7.67	8.20	8.12	8.08	0.04
Kaipara Heads	11	7.74	8.17	8.10	8.07	0.04
Tauhoa Channel	11	7.66	8.16	8.06	8.03	0.04
Hoteo River Mouth	11	7.59	8.08	7.98	7.93	0.04
Makarau Estuary	11	7.58	8.06	7.95	7.93	0.04
Shelly Beach	11	7.60	8.08	7.95	7.93	0.04
Kaipara River	10	7.48	7.97	7.83	7.80	0.05

Table 5-4 Turbidity (NTU) for data collected from January 2016 to December 2016.
**BDL = Below Detection Limit (<0.05NTU)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.25	0.75	0.35	0.39	BDL
Ti Point	12	0.35	2.30	0.60	0.72	0.15
Dawsons Creek	12	2.80	6.60	4.20	4.39	0.37
Mahurangi Heads	12	0.80	2.20	1.30	1.35	0.12
Orewa	12	0.40	1.70	0.50	0.78	0.13
Browns Bay	12	0.45	2.10	0.85	0.96	0.14
Chelsea	12	1.60	5.90	2.95	3.00	0.36
Whau Creek	12	1.90	5.20	3.45	3.52	0.34
Henderson Creek	12	2.30	140.00	4.35	15.90	11.29
Hobsonville Jetty	12	1.90	7.90	3.75	3.83	0.44
Lucas Creek	12	3.50	90.00	7.20	16.50	7.22
Paramoremo Ski Club	12	3.30	70.00	6.35	12.58	5.38
Brighams Creek	12	5.00	160.00	8.25	27.18	13.30
Rangitopuni Creek	12	4.10	140.00	8.95	22.84	11.01
Tāmaki	12	1.20	15.00	2.50	3.88	1.09
Panmure	12	3.30	20.00	6.80	7.46	1.28
Wairoa River Mouth	11	0.60	9.10	4.70	4.20	0.64
Mangere Bridge	12	2.60	27.00	7.10	8.98	1.94
Puketutu Point	12	2.60	7.40	4.75	4.75	0.52
Weymouth	12	3.20	16.00	8.40	8.95	1.09
Waiuku Town Basin	12	BDL	40.00	11.50	14.08	3.39
Clarks Beach	12	2.90	9.50	6.85	6.67	0.66
Grahams Beach	12	0.75	6.50	3.70	3.53	0.49
Shag Point	12	1.20	9.70	5.70	5.61	0.92
Manukau Hbr @ Mouth	12	1.10	4.60	2.25	2.35	0.30
Kaipara Heads	12	0.45	3.60	1.15	1.58	0.29
Tauhoa Channel	12	0.95	5.20	2.60	2.73	0.37
Hoteo River Mouth	12	3.20	13.00	6.30	6.76	0.80
Makarau Estuary	12	4.90	15.00	8.35	8.67	0.78
Shelly Beach	12	3.10	8.60	4.95	5.30	0.55
Kaipara River	11	7.40	27.00	17.00	16.67	1.70

Table 5-5 Suspended sediment (mg/L) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.80	8.40	1.85	2.89	0.78
Ti Point	12	0.50	8.80	2.90	4.30	0.87
Dawsons Creek	12	3.60	16.00	9.90	10.29	1.17
Mahurangi Heads	12	2.60	12.00	4.20	4.98	0.73
Orewa	12	0.75	10.00	3.60	4.40	0.87
Browns Bay	12	1.20	14.00	2.90	4.31	1.06
Chelsea	12	3.80	18.00	8.70	9.18	1.33
Whau Creek	12	3.60	18.00	8.80	9.85	1.09
Henderson Creek	12	6.60	100.00	9.90	17.95	7.51
Hobsonville Jetty	12	6.00	18.00	9.60	10.30	1.14
Lucas Creek	12	7.20	87.00	15.00	22.98	6.58
Paramoremo Ski Club	12	6.40	63.00	12.50	17.83	4.35
Brighams Creek	12	12.00	180.00	16.50	34.58	14.23
Rangitopuni Creek	12	10.00	150.00	14.50	27.83	11.24
Tāmaki	12	3.60	31.00	7.25	9.13	2.10
Panmure	12	6.00	54.00	15.00	18.97	3.76
Wairoa River Mouth	11	5.80	26.00	10.00	12.27	1.92
Mangere Bridge	12	15.00	57.00	25.50	28.08	3.25
Puketutu Point	12	8.40	25.00	14.50	15.62	1.43
Weymouth	12	8.00	50.00	25.00	28.08	3.59
Waiuku Town Basin	12	9.20	130.00	26.50	39.32	10.77
Clarks Beach	12	14.00	44.00	20.00	23.58	2.84
Grahams Beach	12	2.00	47.00	12.00	16.35	3.68
Shag Point	12	7.60	37.00	23.50	22.97	2.70
Manukau Hbr @ Mouth	12	2.40	19.00	10.00	10.28	1.25
Kaipara Heads	12	2.00	19.00	5.60	7.30	1.50
Tauhoa Channel	12	2.80	23.00	8.25	9.86	1.79
Hoteo River Mouth	12	6.40	50.00	15.00	19.10	3.72
Makarau Estuary	12	14.00	34.00	19.00	20.75	1.81
Shelly Beach	12	8.80	35.00	14.00	15.93	2.23
Kaipara River	11	20.00	57.00	34.00	36.45	3.64

Table 5-6 Chlorophyll a (mg/L) for data collected from January 2016 to December 2016
**BDL = Below Detection Limit (<0.0006mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	BDL	0.005	0.001	0.002	BDL
Ti Point	12	0.001	0.003	0.001	0.002	BDL
Dawsons Creek	12	0.001	0.003	0.002	0.002	BDL
Mahurangi Heads	12	BDL	0.002	0.001	0.001	BDL
Orewa	12	0.001	0.002	0.001	0.001	BDL
Browns Bay	12	BDL	0.003	0.001	0.001	BDL
Chelsea	12	0.001	0.003	0.002	0.002	BDL
Whau Creek	12	0.001	0.004	0.002	0.002	BDL
Henderson Creek	12	0.001	0.004	0.002	0.002	BDL
Hobsonville Jetty	12	0.001	0.004	0.002	0.002	BDL
Lucas Creek	12	0.001	0.027	0.003	0.006	0.002
Paramoremo Ski Club	12	0.001	0.017	0.003	0.004	0.001
Brighams Creek	12	0.001	0.050	0.003	0.009	0.004
Rangitopuni Creek	12	BDL	0.023	0.003	0.005	0.002
Tāmaki	12	0.001	0.003	0.002	0.002	BDL
Panmure	12	0.001	0.005	0.002	0.003	BDL
Wairoa River Mouth	11	0.001	0.004	0.002	0.002	BDL
Mangere Bridge	12	0.002	0.034	0.009	0.011	0.003
Puketutu Point	12	0.001	0.028	0.007	0.009	0.002
Weymouth	12	0.002	0.017	0.007	0.007	0.001
Waiuku Town Basin	12	0.001	0.022	0.004	0.008	0.002
Clarks Beach	12	0.001	0.008	0.005	0.004	0.001
Grahams Beach	12	0.001	0.006	0.003	0.003	0.001
Shag Point	12	0.001	0.019	0.005	0.007	0.002
Manukau Hbr @ Mouth	12	0.001	0.007	0.002	0.003	BDL
Kaipara Heads	12	BDL	0.003	0.001	0.001	BDL
Tauhoa Channel	12	0.002	0.007	0.003	0.003	0.001
Hoteo River Mouth	12	0.002	0.014	0.004	0.005	0.001
Makarau Estuary	12	0.002	0.019	0.005	0.007	0.002
Shelly Beach	12	0.002	0.014	0.004	0.004	0.001
Kaipara River	11	0.002	0.012	0.006	0.007	0.001

Table 5-7 Nitrite (mg N/L) for data collected from January 2016 to December 2016
**BDL = Below Detection Limit (<0.002mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	BDL	0.012	BDL	0.004	BDL
Ti Point	12	BDL	0.019	BDL	0.003	0.002
Dawsons Creek	12	BDL	BDL	BDL	BDL	BDL
Mahurangi Heads	12	BDL	0.002	BDL	BDL	BDL
Orewa	12	BDL	0.002	BDL	BDL	BDL
Browns Bay	12	BDL	0.003	BDL	BDL	BDL
Chelsea	12	BDL	BDL	BDL	BDL	BDL
Whau Creek	12	BDL	0.002	BDL	BDL	BDL
Henderson Creek	12	BDL	0.005	BDL	BDL	BDL
Hobsonville Jetty	12	BDL	0.004	BDL	BDL	BDL
Lucas Creek	12	BDL	0.005	BDL	BDL	BDL
Paramoremo Ski Club	12	BDL	0.004	BDL	BDL	BDL
Brighams Creek	12	BDL	0.009	0.002	0.003	BDL
Rangitopuni Creek	12	BDL	0.010	0.002	0.003	BDL
Tāmaki	12	BDL	0.002	BDL	BDL	BDL
Panmure	12	BDL	0.005	BDL	BDL	BDL
Wairoa River Mouth	11	BDL	0.002	BDL	BDL	BDL
Mangere Bridge	12	BDL	0.016	0.008	0.008	0.002
Puketutu Point	12	BDL	0.012	0.005	0.006	BDL
Weymouth	12	BDL	0.007	0.002	0.002	BDL
Waiuku Town Basin	12	BDL	0.011	0.005	0.005	BDL
Clarks Beach	12	BDL	0.003	BDL	BDL	BDL
Grahams Beach	12	BDL	0.002	BDL	BDL	BDL
Shag Point	12	BDL	0.009	0.002	0.003	BDL
Manukau Hbr @ Mouth	12	BDL	0.002	BDL	BDL	BDL
Kaipara Heads	12	BDL	0.003	BDL	BDL	BDL
Tauhoa Channel	12	BDL	0.002	BDL	BDL	BDL
Hoteo River Mouth	12	BDL	0.003	BDL	BDL	BDL
Makarau Estuary	12	BDL	0.005	BDL	BDL	BDL
Shelly Beach	12	BDL	0.003	BDL	BDL	BDL
Kaipara River	11	BDL	0.005	BDL	0.002	BDL

Table 5-8 Nitrate (mg N/L) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.002	0.070	0.010	0.020	0.006
Ti Point	12	0.002	0.038	0.009	0.014	0.004
Dawsons Creek	12	0.002	0.058	0.005	0.010	0.005
Mahurangi Heads	12	0.002	0.019	0.004	0.006	0.002
Orewa	12	0.002	0.017	0.003	0.005	0.001
Browns Bay	12	0.002	0.022	0.006	0.008	0.002
Chelsea	12	0.004	0.031	0.017	0.018	0.003
Whau Creek	12	0.002	0.062	0.014	0.023	0.006
Henderson Creek	12	0.003	0.400	0.016	0.065	0.032
Hobsonville Jetty	12	0.002	0.059	0.017	0.025	0.006
Lucas Creek	12	0.005	0.370	0.022	0.099	0.036
Paramoremo Ski Club	12	0.002	0.290	0.024	0.083	0.030
Brighams Creek	12	0.008	0.610	0.036	0.180	0.068
Rangitopuni Creek	12	0.015	0.670	0.042	0.176	0.062
Tāmaki	12	0.003	0.170	0.013	0.029	0.014
Panmure	12	0.007	0.420	0.025	0.076	0.035
Wairoa River Mouth	11	0.002	0.041	0.006	0.010	0.003
Mangere Bridge	12	0.002	0.370	0.145	0.172	0.036
Puketutu Point	12	0.060	0.350	0.175	0.190	0.025
Weymouth	12	0.002	0.390	0.075	0.121	0.038
Waiuku Town Basin	12	0.002	0.810	0.072	0.252	0.091
Clarks Beach	12	0.002	0.130	0.020	0.045	0.013
Grahams Beach	12	0.002	0.052	0.008	0.014	0.004
Shag Point	12	0.002	0.170	0.044	0.057	0.016
Manukau Hbr @ Mouth	12	0.002	0.039	0.009	0.011	0.003
Kaipara Heads	12	0.002	0.020	0.006	0.008	0.002
Tauhoa Channel	12	0.002	0.039	0.005	0.010	0.004
Hoteo River Mouth	12	0.002	0.084	0.025	0.031	0.008
Makarau Estuary	12	0.002	0.100	0.016	0.028	0.009
Shelly Beach	12	0.002	0.069	0.008	0.018	0.006
Kaipara River	11	0.002	0.079	0.016	0.027	0.007

Table 5-9 Ammonia (mg N/L) for data collected from January 2016 to December 2016
**BDL = Below Detection Limit (<0.005mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	BDL	0.012	0.005	0.005	BDL
Ti Point	12	BDL	0.017	0.005	0.006	BDL
Dawsons Creek	12	BDL	0.017	0.006	0.008	BDL
Mahurangi Heads	12	BDL	0.029	BDL	0.007	BDL
Orewa	12	BDL	0.010	0.005	0.005	BDL
Browns Bay	12	BDL	0.013	0.006	0.006	BDL
Chelsea	12	BDL	0.024	0.006	0.009	BDL
Whau Creek	12	0.005	0.024	0.015	0.015	BDL
Henderson Creek	12	BDL	0.073	0.014	0.019	0.006
Hobsonville Jetty	12	BDL	0.020	0.010	0.011	BDL
Lucas Creek	12	0.005	0.096	0.016	0.024	0.007
Paramoremo Ski Club	12	0.005	0.079	0.016	0.023	0.006
Brighams Creek	12	BDL	0.120	0.015	0.031	0.010
Rangitopuni Creek	12	0.011	0.083	0.027	0.031	0.006
Tāmaki	12	0.008	0.058	0.025	0.024	BDL
Panmure	12	0.011	0.096	0.029	0.037	0.007
Wairoa River Mouth	11	BDL	0.020	0.008	0.009	BDL
Mangere Bridge	12	0.007	0.140	0.071	0.068	0.014
Puketutu Point	12	0.013	0.130	0.055	0.059	0.011
Weymouth	12	0.008	0.093	0.032	0.035	0.006
Waiuku Town Basin	12	0.006	0.084	0.023	0.035	0.008
Clarks Beach	12	BDL	0.045	0.019	0.018	BDL
Grahams Beach	12	BDL	0.045	0.007	0.010	BDL
Shag Point	12	BDL	0.120	0.021	0.034	0.010
Manukau Hbr @ Mouth	12	BDL	0.029	0.008	0.008	BDL
Kaipara Heads	12	BDL	0.016	0.002	0.004	BDL
Tauhoa Channel	12	BDL	0.017	0.006	0.006	BDL
Hoteo River Mouth	12	0.005	0.086	0.027	0.031	0.007
Makarau Estuary	12	BDL	0.068	0.017	0.024	0.006
Shelly Beach	12	BDL	0.047	0.008	0.014	BDL
Kaipara River	11	BDL	0.066	0.023	0.030	0.007

Table 5-10 Total kjedahl nitrogen (mg N/L) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.015	0.072	0.044	0.045	0.007
Ti Point	12	0.015	0.126	0.068	0.064	0.009
Dawsons Creek	12	0.048	0.150	0.096	0.098	0.010
Mahurangi Heads	12	0.021	0.095	0.057	0.059	0.008
Orewa	12	0.025	0.092	0.064	0.061	0.007
Browns Bay	12	0.039	0.130	0.076	0.078	0.008
Chelsea	12	0.038	0.670	0.110	0.158	0.049
Whau Creek	12	0.064	0.270	0.130	0.133	0.014
Henderson Creek	12	0.078	0.740	0.140	0.185	0.052
Hobsonville Jetty	12	0.033	0.160	0.115	0.110	0.010
Lucas Creek	12	0.096	0.780	0.185	0.280	0.064
Paramoremo Ski Club	12	0.086	1.200	0.210	0.298	0.087
Brighams Creek	12	0.075	1.200	0.280	0.415	0.108
Rangitopuni Creek	11	0.130	0.780	0.290	0.349	0.064
Tāmaki	12	0.072	0.210	0.140	0.144	0.011
Panmure	12	0.097	0.350	0.190	0.203	0.025
Wairoa River Mouth	11	0.028	0.130	0.094	0.094	0.008
Mangere Bridge	12	0.120	0.410	0.230	0.256	0.025
Puketutu Point	12	0.090	0.450	0.230	0.244	0.030
Weymouth	12	0.091	0.290	0.175	0.189	0.017
Waiuku Town Basin	12	0.150	0.390	0.240	0.261	0.021
Clarks Beach	12	0.020	0.190	0.135	0.119	0.016
Grahams Beach	12	0.038	0.130	0.091	0.091	0.010
Shag Point	12	0.075	0.250	0.155	0.165	0.017
Manukau Hbr @ Mouth	12	0.023	0.150	0.084	0.078	0.010
Kaipara Heads	12	0.005	0.089	0.050	0.044	0.007
Tauhoa Channel	12	0.022	0.150	0.080	0.080	0.012
Hoteo River Mouth	12	0.069	0.390	0.140	0.172	0.025
Makarau Estuary	12	0.110	0.250	0.170	0.173	0.011
Shelly Beach	12	0.068	0.550	0.140	0.161	0.037
Kaipara River	11	0.110	0.320	0.210	0.204	0.020

Table 5-11 Total nitrogen (by calculation, mg N/L) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.021	0.120	0.066	0.064	0.009
Ti Point	12	0.026	0.100	0.081	0.069	0.008
Dawsons Creek	12	0.062	0.150	0.104	0.108	0.010
Mahurangi Heads	12	0.024	0.100	0.059	0.064	0.008
Orewa	12	0.013	0.110	0.067	0.064	0.008
Browns Bay	12	0.042	0.140	0.087	0.085	0.009
Chelsea	12	0.056	0.690	0.120	0.175	0.049
Whau Creek	12	0.076	0.280	0.150	0.156	0.015
Henderson Creek	12	0.091	1.100	0.160	0.246	0.080
Hobsonville Jetty	12	0.048	0.190	0.140	0.135	0.011
Lucas Creek	12	0.110	1.100	0.270	0.378	0.093
Paramoremo Ski Club	12	0.099	1.500	0.225	0.382	0.112
Brighams Creek	12	0.088	1.800	0.305	0.601	0.167
Rangitopuni Creek	12	0.160	2.000	0.340	0.636	0.171
Tāmaki	12	0.110	0.350	0.145	0.174	0.019
Panmure	12	0.130	0.770	0.240	0.282	0.048
Wairoa River Mouth	11	0.069	0.140	0.099	0.106	0.008
Mangere Bridge	12	0.230	0.680	0.500	0.436	0.043
Puketutu Point	12	0.230	0.730	0.445	0.442	0.039
Weymouth	12	0.130	0.560	0.305	0.313	0.044
Waiuku Town Basin	12	0.240	0.970	0.385	0.518	0.078
Clarks Beach	12	0.082	0.300	0.150	0.164	0.019
Grahams Beach	12	0.068	0.140	0.105	0.104	0.007
Shag Point	12	0.120	0.350	0.230	0.226	0.022
Manukau Hbr @ Mouth	12	0.033	0.180	0.086	0.087	0.012
Kaipara Heads	12	0.018	0.093	0.053	0.051	0.007
Tauhoa Channel	12	0.011	0.150	0.084	0.087	0.011
Hoteo River Mouth	12	0.100	0.420	0.170	0.203	0.027
Makarau Estuary	12	0.150	0.260	0.190	0.202	0.011
Shelly Beach	12	0.092	0.570	0.150	0.179	0.037
Kaipara River	11	0.140	0.370	0.250	0.231	0.021

Table 5-12 Total phosphorus (mg/L) for data collected from January 2016 to December 2016
**BDL = Below Detection Limit (<0.004mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.004	0.021	0.010	0.010	BDL
Ti Point	12	0.005	0.018	0.011	0.011	BDL
Dawsons Creek	12	0.013	0.022	0.018	0.017	BDL
Mahurangi Heads	12	0.008	0.026	0.013	0.014	BDL
Orewa	12	0.009	0.017	0.014	0.013	BDL
Browns Bay	12	0.012	0.025	0.017	0.017	BDL
Chelsea	12	0.015	0.028	0.021	0.022	BDL
Whau Creek	12	0.019	0.031	0.024	0.024	BDL
Henderson Creek	12	0.019	0.150	0.027	0.036	0.010
Hobsonville Jetty	12	0.018	0.028	0.024	0.024	BDL
Lucas Creek	12	0.021	0.120	0.033	0.045	0.010
Paramoremo Ski Club	12	0.014	0.160	0.033	0.041	0.011
Brighams Creek	12	0.017	0.230	0.039	0.068	0.020
Rangitopuni Creek	12	0.016	0.200	0.042	0.060	0.015
Tāmaki	12	0.018	0.035	0.027	0.026	BDL
Panmure	12	0.025	0.049	0.038	0.038	BDL
Wairoa River Mouth	11	0.013	0.033	0.023	0.022	BDL
Mangere Bridge	12	0.086	0.160	0.110	0.115	0.007
Puketutu Point	12	0.068	0.300	0.097	0.118	0.018
Weymouth	12	0.033	0.057	0.044	0.044	BDL
Waiuku Town Basin	12	0.026	0.093	0.042	0.051	0.006
Clarks Beach	12	0.016	0.047	0.027	0.029	BDL
Grahams Beach	12	0.015	0.031	0.024	0.023	BDL
Shag Point	12	0.034	0.081	0.060	0.060	0.004
Manukau Hbr @ Mouth	12	0.012	0.020	0.017	0.017	BDL
Kaipara Heads	12	0.006	0.016	0.010	0.010	BDL
Tauhoa Channel	12	0.011	0.021	0.016	0.015	BDL
Hoteo River Mouth	12	0.021	0.055	0.028	0.030	BDL
Makarau Estuary	12	0.026	0.042	0.033	0.033	BDL
Shelly Beach	12	0.017	0.030	0.022	0.022	BDL
Kaipara River	11	0.021	0.056	0.040	0.040	BDL

Table 5-13 Soluble reactive phosphorus (mg/L) for data collected from January 2016 to December 2016
**BDL = Below Detection Limit (<0.002mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.003	0.014	0.007	0.008	BDL
Ti Point	12	0.003	0.013	0.007	0.008	BDL
Dawsons Creek	12	0.007	0.014	0.011	0.011	BDL
Mahurangi Heads	12	0.007	0.017	0.010	0.010	BDL
Orewa	12	0.006	0.015	0.011	0.010	BDL
Browns Bay	12	0.010	0.020	0.014	0.014	BDL
Chelsea	12	0.011	0.026	0.015	0.016	BDL
Whau Creek	12	0.012	0.026	0.017	0.018	BDL
Henderson Creek	12	0.012	0.026	0.017	0.017	BDL
Hobsonville Jetty	12	0.012	0.028	0.017	0.018	0.002
Lucas Creek	12	0.009	0.029	0.017	0.018	0.002
Paramoremo Ski Club	12	0.013	0.030	0.020	0.020	0.002
Brighams Creek	12	0.008	0.032	0.022	0.021	0.002
Rangitopuni Creek	12	0.013	0.031	0.025	0.023	0.002
Tāmaki	12	0.016	0.027	0.019	0.020	BDL
Panmure	12	0.015	0.036	0.024	0.025	0.002
Wairoa River Mouth	11	0.008	0.021	0.013	0.015	BDL
Mangere Bridge	12	0.059	0.120	0.084	0.086	0.006
Puketutu Point	12	0.059	0.240	0.084	0.098	0.015
Weymouth	12	0.011	0.033	0.025	0.023	0.002
Waiuku Town Basin	12	0.003	0.038	0.025	0.023	0.003
Clarks Beach	12	0.009	0.026	0.019	0.018	0.002
Grahams Beach	12	0.007	0.024	0.015	0.015	0.002
Shag Point	12	0.019	0.065	0.042	0.044	0.005
Manukau Hbr @ Mouth	12	0.007	0.015	0.012	0.011	BDL
Kaipara Heads	12	0.005	0.008	0.006	0.006	BDL
Tauhoa Channel	12	0.005	0.013	0.008	0.009	BDL
Hoteo River Mouth	12	0.011	0.022	0.015	0.015	BDL
Makarau Estuary	12	0.011	0.021	0.014	0.015	BDL
Shelly Beach	12	0.008	0.017	0.011	0.011	BDL
Kaipara River	11	0.012	0.021	0.015	0.016	BDL

Table 5-14 Dissolved oxygen (% saturation) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	94.40	104.60	99.55	99.63	0.96
Ti Point	12	95.70	103.20	99.50	99.88	0.63
Dawsons Creek	12	90.80	99.70	95.55	95.12	0.76
Mahurangi Heads	12	94.80	102.90	98.85	98.88	0.60
Orewa	12	96.60	104.60	100.40	100.63	0.65
Browns Bay	12	92.90	108.20	99.10	98.69	1.11
Chelsea	12	94.70	102.80	97.25	98.36	0.73
Whau Creek	12	94.40	104.30	97.15	98.12	0.88
Henderson Creek	12	92.30	104.40	97.85	97.34	1.08
Hobsonville Jetty	12	94.30	104.30	98.95	98.68	0.82
Lucas Creek	12	86.50	107.70	91.95	94.03	1.86
Paramoremo Ski Club	12	87.20	100.70	95.50	94.62	1.28
Brighams Creek	12	82.70	105.10	94.50	93.93	1.82
Rangitopuni Creek	12	81.50	100.70	92.90	92.28	1.67
Tāmaki	12	93.40	99.60	97.35	96.93	0.60
Panmure	12	88.30	97.20	95.40	94.50	0.74
Wairoa River Mouth	11	93.00	102.80	97.40	97.95	0.97
Mangere Bridge	12	95.20	122.40	102.30	103.16	2.05
Puketutu Point	12	96.80	114.70	103.95	103.85	1.44
Weymouth	12	94.30	103.60	98.45	98.42	0.85
Waiuku Town Basin	12	88.40	104.60	97.00	97.14	1.38
Clarks Beach	12	92.20	105.40	98.05	98.69	1.19
Grahams Beach	12	97.40	108.00	101.60	101.83	0.83
Shag Point	12	95.90	114.80	103.90	103.94	1.58
Manukau Hbr @ Mouth	12	99.50	105.10	102.15	102.32	0.51
Kaipara Heads	12	102.10	106.40	103.45	103.82	0.44
Tauhoa Channel	12	98.90	104.40	101.65	101.74	0.49
Hoteo River Mouth	12	90.90	100.80	97.10	96.59	0.94
Makarau Estuary	12	93.00	102.20	98.05	97.83	0.71
Shelly Beach	12	96.40	101.30	99.10	99.18	0.42
Kaipara River	11	90.80	99.20	95.70	95.56	0.72

Table 5-15 Dissolved oxygen (ppm) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	7.16	8.38	7.66	7.74	0.11
Ti Point	12	7.16	8.67	7.81	7.79	0.14
Dawsons Creek	12	6.82	8.53	7.45	7.50	0.18
Mahurangi Heads	12	6.97	8.80	7.69	7.73	0.17
Orewa	12	7.00	8.88	7.81	7.85	0.17
Browns Bay	12	6.70	9.26	7.64	7.72	0.21
Chelsea	12	6.67	8.79	7.87	7.82	0.20
Whau Creek	12	6.68	9.05	7.97	7.92	0.22
Henderson Creek	12	6.44	9.07	7.94	7.89	0.23
Hobsonville Jetty	12	6.61	8.92	7.97	7.89	0.20
Lucas Creek	12	6.06	10.03	7.70	7.83	0.33
Paramoremo Ski Club	12	6.11	9.13	7.77	7.77	0.27
Brighams Creek	12	5.82	9.53	7.96	7.96	0.36
Rangitopuni Creek	12	5.73	9.76	7.92	7.98	0.40
Tāmaki	12	6.72	8.58	7.33	7.51	0.19
Panmure	12	6.49	9.00	7.41	7.49	0.22
Wairoa River Mouth	11	6.80	8.89	7.72	7.69	0.19
Mangere Bridge	12	6.97	10.09	8.06	8.21	0.31
Puketutu Point	12	7.22	9.51	7.91	8.18	0.27
Weymouth	12	6.98	9.25	7.49	7.82	0.24
Waiuku Town Basin	12	6.89	9.37	7.75	7.88	0.26
Clarks Beach	12	6.56	9.26	7.69	7.77	0.25
Grahams Beach	12	7.16	9.27	7.69	7.95	0.20
Shag Point	12	7.15	9.39	7.91	8.15	0.24
Manukau Hbr @ Mouth	12	7.29	8.80	7.83	7.96	0.16
Kaipara Heads	12	7.38	8.92	8.08	8.10	0.16
Tauhoa Channel	12	7.01	9.03	7.96	8.00	0.21
Hoteo River Mouth	12	6.47	9.13	7.57	7.78	0.27
Makarau Estuary	12	6.58	9.32	7.62	7.81	0.27
Shelly Beach	12	6.83	9.00	7.70	7.84	0.23
Kaipara River	11	6.67	8.87	7.30	7.57	0.25

Table 5-16 Summary table of temperature (°C) for data collected from January 2016 to December 2016

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	14.04	22.21	16.48	17.61	0.87
Ti Point	12	13.63	22.55	16.35	17.46	0.91
Dawsons Creek	12	12.65	23.43	17.63	17.61	1.06
Mahurangi Heads	12	13.12	23.08	17.28	17.63	1.04
Orewa	12	13.03	23.47	16.86	17.61	1.03
Browns Bay	12	13.34	23.58	16.76	17.57	1.04
Chelsea	12	12.44	23.49	17.87	17.80	1.09
Whau Creek	12	11.13	23.79	17.51	17.63	1.16
Henderson Creek	12	11.26	23.38	17.79	17.79	1.16
Hobsonville Jetty	12	11.95	23.56	17.97	17.94	1.12
Lucas Creek	12	11.14	23.41	17.85	17.89	1.20
Paramoremo Ski Club	12	11.51	23.48	18.22	18.13	1.17
Brighams Creek	12	11.28	23.52	18.21	18.15	1.21
Rangitopuni Creek	12	10.89	23.63	18.00	17.82	1.23
Tāmaki	12	12.45	23.70	18.00	18.11	1.07
Panmure	12	11.91	24.06	18.25	18.01	1.10
Wairoa River Mouth	11	12.07	23.24	17.77	17.73	1.05
Mangere Bridge	12	11.99	24.30	18.88	18.16	1.33
Puketutu Point	12	12.13	24.32	18.84	18.20	1.31
Weymouth	12	11.95	23.68	18.76	18.02	1.29
Waiuku Town Basin	12	11.57	24.33	18.94	18.04	1.41
Clarks Beach	12	12.47	23.68	18.25	18.00	1.23
Grahams Beach	12	12.59	23.32	18.36	18.06	1.19
Shag Point	12	12.19	23.91	18.67	18.11	1.29
Manukau Hbr @ Mouth	12	13.13	22.70	18.05	18.00	1.01
Kaipara Heads	12	13.83	21.89	17.64	17.73	0.86
Tauhoa Channel	12	13.05	23.24	18.20	18.07	1.14
Hoteo River Mouth	12	11.90	24.55	18.30	17.81	1.31
Makarau Estuary	12	11.99	24.19	18.63	17.99	1.30
Shelly Beach	12	12.29	23.76	18.40	18.07	1.26
Kaipara River	11	12.14	24.21	18.73	18.30	1.33

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Appendix A Physical-chemical measures

Table A-1 Summary of marine water quality parameters, detection limits, analytical methods and source of data collection

Parameter	Unit	Detection Limit	Method	Source
Dissolved oxygen	ppm	0.1	EXO Sonde (Xylem Analytics)	Field
Dissolved oxygen saturation	% sat	0.01	EXO Sonde (Xylem Analytics)	Field
Temperature	°C	0.01	EXO Sonde (Xylem Analytics)	Field
Conductivity	mS/cm	0.01	EXO Sonde (Xylem Analytics)	Field
Salinity	ppt	0.2	EXO Sonde (Xylem Analytics)	Field
pH	pH units	0.1	EXO Sonde (Xylem Analytics)	Field
Suspended sediment	mg/L	0.4	APHA (2012) 2540 D	Lab
Turbidity	NTU	0.05	APHA (2012) 2130 B (modified)	Lab
Chlorophyll *a*	mg/L	0.0006	APHA (2012) 10200 H (modified)	Lab
Nitrate nitrogen (NO_3)	mg/L	0.002	Calculation (NNN – NO2)	Lab
Nitrite nitrogen (NO_2)	mg/L	0.002	APHA (2012) 4500-NO2 B (modified)	Lab
Ammoniacal nitrogen (NH_4-N)	mg/L	0.005	APHA (2012) 4500-NH3 G (modified)	Lab
Total kjeldahl nitrogen (TKN)	mg N/L	0.02	APHA (2012) 4500-org A, D (modified)	Lab
Total nitrogen (TN)	mg N/L	0.01	APHA (2012) 4500-P J, 4500 NO3 F (modified)	Lab
Soluble reactive phosphorus	mg/L	0.002	APHA (2012) 4500-P B, F (modified)	Lab
Total phosphorus	mg/L	0.004	APHA (2012) 4500-P B, J (modified)	Lab

Appendix B Water Quality Indices

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;

- Greater than 90 = excellent water quality
- Between 75 and 90 = good water quality
- Between 60 and 75 = fair water quality
- Lower than 60 = poor water quality

The above indices are calculated for each site based on seven water quality parameters presented in Table B-1. The objectives against which the water quality data are tested are derived from the ranges observed at six reference sites (Goat Island, Ti Point, Manukau Heads, Kaipara Heads, Chelsea and Hobsonville Jetty) over the five years preceding the report (2011 to 2015). It was considered thresholds based on a fixed period, whilst providing consistency would not capture longer term trends in water quality, nor account for improvements in the measurement of parameters (for example, improved meter performance or improvements in detection limits).

The ranges at these reference sites were used, as this represents the best achievable water quality in the Auckland region. Therefore, the index represents the deviation from "actual" conditions in the Auckland region, rather than indicating whether the water quality is suitable for a particular purpose.

Table B-1 The seven water quality parameters, and their objectives, used to produce the water quality indices

Parameter	Objective (acceptable if)
Dissolved oxygen (% saturation)	greater than 91%
pH	Between 7.6 and 8.3
Turbidity	Less than 7.8 NTU
Ammoniacal nitrogen	Less than 0.024 mg N/L
Total suspended sediment	Less than 20 mg/L
Total phosphorus	Less than 0.040 mg P/L
Nitrate + nitrite nitrogen	Less than 0.042 mg N/L

Appendix C Historical sites

The table below contains a list of all sites that have been part of the marine water quality programme since its inception in 1987. The table includes when the site was initiated, its location, and status. N.B some of the details are missing due to absence of records for these sites.

Table C-1 Complete list of both current and historical marine water quality sites sorted from north to south, grouped by location. Spatial reference is NZTM coordinates**.**

Site #	Site	Location	Easting	Northing	Sampling method	Year established	Status
6315	Goat Island	East Coast	1761835	5984910	Helicopter	1993	Current
6514	Ti Point	East Coast	1760222	5978524	Helicopter	1991	Current
	Kawau Bay (Algies Beach)	East Coast			Helicopter??	1991	Dropped 1999
	Warkworth (Town Basin)	East Coast	1749158	5970678	Boat	1993	Dropped 2007
	Mahurangi	East Coast			Boat??	1991	Dropped 1999
6843	Mahurangi Heads	East Coast	1754382	5959892	Helicopter	1993	Current
6843	Dawsons Creek	East Coast	1753554	5966410	Helicopter	1993	Current
7207	Orewa	East Coast	1753273	5949612	Helicopter	1991	Current
7518	Browns Bay	East Coast	1757934	5935780	Helicopter	1991	Current
45214	Shelly Beach	Kaipara Harbour	1723526	5951872	Helicopter	1991	Current
45374	Kaipara River	Kaipara Harbour	1726372	5946975	Helicopter	2009	Current
45506	Makarau Estuary	Kaipara Harbour	1728450	5953472	Helicopter	2009	Current
45700	Omokoiti Beacon	Kaipara Harbour	1718659	5961178	Helicopter	2009	Dropped 2015
45103	Kaipara Heads	Kaipara Harbour	1709351	5970137	Helicopter	2009	Current
45801	Tauhoa Channel	Kaipara Harbour	1717979	5969681	Helicopter	2009	Current
45700	Hoteo River	Kaipara Harbour	1726690	5967497	Helicopter	2009	Current
7705	Chelsea	Waitematā Harbour	1753944	5922872	Boat	1991	Current
8005	Whau Creek	Waitematā Harbour	1748289	5920291	Boat	1991	Current
7919	Henderson Creek	Waitematā Harbour	1746714	5923648	Boat	1991	Current

	Hobsonville	Waitematā Harbour			Boat	1991	Dropped 1999
7702	Hobsonville Jetty	Waitematā Harbour	1749321	5927317	Boat	1993	Current
7703	Waimarie Road	Waitematā Harbour	1746213	5929089	Boat	1993	Dropped 2015
7821	Rawawaru Creek	Waitematā Harbour	1744434	5928653	Boat	1993	Dropped 2015
7704	Confluence	Waitematā Harbour	1743655	5929055	Boat	1993	Dropped 2014
7809	Paremoremo Ski Club	Waitematā Harbour	1745746	5930178	Boat	1993	Current
7884	Rangitopuni Creek	Waitematā Harbour	1742836	5929868	Boat	1993	Current
7883	Brighams Creek	Waitematā Harbour	1742758	5928019	Boat	1993	Current
7882	Lucas Creek	Waitematā Harbour	1750045	5932471	Boat	1993	Current
8221	Tāmaki (No. 7 Buoy)	Tāmaki Estuary	1769372	5917448	Land	1992	Current
8220	Panmure	Tāmaki Estuary	1765295	5913934	Land	1992	Current
8413	Turanga Estuary	Tāmaki Strait	1774464	5914091	Helicopter	2009	Dropped 2015
8569	Wairoa River	Tāmaki Strait	1786443	5909850	Helicopter	2009	Current
43904	Papakura Channel	Manukau Harbour			Helicopter	1987	Dropped 1999
43507	Grahams Beach (Waiuku Channel)	Manukau Harbour	1749651	5888082	Helicopter	1987	Current
43506	Clarks Beach (Waiuku River)	Manukau Harbour	1748630	5897349	Helicopter	1987	Current
43519	Waiuku Town Basin	Manukau Harbour	1753690	5878187	Helicopter	2012	Current
44010	Shag Point (Titirangi)	Manukau Harbour	1748379	5908452	Helicopter	1987	Current
43906	Puketutu Point	Manukau Harbour	1753877	5908724	Helicopter	1987	Current
43904	Weymouth	Manukau Harbour	1764925	5897672	Helicopter	1987	Current
43905	Mangere Bridge	Manukau Harbour	1758588	5910714	Helicopter	1987	Current
43513	Manukau Heads	Manukau Harbour	1708915	5970600	Helicopter	2009	Current

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