Chatham Islands

Surface Water Summary 2020-21

Our people, our Islands, our future

chatham islands council

Environment Canterbury Science Summary:
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July 2023

Key messages

- ❖ Rainfall records indicate 2020/21 (and the previous 2019/20) had lower than average rainfall with cummulative drought periods over spring and summer. These can put pressure on limited water supplies on the island. Maintaining consistent rainfall monitoring sites particularly at Waitangi and the Airport are necessary for maintaining long term trends and management of community water supply resilience.

- ❖ Flow regimes of the major river systems are now well understood and characterised for both low flow and flood conditions. Flow monitoring of the rivers could be rationalised to monitoring priority rivers such as Te Awainanga and Nairn Rivers.

- ❖ Degrading water quality of waters across the island are likely caused primarily by climate patterns (drought) although changing farming emphasis to heavier livestock (sheep to cattle) appear to strongly interact with climate particularly where organic (peat) soils are poor at supporting heavier animals and contribute to erosion, pugging, compaction and casualty animal effects.

- ❖ Reduction in state or degrading trends were particularly notable at key sites. Blind Jims Creek exhibited both degrading water quality, impacted riparian habitats and an accompanying poor water quality in the Te Whanga receiving environment. Mangape Creek and the lower reaches of the Nairn River it discharges to were both showing effects of anoxic water, increasing nutrient concentrations and high microbiological concentrations. These catchments show conspicuous effects and a high water quality risk profile and deserve attention to riparian and stream management.

- ❖ The degrading water quality of Lake Rangitai is highly likely to be a result of the greatly reducing area of this lake as it is highly abstracted from for stockwater and domestic water use for the township of Kaingaroa. These water resources are largely being mined under sustained drought conditions, and as the lake becomes relatively small and shallow the water quality degrades and becomes less suitable for its uses. More careful or strategic management of this water resource is warranted.

- ❖ Te Whanga lagoon is a highly visible and important taonga or community asset. The very likely increasing trends in nitrogen, phosphorus and DOC in the lagoon are therefore of some notable concern. Scrutiny of these water quality results and trends for freshwaters in and flowing into Te Whanga lagoon should not be ignored.

- ❖ Closer attention to monitoring the limited domestic and potable water resources of the island are warranted including scoping monitoring of the groundwater resources and assessing the capacity of potential water resources.

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1 Introduction

Chatham Islands Council (CIC) is a unitary authority, acting as both a regional and a local council set up under its own act of parliament. Environment Canterbury (ECan) has been contracted since 2005 to provide advice and services to help CIC meet their Regional Council obligations including freshwater management. The water quality monitoring of the islands has been reported regularly via annual summary reports (2007, 2005-2010, 2014, 2015, 2016, 2018). These reports are available on the CIC website (https://cic.govt.nz/services/environmental-data/water-quality-data/). Another study undertaken with concurrent gaugings showed the correlations between flow rate for smaller streams (Ritson, 2010). Recently, Pattle Delamore, was engaged to undertake a review and report of the environmental monitoring on Chatham Island, including both water quality and historical qualitative and quantitative hydrological data and climate records. Another study undertaken with concurrent gaugings showed the correlations between flow rate for smaller streams (Ritson, 2010). This report provides an update of surface water monitoring (both water quality, quantity, and rainfall) state and trends for the main Chatham Island for the 2020-2021 year. Other islands such as the permanently occupied Pitt Island has not been monitored in this programme. A commentary is provided on the likely influences of any trends or changes in water quality and quantity state identified. (https://cic.govt.nz/services/environmental-data/water-quality-data/) and climate records. (Ritson, 2010) This report provides an update of surface water monitoring (both water quality, quantity, and rainfall) state and trends for the main Chatham Island for the 2020-2021 year. Other islands such as the permanently occupied Pitt Island has not been monitored in this programme. A commentary is provided on the likely influences of any trends or changes in water quality and quantity state identified.

The Chatham Islands form an archipelago of 10 islands with an approximate 60 km radius, these islands were formed from a volcanic upthrust causing the catchment geology to consist of volcanic basalt, unconsolidated sand, limestone, and schist. This is overlain with peat, sand, mudstone, and silt (GNS, 2014). Up to 60% of the main island, Chatham Island, is covered in peat or peat derived soils, ranging in thickness from half a metre to over 10 metres deep (Figure 1-1).

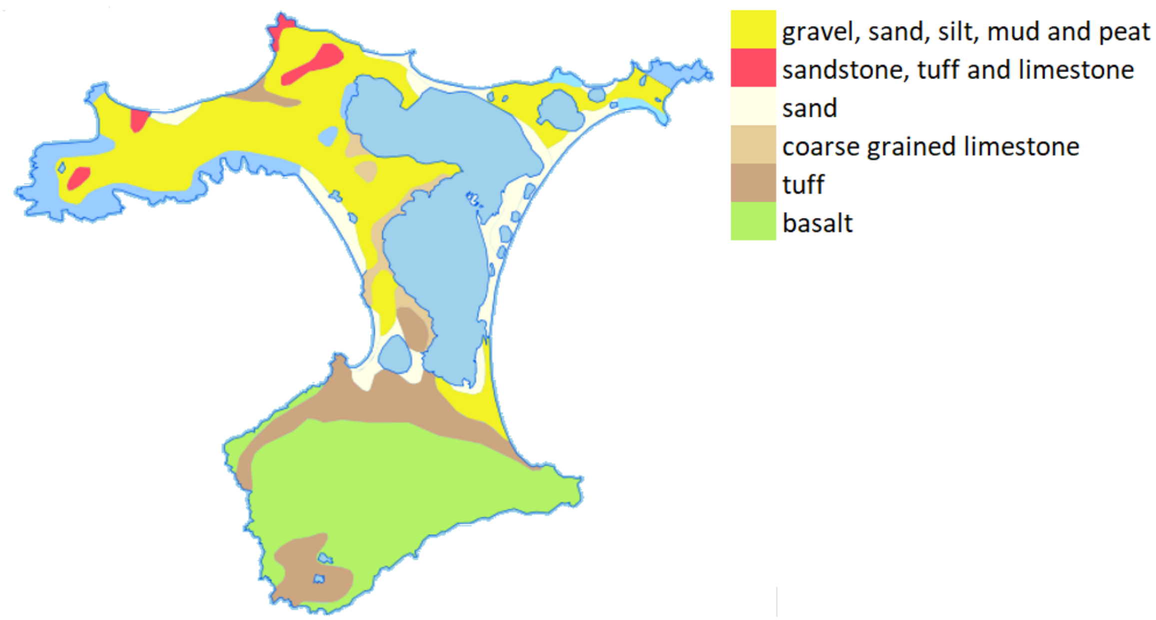

Figure 1-1: A map of Chatham Island with an overlay of the land type from the GNS - geological map of New Zealand 1:250k (GNS, 2014)

Many of the watercourses on Chatham Island drain peat basins, are highly peat stained and often have consolidated or mobile peat bed materials. The peatlands can buffer extreme weather patterns and rainfall events by acting like a sponge (rapidly absorbing and more slowly releasing water). This peat nature dominates both the resulting flow regime and water quality of the streams and rivers. These waterways are therefore a dominant and conspicuous part of the Chatham Islands environment. However, they currently provide very little contribution to developed and used water resources. These waters are not generally of suitable potable or domestic use standard, do not provide for high recreational or amenity uses, and are currently not developed for any industrial uses. They are utilised as an opportunistic livestock drinking water resource (stockwater) and support the natural aquatic ecology of the island including supporting gathered foods and resources (mahinga kai) including eels (tuna). There are no introduced sports fish or pest fish species in island waterways. There is therefore very little, if any, water use (water allocation) pressure on these resources, little scope for major engineering developments (damming, diversion or channelisation), and little concern for discharge of contaminants generating water quality concerns or achievement of better than national bottom lines (targets).

The 160 km^2 Te Whanga Lagoon in the northern part of the island accounts for approximately 20% of the total area of Chatham Island. It is of comparable size to other large coastal lagoons in New Zealand (eg. Te Waihora/Lake Ellesmere). It is enclosed by sand dunes to the north and east and operates as a large shallow coastal lake or lagoon system. It both naturally opens to the sea through a sand barrier beach and it is occasionally necessary to mechanically be opened to the sea to prevent excessive water levels damaging roading and land infrastructure. It is currently considered to be a brackish water lagoon with up to 50% seawater. It was last mechanically opened in 2019 (Owen Pickles- CIC, pers. comm.).

Only the clear freshwaters of the Chatham Islands that are potentially suitable for potable, domestic, and commercial use, and are largely restricted to the water contained within sand dune lakes along the western coast (Lake Marakapia, Tennants Lake etc.) and in the north (Lake Rangitai); groundwater seeps from the steeper basaltic geology of the island, and some limited shallow groundwater aquifers associated with the dune formations or limestone sand strata. This limited presence of domestic quality freshwater resources results in widespread collection and storage of roof water runoff from rainfall for domestic use outside the main townships. These limited natural potable freshwater resources are generally only under pressure during annual or sustained drought periods when rainfall collection or aquifer and lake recharge are depleted. It is therefore important that these important freshwater resources are well represented in monitoring activities to ensure their effective management and protection.

To date, monitoring of the waters of the Chatham Islands have not significantly distinguished between the different waterbody types and have largely focussed on monitoring major surface water bodies representing all parts of the island. No monitoring of water is undertaken on Pitt Island or any of the other off shore islands. The purpose of this water quality summary is to update and review the current water quality state and long-term trends of the sites monitored on the Chatham Islands and give some commentary on likely cause of any change in state or trend.

There are six Environment Canterbury operated rainfall stations, three in the northern part of the island and three in the south of the island (Figure 4-1). Chatham Island also has four long term flow recorders on the four largest surface water drainages (rivers) on the island. Three flow recorder sites sit alongside rainfall sensors; one of these flow recorders is on the northern half of the island and three are on the southern part of the island (Figure 4-1). The recorders measure the water height and then convert it to flow using information from the river profile, which is collected every time the river is gauged (generally 4 to 6 times per year). It is important to maintain these recorders so that we can establish long term trends and determine whether there are any natural or anthropogenic influences on river flow requiring clarification or management.

The groundwater resource is not currently routinely monitored, but recently the available information on the development of groundwater resources (bores and wells) have been gathered, and some one-off measurements of bore characteristics of private bores undertaken (water depth, water quality). It is hoped to incorporate regular groundwater monitoring in this programme in the future.

2 Methodology and Data analysis

2.1 Water Quality Data

Long term water quality monitoring data is collected quarterly from 22 stream, lake, and lagoon sites across the main island of the Chatham Islands (Figure A1, Table 2-1). The streams and rivers are sampled at single easily accessible locations near the lower end of their length (Figure 2-1). The lakes are also sampled from easily accessible lake edge sites by wading rather than by boat. Te Whanga lagoon is also sampled from the lagoon edge by wading at three distinct locations representing the three distinct basins. Sampling began in 2005 for most of the sites, excluding Nairn River and Te Whanga Lagoon at the Southern Basin, which were first sampled in 2006.

Table 2-1: Site list and IDs for the Chatham Islands

Site ID	Site Name	Site ID	Site Name
SQ34829	Awamata Stm	SQ34860	Waitāmaki Ck
SQ34830	Awatōtara Ck	SQ34834	Washout Ck
SQ34844	Blind Jim's Ck	SQ34838	Whangamoe Inlet Stm
SQ34854	Mangahōu Stm	SQ34859	Lake Hurō
SQ34851	Mangapē Ck	SQ34893	Lake Marakapia
SQ35078	Nairn River	SQ34846	Lake Rangitai
SQ34841	North Trib Rakautahi	SQ34887	Lake Te Wāpu
SQ34832	Te Awainanga River	SQ34842	Tennants Lake
SQ34857	Te One Ck	SQ35082	Te Whanga Southern
SQ34863	Waimāhana Ck	SQ34843	Te Whanga Blind Jim's
SQ34849	Waitaha Ck	SQ34861	Te Whanga Waitāmaki

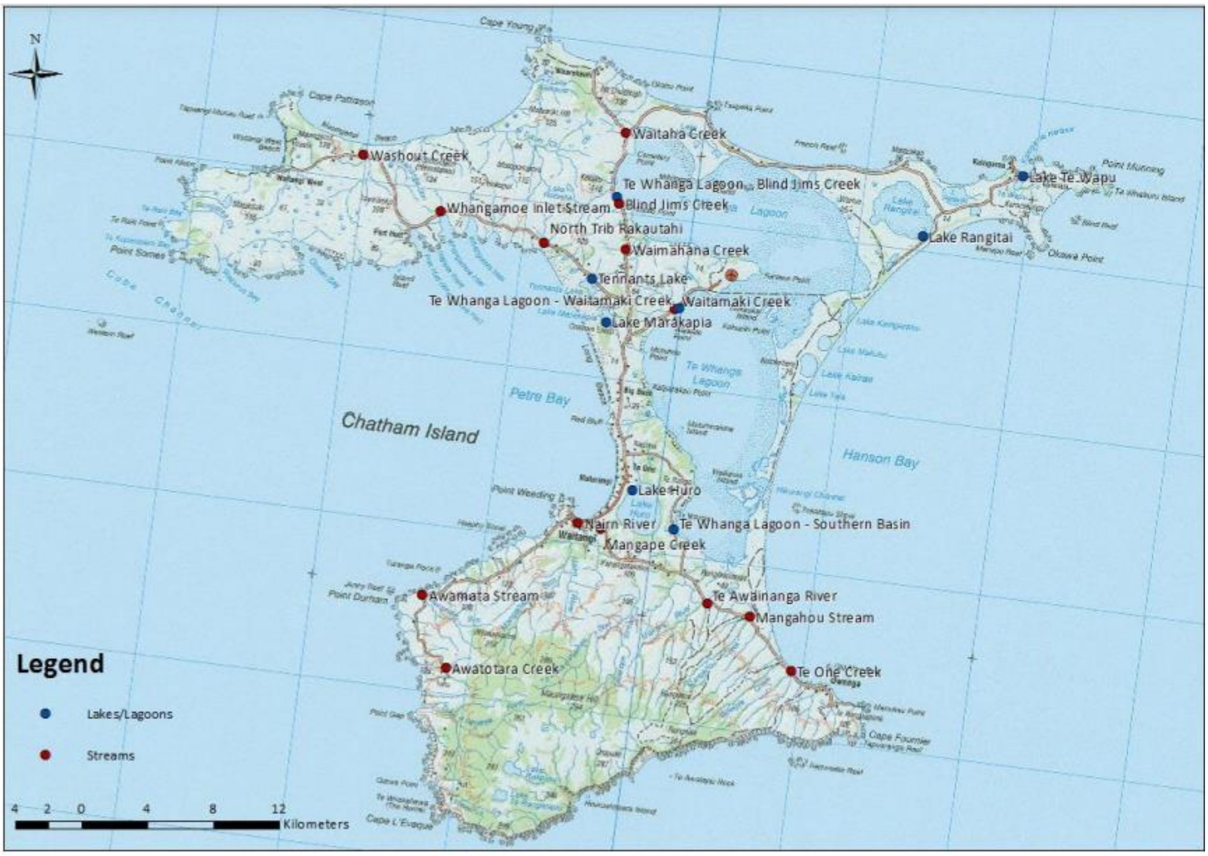

Figure 2-1: Map of Chatham Island showing the river, stream, lake and lagoon water quality monitoring sites

Current water quality state was determined by averaging the most recent five years of water quality monitoring data (July 2016 to June 2021). Long term trends were assessed using the latest Timetrends software and using only the previous ten years of available monitoring data (2011 – 2021).

Censored data (values outside of laboratory minimum and maximum detection limits) were adjusted before analysis using the following method. Each parameter at each site has been assessed separately. If 70% or more of any parameter values at a site were censored, that specific site was removed from that measurement analysis as unreliable. If less than 70% of the values were censored, and censored values were below detection, the censored values were converted to half of the highest censored value. Where measured results fell below the highest censored value, the measured result was also included as ‘censored’ and was converted. There were no values higher than the maximum laboratory value. The issues with censoring of dissolved inorganic nitrogen values is discussed further in section 3.5.2.

The current state data is presented as box and whisker plots of the data distribution displaying the variation in monitoring data over the past five years (where censored data < 70%). For long term trends each parameter at each site was required to have at least 80% available data (no more than 20% missing values). As the Chatham Island sites are only sampled quarterly, there needed to be at least 32 samples over a ten-year period to be considered suitable for determination of long-term trends. Calculations for long term trends were performed using Python software. Long term trends displayed in the relevant section were analysed and reported using Land, Air and Water Aotearoa (LAWA) trend likelihoods.

Trophic Level Index (TLI) values have been calculated for lake and lagoon sites on the Chatham Islands using methods defined in Burns *et al.* (1999). Secchi disk was not able to be measured and so is not included in calculations. This is because sampling is from the lake edges where secchi cannot be readily carried out. TLI therefore does not include Secchi disk measurements and is reported as a TLI3 index.

The Trophic Level Index relies on close correlation between 4 algal biomass attributes. However, reduced water clarity of the Chatham Island lakes is primarily caused by wind resuspension of bed sediments, or from high dissolved colour and suspended peat in peat lakes. Reduced water clarity is therefore frequently may not be a result of eutrophication and would correlate poorly with the other TLI biomass attributes - nutrient concentrations and algal biomass. The approach of not including a clarity component in TLI was therefore considered appropriate.

2.2 Hydrology Data

2.2.1 Rainfall

NIWA has produced Chatham Island rainfall data from 1956 but there has not been one continuous record, the historical stations have been discontinued and new stations have replaced them, often they're in the same location with most located near the airport or Waitangi township.

To create a continuous long-term rainfall record on Chatham Island, three historical NIWA stations were combined with current sites. Chatham Islands Aws (986105) and the historical NIWA Waitangi site (K98601) were located near Waitangi, the largest settlement on the island, and Chatham Islands Ews (986106) was located close to the airport (Figure 2-2). This shows overall that 2020 was a moderately dry year. Such dry years appear to occur every 6-7 years in this record, and often accompany dry years adjacent to each other.

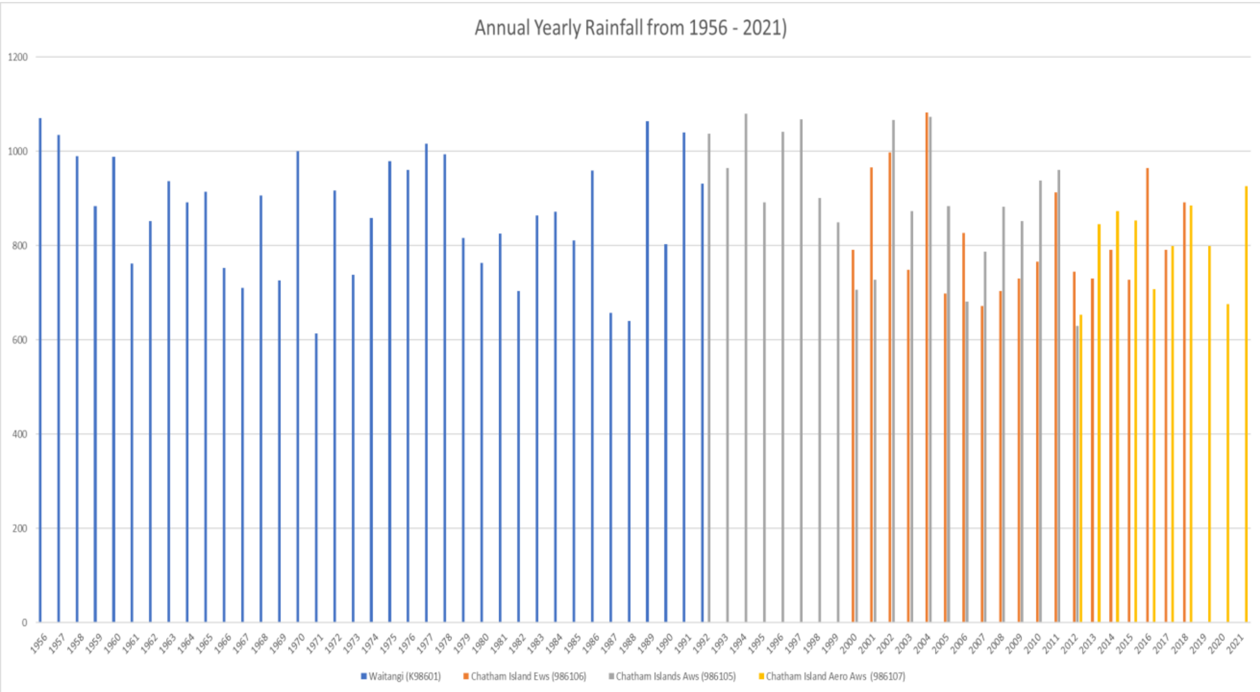

Figure 2-2: Annual rainfall at four NIWA weather stations across Chatham Island from 1956 to 2021

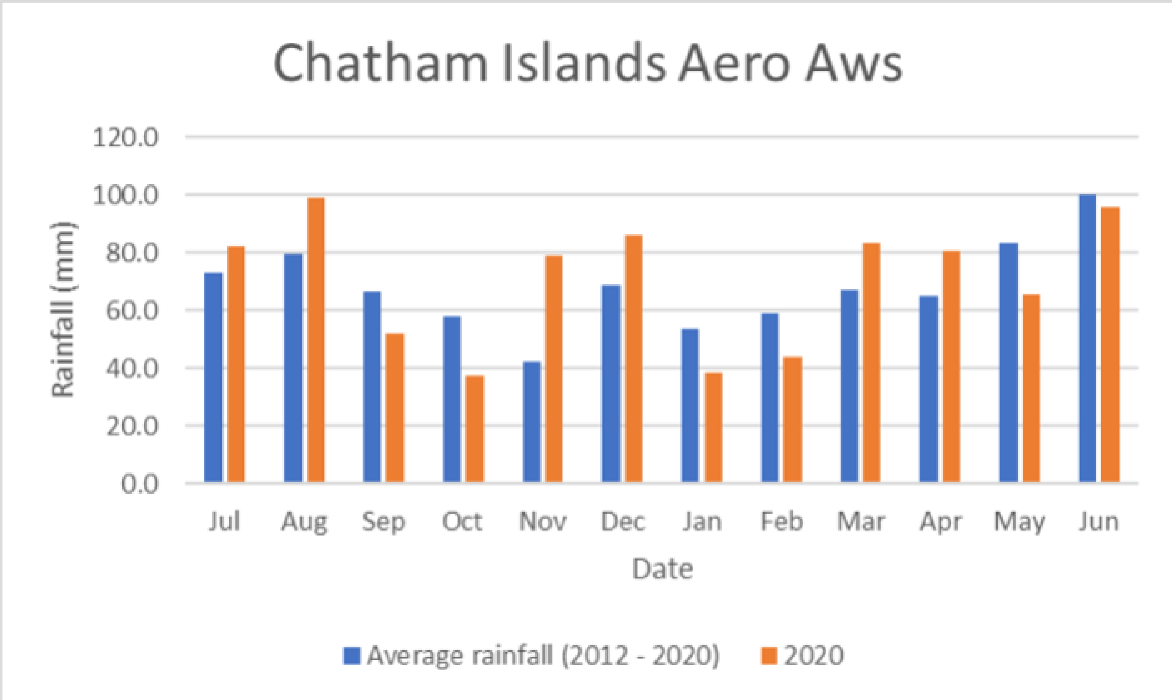

Figure 2-3: Total rainfall (mm) at the NIWA Chatham Islands Aero Aws station (986107) for the 2020 hydrological year and the average rainfall from 2012 – 2020

The NIWA site Chatham Islands Aero Aws (986107) was recording alongside Chatham Islands Ews from 2012 to 2018 and is also located near the airport. The rainfall at Chatham Islands Aws and Chatham Islands Ews correlated reasonably well with comparable rainfall in wetter years between 2000 – 2008 (Ritson, 2010) The NIWA Waitangi station and Chatham Islands Aws were recording in the same location and therefore the NIWA Waitangi station and the Chatham Islands Ews stations have correlated similarly. The Environment Canterbury rainfall stations have been assigned site IDs which have been kept in line with the labelling of the NIWA sites (Table 2-2).

Monthly rainfall totals for the 2020/21 year are presented alongside monthly rainfall averaged from 2012-2020 (Figure 2-3). These show variations in rainfall over the 2020/21 year and illustrate whether individual months (and the year as a whole) can be considered in rainfall deficit (drought) or excess (wet year). This shows the 2020/21 year had lower than average rainfall in spring (September and October) and summer (January and February). Overall, six months had rainfall higher than the average and six months with rainfall lower than the average.

Table 2-2: Site names and numbers for flow and rainfall

	Rainfall ID	Flow ID
Chatham Island Aero Aws (NIWA)	986107	
The Landing at Muirsons	986206	
Waitangi at Met Station	986207	
Wharekauri at Tonys	986205	
Te Awainanga at John Days	986109	
Te Awainanga at Falls		3446051
Tutuiri River at Shists Outcrop	986108	3436871
Awamata at Old Hydro Intake	986200	3446071

2.2.2 Flow

Site visits and gauging at the Chatham Island sites typically occur between four and six times per year. During these visits the water level recorders are assessed, and maintenance carried out, and the water courses are gauged. By using the relationship between the gauging and the water level, we determine a rated flow rate of the water course.

Logistically, it is difficult to undertake gaugings over the full flow range, but ideally gaugings are undertaken through a range of flows including both low and normal flow conditions. It may be difficult to schedule visits with high flow times and may be unsafe to gauge in high flow situations (Pattle Delamore Partners Ltd, 2020). During the 2020 hydrological year, there were six visits to Chatham Island where Tutuiri River was gauged, however, Te Awainanga River and Awamata Stream were gauged twice, and Tuku a Tamatea was gauged three times.

The National Environmental Monitoring Standard (NEMS) require gaugings to occur at sufficient intervals to maintain an accurate stage – discharge rating curve and to detect when this relationship may have changed. The gauging frequency may vary year to year but there cannot be an interval greater than 9 months in natural channels. At a site where there is a stable natural control gauging frequency can be reduced provided that the rating is well established and is checked within one month of any event that is likely to affect the rating (National Environmental Monitoring Standard, 2019).

3 Water Quality

3.1 Dissolved oxygen

Lakes, and Te Whanga Lagoon on Chatham Island are generally well oxygenated, generally above 80% saturation, while the oxygen concentrations of streams are more variable (Appendix A, Figure A1 and Appendix B). The six larger streams and rivers maintain high oxygen concentrations (generally above 80% saturation). This reflects high reaeration from significant turbulent flow over bedrock and rougher terrain. The other seven streams had much greater ranges of dissolved oxygen, often as low as 0% saturation. These streams drain peat basins and so contain high biochemical oxygen demand from peat materials and reflect sluggish flow through wetland-like flow paths.

Washout Creek and Whangamoe Inlet Stream have previously recorded low dissolved oxygen (DO) % saturation; however, Washout Creek has remained reasonably stable with consistently low DO over the past ten years. Mangapē Creek and Waitāmaki Creek have recently experienced lower concentrations of dissolved oxygen than they have previously had.

Trend analysis indicate 4 streams that have significantly decreasing dissolved oxygen concentration (DO %saturation). Mangapē Creek, the North Tributary of Rakautahi Stream are very likely decreasing, and Waitāmaki Creek and Whangamoe Inlet Stream that is likely decreasing. No streams had trends of increasing dissolved oxygen concentration. Te Whanga lagoon near Blind Jims Creek was the only lake or lagoon site with a (decreasing) trend in dissolved oxygen.

These dissolved oxygen patterns and trends may be associated with the 2020-21 year being often dryer than normal and so with lower and more sluggish flows in streams (particularly from the peat basins). There may also be more pugging of stream margins generating less well-defined drainage as access to flowing water for livestock may have become more difficult.

3.2 Water temperature

Water temperature ranges varied greatly between sites (Figure A2). This is likely to be due to considerable difference in degree of shading and exposure to sunlight across different drainages on the island. The drainage or flow rate may also have been reduced giving more time for solar heating of watrerways. Awatotara and Waimahana creeks were the coolest streams and with the lowest temperature ranges and correspondingly are the most forested sites. Blind Jims Creek was the warmest stream (maximum of 24°C) and with a high seasonal temperature range. This is an open highly grazed peat basin stream with high exposure to sunlight. The degree of peat discolouration may also influence (increase) the degree of solar heating of streams. Many streams also recorded very likely increasing trends in water temperature, and this may also be associated with the dry climate period leading up to and including 2020-21.

Many of the lakes showed peak temperatures as high as 24 or 25°C. Many of these lakes were also recorded as showing very likely increasing trends in water temperature. These high peak temperatures and trends may be associated low lake levels associated with the dry climate period leading up to 2020-21. These high temperatures may put the ecology (fishes and other aquatic life) of the lakes at risk.

3.3 pH

Water acidity (pH) of Chatham Island was measured in-situ by field technicians until June 2013 using YSI field meters. All pH measurements after June 2013 were undertaken by R J Hill Laboratories Limited (Hills) from stored samples. To produce long term trends for pH, field and laboratory measurements have been combined. Due to a difference in methods and the time samples take to arrive at Hills, the data may vary between these timeframes and these comparisons should be treated with caution.

The pH of Chatham Island streams varied greatly in both median pH and range (Figure A3). The acidic pH levels of many streams are due to the drainage from naturally acidic peat soils, but Chatham Island peats are not as naturally acidic as peat in many other parts of the country. For example, Awatotara Creek on the south of the island has very acidic water in the range 4-5 while peat streams on the north of the island (i.e., Blind Jims Creek and Mangape Creek) were consistently alkaline. These differences may also be associated with the prevalence of limestone in the catchments. (Appendix A, Figure A3).

The pH of the monitored lakes and lagoon sites are all alkaline and similar with median pH ranging from 8-9. There are no significant long-term trends for pH at any stream or lake sites on Chatham Island (Appendix B).

3.4 Dissolved organic carbon

Dissolved organic carbon concentrations (DOC) are measured as an indication of the degree of dissolved peat/peat staining of waterways. DOC median concentration and range varies greatly between the streams on Chatham Island (Appendix A, Figure A1). Blind Jim's Creek, Mangapē Creek, Waitāmaki Creek, and Waimāhana Creek are the clearest water but still with appreciable DOC (visible discolouration) compared to streams in mainland New Zealand. The other rivers and streams were much more strongly coloured by DOC concentrations.

Most of the streams show increasing trends for DOC concentration, except Mangapē Creek (which has no significant trend) and Waimāhana Creek, which has a likely decreasing trend (Appendix B). Again, these increasing trends in DOC concentration may be associated with lower flows associated with the dry climate period leading up to and including 2020-21. Under drought conditions there is likely to be increased time for leaching of peat materials and less dilution with rainfall runoff.

The monitored lake and lagoon sites have much lower concentrations of DOC than the streams, excepting Lake Te Wapu (Figure A4). However, we no longer monitor many of the more highly peat-stained lakes of Chatham Island. Most lake and lagoon sites had increasing DOC concentrations. Lake Te Wāpu and Te Whanga Lagoon at the Southern Basin have decreasing trends over time. Lake Hurō has no significant long-term trend (Appendix B). These trends may also be associated with the dry climate period leading up to and including 2020-21 that allowed peat materials to settle and oxidise.

3.5 Nutrients

3.5.1 Phosphorus

Washout Creek, Waimāhana Creek, Mangapē Creek and generally creeks on the north of the island have the highest concentrations of both dissolved reactive phosphorus (DRP) and total phosphorus (TP) (Appendix A, Figure A5 and Figure A6). This may reflect the differing geology on the north of the island compared to the basaltic geology in the south. Mangapē Creek and Te Awainanga River have increasing DRP and TP trends, other streams on the Chatham Islands either have no significant trends or have decreasing DRP concentrations (Appendix B). These trends may have several likely causes, but again may be due to the dry climate period leading up to and including 2020-21. In some waterways the natural phosphorus concentrations may not be being diluted as effectively by rainfall runoff, but in other streams increasing growth of macrophytes may be taking up more of the natural phosphorus of the island's geology.

DRP and TP concentrations in the Chatham Island lakes were consistently low. This is not surprising with many lakes being phosphorus limited and sequestering all available phosphorus. Te Whanga Lagoon sites had an increasing DRP trend (very likely increasing) but a decreasing TP trend (Appendix B). This may be influenced by the brackish (marine) nature of the lagfoon with seawater being more phosphorus rich and nitrogen poor. Lake Marakapia and Tennants Lake had increasing TP trends possibly reflecting the lakes becoming increasingly eutrophic because of lowering lake levels and nutrient recycling.

3.5.2 Nitrogen

Total nitrogen concentrations (TN) were relatively consistent between the streams, lakes, and lagoon sites on Chatham Island with median concentrations between 0.5 and 1.5 mg/l (Figure A7). Lowest concentrations were in Blind Jims Creek and Waimahana Creek. These are relatively low river nitrogen concentrations in a national context and reflect the small catchments and island nature of Chatham Island. The highest nitrogen concentrations were measured at Mangapē Creek and Lake Te Wāpu (Figure A7) and may reflect the river and lake with highest nutrient loss from higher livestock density and historic landfill leachate respectively.

The majority of sites monitored on Chatham Island had increasing TN trends (Figure B1). Only Lake Hurō and Lake Te Wāpu have decreasing TN trends, while Mangapē Creek and Te Whanga Lagoon at the Southern Basin have no significant trends. The increasing trends may reflect changing livestock type (cattle) and livestock density, as nitrogen originates primarily from biological sources rather than from geological sources.

The concentrations of dissolved inorganic nitrogen (Nitrate and ammonia) are very low. Due to the high number of censored values within the ammoniacal nitrogen (NH_4N) and nitrate-nitrite-nitrogen (NNN) datasets (mostly below detection levels) the resulting dissolved inorganic nitrogen (DIN) was unable to be calculated for the most sites on Chatham Island. This analysis means most of the nitrogen in waterways of Chatham Island are composed of particulate or dissolved organic nitrogen. Some of this may be of peat origin but increasing quantities may be from livestock sources, particularly with the increasing predominance of cattle farming on the island.

Most sites on Chatham Island had no significant trend for NH_4N, except for Mangapē Creek and Waitamaki Creek, which had increasing and decreasing trends of NH_4N, respectively (Figure B1). The increasing trend in NH_4N in Mangapē Creek may be associated with the stream reaches becoming increasingly anoxic and providing a reducing environment for nitrogen. Te Awainanga River, Waimāhana Creek, Waitaha Creek and Washout Creek have increasing NNN trends. Mangapē Creek and Te Whanga Lagoon at Blind Jim's Creek have decreasing NNN trends. These trends can only be explained from the perspective of livestock type and densities.

3.6 Chlorophyll *a*

Chlorophyll *a* concentrations for the lakes and Te Whanga Lagoon sites are generally low (<5 ug/l) but there are significant high concentration outliers in the dataset for most lakes. Chlorophyll a is generally higher when there are increased nutrient concentrations (TP and TN). Chlorophyll *a* concentrations are greatest for Lake Te Wāpu (Appendix A, Figure A8), however, Lake Te Wāpu also has a decreasing trend for chlorophyll *a* (Appendix B). Other lake and lagoon sites on the Chatham Islands have no significant trends for chlorophyll *a* concentration.

3.7 Water clarity

Water clarity for the streams, lakes and lagoon on the Chatham Islands is measured using a SHMAK clarity tube, which can measure clarity up to 100 cm (Appendix A, Figure A9). Water clarity is often greater than 100 cm for Blind Jim's Creek and Waimāhana Creek. Other streams on Chatham Island have varying water clarity, with medians mostly between 20 cm and 40 cm. Water clarity trends in all streams is either decreasing or has no significant trend (Appendix B). This suggests that water bodies on Chatham Island are becoming more highly coloured or more turbid or both.

Lake Hurō and Lake Te Wāpu have water clarity medians around 60 cm. The other lakes and lagoon sites are around 100 cm or greater. Water clarity is very likely to be increasing at Lake Hurō but decreasing at Lake Te Wāpu and Tennants Lake. The lagoon sites have no significant long-term trends for water clarity.

3.8 Lake eutrophication

The TLI for lake and lagoon sites of the Chatham Islands is a calculation derived from annual averages of total nitrogen, total phosphorus, and chlorophyll a concentrations; and are used to indicate the level of eutrophication or nutrient enrichment (Burns, Rutherford, & Clayton, 1999). All lake and lagoon sites, except Te Whanga Lagoon at the Southern Basin, were graded eutrophic during the 2020 – 2021 year and reflect a moderately high degree of nutrient enrichment. This will be reflected in subsequent elevated chlorophyll a concentrations and reduced water clarity, all indicators of a degree of degradation in these waterbodies. The five-year (2016 – 2021) averaged TLI's indicate Lake Rangitai and Te Whanga Lagoon at Waitāmaki Creek were in Mesotrophic states (

Table 3-1 and Table 3-2) prior to the 2021 eutrophic result.

These high TLI gradings (eutrophic) would be of concern in a national context but may be somewhat naturally elevated by stable organic nutrient components that may be unavailable for stimulating algal growth. There should be ongoing scrutiny of the intensity of grazing and livestock access to lake margins to ensure these trends are not generated by landuses and do not continue to degrade.

Table 3-1: Description of trophic states

TLI	Tropic state	General description
<1	Ultra-microtrophic	Practically pure, very clean, often have glacial sources
1-2	Microtrophic	Very clean, often have glacial sources, very low nutrient concentrations
2-3	Oligotrophic	Clear and blue, with low levels of nutrients and algae
3-4	Mesotrophic	Moderate levels of nutrients and algae
4-5	Eutrophic	Green and murky, with higher amounts of nutrients and algae
5-6	Supertrophic	Very high nutrient enrichment and high algae growth
>6	Hypertrophic	Saturated in nutrients, highly fertile, excessive algae growth

Table 3-2: Annual trophic state for lake and lagoon sites on Chatham Island

Site	TLI					Five-year average TLI
	2016 - 2017	2017 - 2018	2018 - 2019	2019 - 2020	2020 - 2021	
Lake Hurō	4.456	4.071	4.672	4.735	4.883	4.633
Lake Marakapia	4.167	4.405	4.030	4.115	4.358	4.241
Lake Rangitai	4.326	2.864	2.855	3.474	4.041	3.705
Lake Te Wāpu	4.616	5.215	5.596	4.628	4.493	5.000
Te Whanga Blind Jim's	4.346	4.314	5.117	4.452	4.359	4.584
Te Whanga Southern	3.745	3.012	4.073	3.642	3.682	3.704
Te Whanga Waitāmaki	4.151	3.538	4.096	3.366	4.160	3.964
Tennants Lake	3.614	4.613	3.969	3.578	4.044	4.060

3.9 Microbial water quality

Water samples are tested for faecal indicator bacteria such as *E. coli* in freshwater, and both *E. coli* and *Enterococci* in water with a saline influence such as Te Whanga Lagoon and the Nairn River at the river mouth.

Mangapē Creek and Nairn River have the highest faecal indicator bacteria concentrations, while the lagoon sites have the lowest concentrations (Appendix A, Figure A10). Lake Rangitai and Nairn River both have increasing trends for *E. coli* concentrations (Appendix B). Other sites on Chatham Island sampled for *E. coli* have no significant trends over time or are indeterminate.

Sources of these microbiological contaminants should be identified and minimised wherever possible. The area of Lake Rangitai has been decreasing rapidly as water abstraction has generated a significant water deficit. This may be allowing increased waterfowl accumulation into a smaller area on the lake, and/or stock access may be becoming a problem with dry lake margins. Mangape Creek and the lower reaches of the Nairn River support higher numbers of livestock than elsewhere on the island but are also potentially within the catchment for any human effluent losses from the area of Te One, from several individual residence effluent systems alongside the lower Nairn River, and is the receiving environment if there were any losses from the Waitangi wastewater treatment plant system. These range of sources should all be examined more closely as they are of potential health risk, particularly any that are of human effluent origin. These results could warrant further investigation such as Faecal source tracking (FST) to differentiate the presence of various sources of the E coil (i.e., whether the contamination is of human, bovine, avian, or other (dog?) sources).

3.10 National Policy Statement objectives and limits

The NZ Freshwater National Policy Statement (NPS) was released initially in 2011 and variously replaced and updated in 2014, 2017 and 2020 to guide freshwater management at a national level within New Zealand and to set or guide establishment of water quality limits.

Appendix 2A within the NPS provides a framework of numeric values and attribute states for freshwater management and sets national bottom lines of minimum acceptable states for the compulsory values of ecosystem health and human health for recreation. The framework is structured in a grading-based format from A to E, with the national bottom-line state generally set between the “C” and “D” bands. For more information refer to “National Policy Statement for Freshwater Management 2020” (Ministry for the Environment, 2020).

All streams on Chatham Island have NNN (Nitrate-N) median concentrations consistently within the “A” band attribute state. This can indicate a high conservation value where there is unlikely to be effects on sensitive species (Table 3-3). However, in the Chatham Island environment where the peat soils are a highly reducing environment Nitrate-N is very unlikely to persist. While the A banding are a very good state, they should be interpreted with caution.

Mangapē Creek and Washout Creek both have median NH_4N concentrations that fall within the “B” attribute band. Maximum NH_4N concentrations for most streams also fall within the “B” attribute band. The only site to fall below the national bottom line is the maximum NH_4N concentration at Mangapē Creek, which is also in the median “C” band. Again, the elevated presence of nitrogen in the NH_4N form may be more a consequence of hypoxic or anoxic water, and the reducing peat soil environment as nitrogen leached will be denitrified or reduced.

Lake Marakapia and Te Whanga Lagoon at Blind Jim’s Creek both fall into the “B” attribute band for median NH_4N, while the other lake and lagoon sites are all within the “A” band. All the NH_4N maximum concentrations for the lake and lagoon sites on Chatham Island fall between the “B” and “C” attribute bands.

TN median concentrations for the lakes and lagoon on Chatham Island are all in attribute band “C” or “D” (“D” attribute band is below the national bottom line). TP median concentration at Lake Rangitai is within the "A" attribute band, other lakes and lagoon sites are between attribute band "B" and "C." Lakes and lagoon sites on Chatham Island have median chlorophyll *a* concentration between attribute band "A" and "B." The chlorophyll *a* maximums are "A" and "B," however Lake Hurō has a "C" classification. Both the median and maximum concentrations for chlorophyll *a* at all the lake and lagoon sites are above the national bottom line. These grades are difficult to reconcile together, as they should correlate (to give rise to the TLI).

The D and C bands for TN (and to a lesser extent TP) may be a consequence of particulate and/or dissolved organic nutrients derived from the peat environment. These organic nutrient sources may not be reactive or directly available for eutrophication of the water bodies. Care should be exercised in assessing the significance of these gradings and whether they require any urgent action.

Table 3-3: National attribute states[1] for streams and lakes on Chatham Island

Site	NNN[2]	NH_4-N[3]		TN	TP	Chlorophyll a	
	Median	Median	Max	Median	Median	Median	Max
Awamata Stm	A	A	A				
Awatōtara Ck	A	A	A				
Blind Jim's Ck	A	A	A				
Mangahōu Stm	A	A	A				
Mangapē Ck	A	B	C				
Nairn River							
North Trib Rakautahi	A	A	B				
Te Awainanga River	A	A	A				
Te One Ck	A	A	B				
Waimāhana Ck	A	A	A				
Waitaha Ck	A	A	B				
Waitāmaki Ck	A	A	B				
Washout Ck	A	B	B				
Whangamoe Inlet Stm	A	A	A				
Lake Hurō		A	B	D	C	B	C
Lake Marakapia		B	C	D	B	A	A
Lake Rangitai		A	C	C	A	A	A
Lake Te Wāpu		A	B	D	C	B	B
Tennants Lake		A	B	C	B	A	B
Te Whanga Southern		A	B	C	B	A	A
Te Whanga Blind Jim's		B	B	D	C	B	B
Te Whanga Waitāmaki		A	B	C	B	A	B

E. coli results range across all the NPS attribute bands for the streams, lakes, and lagoon on Chatham Island (Table 3-4). The two streams sampled for *E. coli* (Mangapē Creek and Nairn River) both fall within the "E" attribute band, the category with the highest risk of Campylobacter infection (Ministry for the Environment, 2020). Lake Rangitai is within the "D" attribute band, where the predicted average infection risk is >3%. The lagoon sites fall between attribute bands "A" and "C," where the predicted average infection risk is 1% - 3%. These microbiological concentrations and gradings indicate some concern, especially where Lake Rangitai is used as a potable water source for Kaingaroa township, and

[1] Attribute states have been assessed using quarterly monitoring data over five years (2016 – 2021). NPSFM (2020) recommends using monthly data to assess attribute states.
[2] Assessed against nitrate attribute state (NPSFM, 2020).
[3] NH_4N concentrations have been pH adjusted as per (Ministry for the Environment (MfE), 2018) to assess compliance with NPSFM (2020).

Mangape Creek and Nairn River are close to the main township of Waitangi. The sources of this contamination should be assessed and minimised.

Table 3-4: National *E. coli* attribute states for streams and lakes on Chatham Island

Site	*E. coli*[4]				
	% exceedances over 540/100 mL	% exceedances over 260/100 mL	Median	Hazen 95th Percentile	Attribute band[5]
Lake Rangitai	11	17	28	1829	D
Mangapē Ck	35	47	192	2268	E
Nairn River	40	70	504	2081	E
Te Whanga Southern	0	0	10	160	A
Te Whanga Blind Jim's	15	15	20	1036	C
Te Whanga Waitāmaki	5	5	10	493	B

[4] *E. coli* attribute states have been assessed using quarterly monitoring data over five years (2016 – 2021). NPSFM (2020) recommends using a minimum of 60 samples over a maximum of five years to assess attribute states.
[5] Sites must meet all four criteria to qualify for an attribute band (Ministry for the Environment (MfE), 2018)

4 Rainfall and Flow

Figure 4-1: Environment Canterbury rainfall and flow stations across Chatham Island. Site names are found in Table 2-2 (Site 986107 is the NIWA Airfield site)

The four water level recorders appear to all respond rapidly to rainfall events; however, the potential evaporation often causes a deficit in the water balance. During the warmer months the flow of some of these water courses can dwindle, especially during longer droughts (Ritson, 2010).

Table 4-1: Long term seven-day annual low flow (7D ALF) for the four Environment Canterbury recorder locations over the 2007 - 2020 hydrological years (m^3/s)

	Te Awainanga	Tuku a Tamatea	Tutuiri	Awamata
2007			0.003	
2008			0.001	
2009		0.109	0.005	
2010		0.067	0.004	
2011		0.058	0.004	
2012		0.071	0.003	
2013	0.361	0.106	0.002	0.006
2014	0.321	0.048	0.002	0.009
2015	0.390	0.037	0.001	0.014
2016	0.296	0.092	0.003	0.021
2017	0.210	0.044	0	0.004
2018	0.249	0.048	0.001	0.005
2019	0.312	0.049	0	0.016
2020	0.255	0.063	0.001	0.017
7D MALF	0.299	0.066	0.002	0.012

The seven-day mean annual low flow is the average annual low flow (Table 4-1), which shows the lowest seven day rolling average flow over the hydrological year. The Mean annual low flows are calculated from Environment Canterbury's archived records and is an average of all the yearly average low flows that are on record. Only the Te Awainanga River has significant flows and may be deserved of the title River. The other three named rivers have very low base flows.

4.1 The Landing

The Landing had an annual rainfall of 849 mm over 154 days that had recorded rainfall. It had a particularly dry August, September, and October totals with 54, 33.5, and 24 mm of rain respectively. The next two months showed typical rainfall and then another dry month in January, where the rainfall was 20 mm compared to the long-term average of 38.9 mm (Figure 4-2). These reflect a cumulative spring/summer drought period.

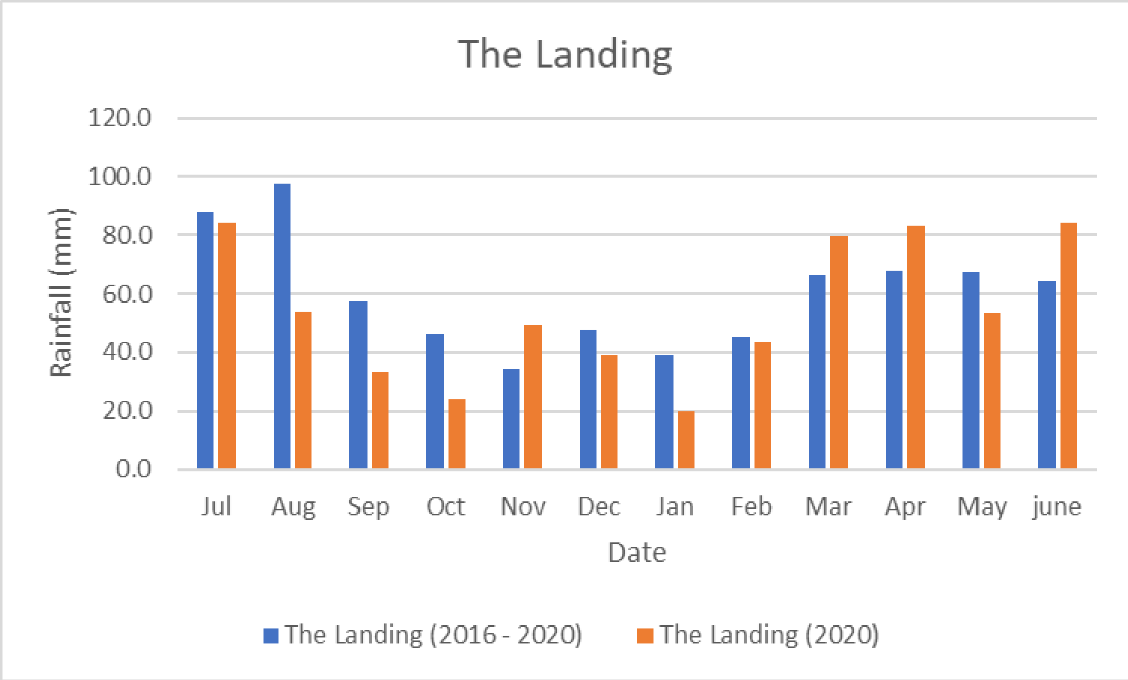

Figure 4-2: Monthly rainfall (mm) for The Landing site through the 2020 hydrological year

4.2 Waitangi

The Waitangi rainfall gauge was re-installed after a recommendation from PDP (2020) so that there would be a station in the same location as long-term historical data. The average rainfall data used within Figure 4-3 has been obtained from a NIWA station that was operational in the same area between 1991 and 2020. This site was only active for one full month during the 2020 hydrological year. Going forward, the Waitangi site will provide critical information that can be analysed against historic data for changes in long term trends.

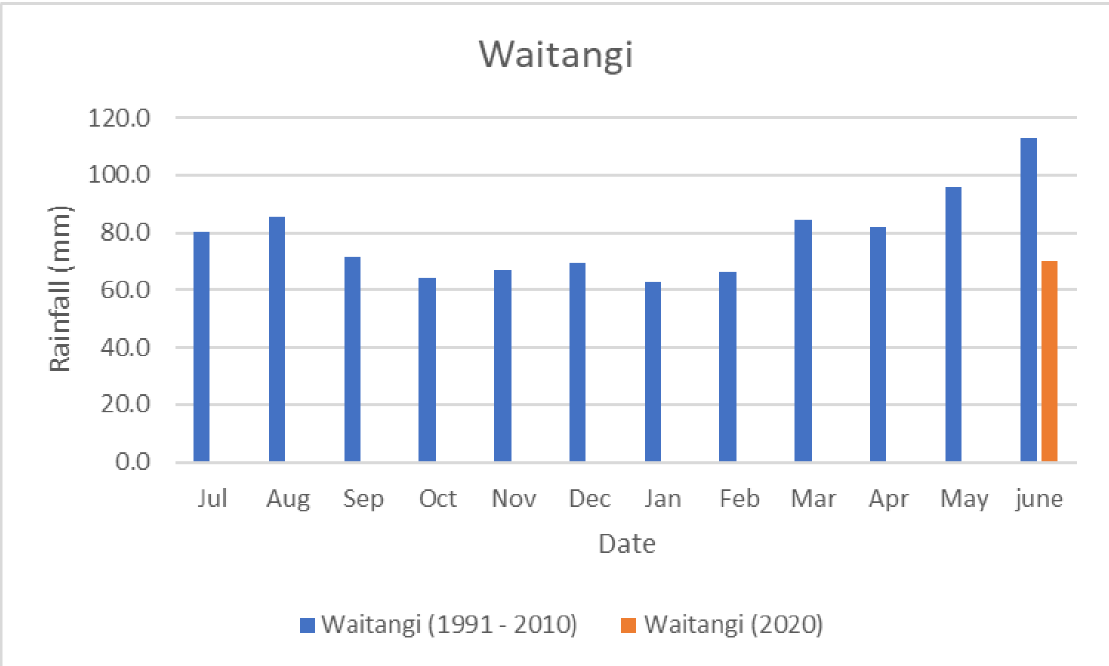

Figure 4-3: Monthly rainfall (mm) for the Waitangi site through the 2020 hydrological year

4.3 Wharekauri

The Wharekauri weather station had total recorded rainfall of 623 mm for the 2020-2021 hydrological year with 149 days of recorded rain. There are 30 days of data which have been given the quality code of poor, between 28th January and 5th March and sixteen days of missing rainfall data between 1st July and 14 July which occurred due to battery issues (Figure 4-4). These show a similar pattern to The Landing with dry months with low rainfall in August, September, October and January and reflect a cumulative summer drought in the north of the island.

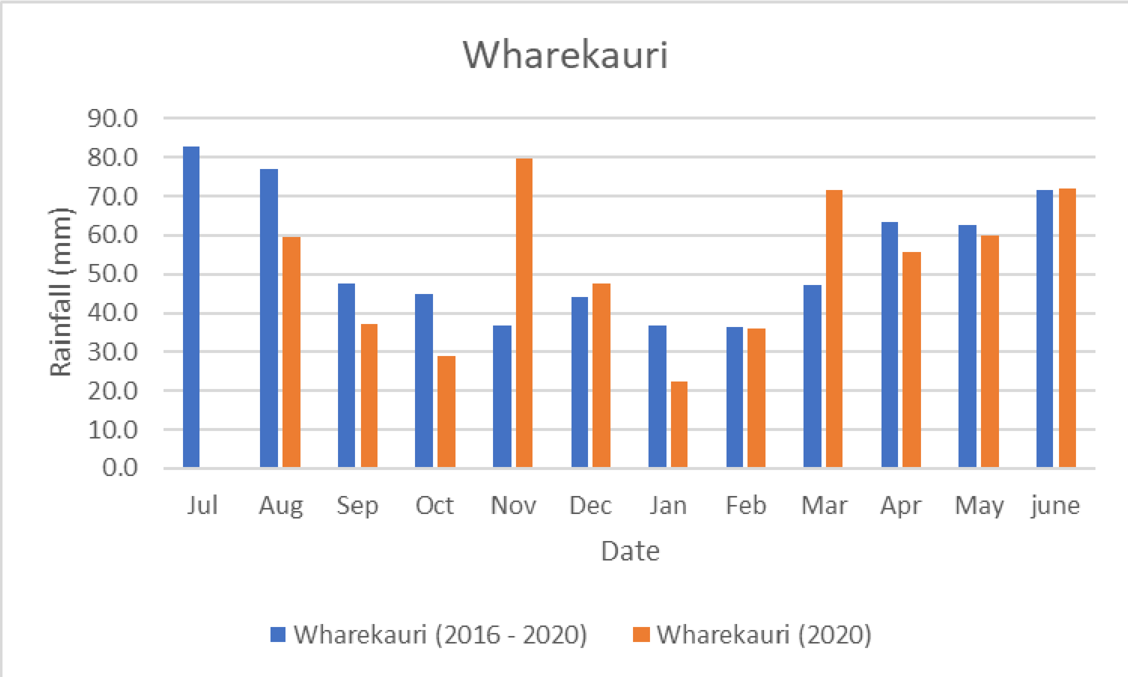

Figure 4-4: Monthly rainfall (mm) for the Wharekauri site through the 2020 hydrological year

4.4 Te Awainanga River

The 2020 hydrological year had 193 days of recorded rainfall with a total volume of 771 mm at the Te Awainanga site. Similar to The Landing, the Te Awainanga station experienced a drier September, October and January with 38, 36, and 23.5 mm of rain respectively. Te Awainanga also had a dry February with 38 mm of rain compared to an average rainfall between 2013 and 2020 of 60.6 mm (Figure 4-5). This reflects a cumulative summer drought in this southern part of the island.

The maximum annual flow at the Te Awainanga River recorder was 22.8 m^3/s with a mean flow of 1.57 m^3/s and the seven days of lowest flow (7D ALF) of 0.255 m^3/s (Figure 4-6 and Table 4-1).

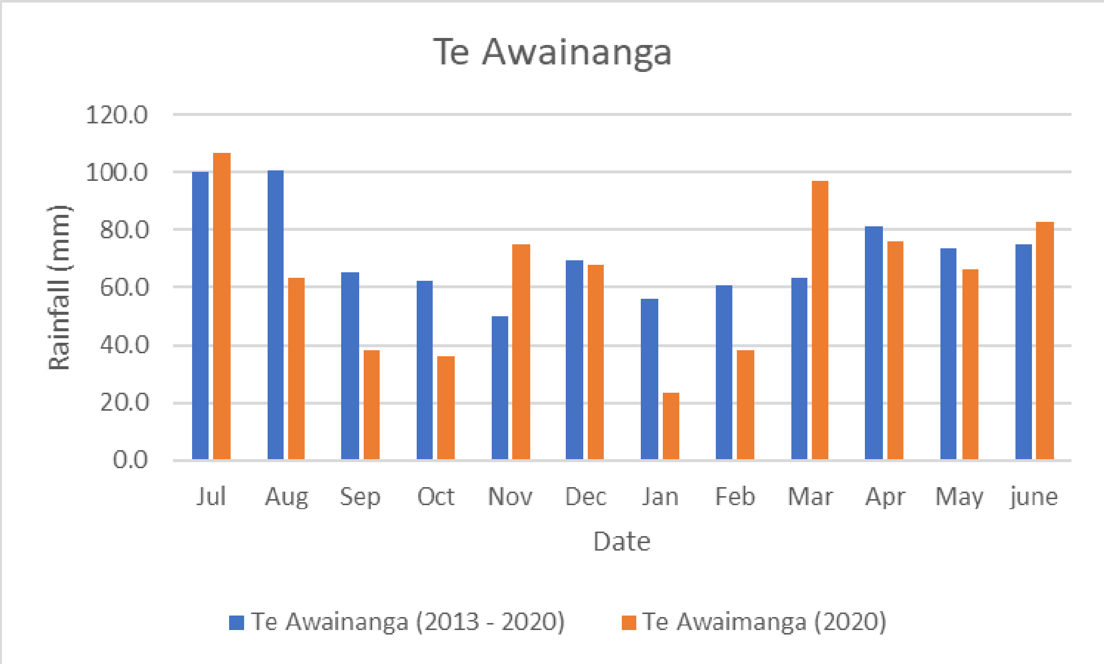

Figure 4-5: Monthly rainfall (mm) for the Te Awainanga site through the 2020 hydrological year

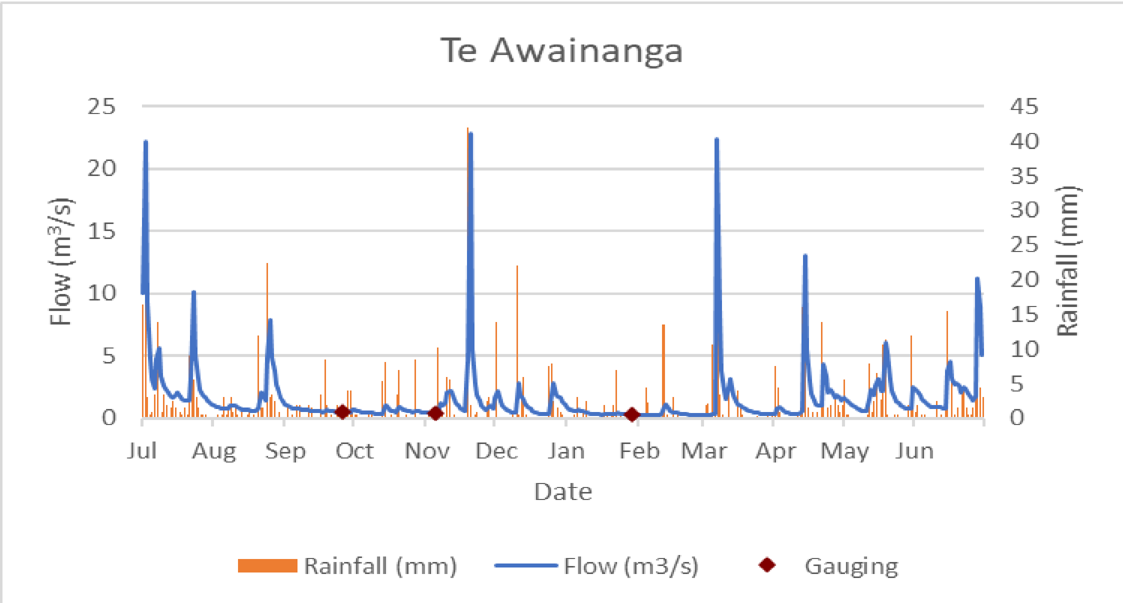

Figure 4-6: Daily mean flow at the Te Awainanga flow recorder over the 2020 hydrological year with the associated rainfall station along with the associated rainfall for the period

4.5 Tutuiri River

Tutuiri also had significantly less rainfall from August to October and in January with 22, 23, 28.5, and 18.5 mm compared to an average of 70.3, 55.1, 37.8, and 42.9 mm of rain. There was significant rainfall in November with 84 mm of rainfall where the average rainfall between 2007 - 2020 is 43.8 mm (Figure 4-7).

The maximum annual flow for the 2020 hydrological year was 3.54 m^3/s with a mean flow of 0.13 m^3/s with a 7D ALF of 0.001 m^3/s (Figure 4-8 and Table 4-1). Similar to the Awamata station, this stream is known to run dry in periods of drought (Pattle Delamore Partners Ltd, 2020).

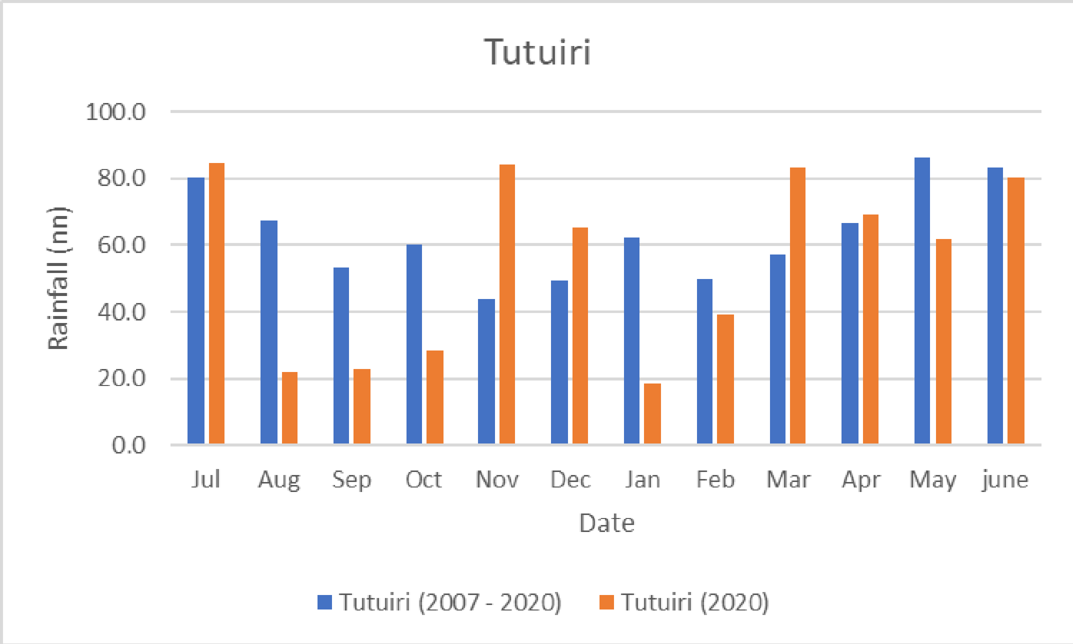

Figure 4-7: Monthly rainfall (mm) for the Tutuiri site through the 2020 hydrological year

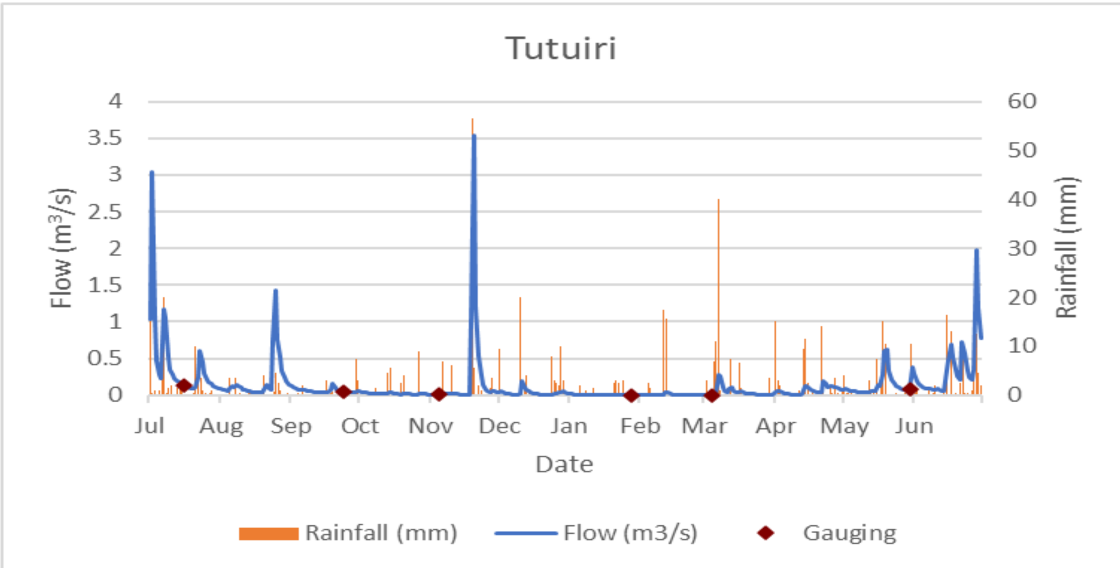

Figure 4-8: Daily mean flow at the Tutuiri flow recorder over the 2020 hydrological year with the associated rainfall station along with the associated rainfall for the period

4.6 Awamata River

The total rainfall at the Awamata Station during the 2020 hydrological year was 607 mm over 143 rain days, there were three significant rainfall events, two of which had large corresponding increases in the flow, one in June and the other in March (Figure 4-9 and Table 4-1). Awamata had an annual maximum flow of 3.79 m^3/s with an average annual flow of 0.14 m^3/s. There were two periods where the seven-day annual low flow was 0.017 m^3/s (Figure 4-10).

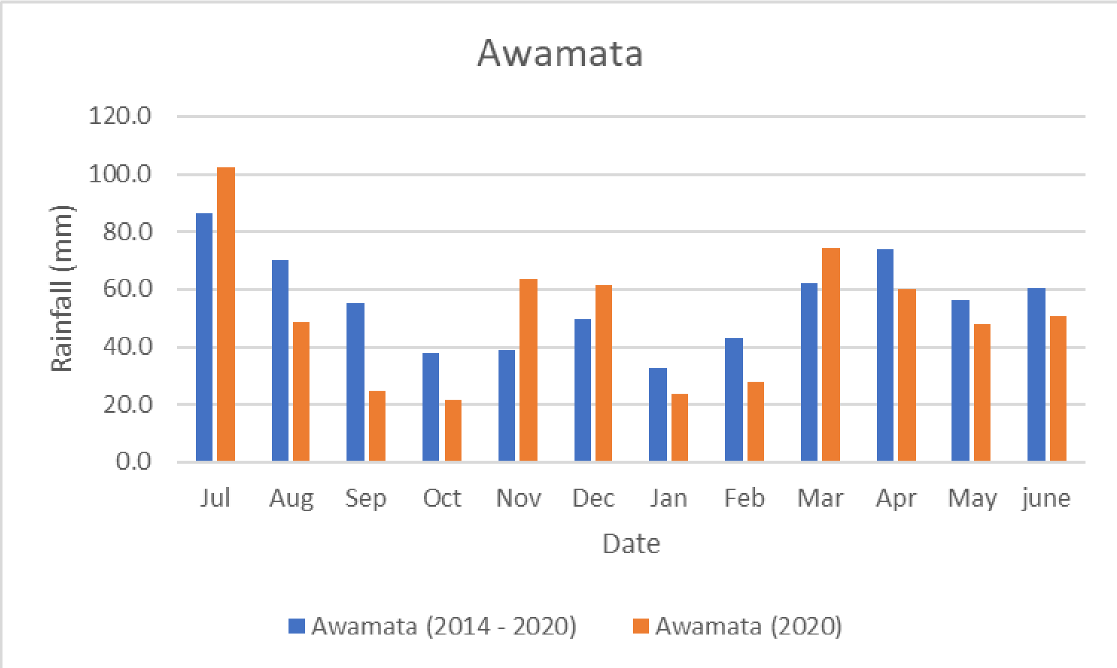

Figure 4-9: Monthly rainfall (mm) for the Awamata site through the 2020 hydrological year

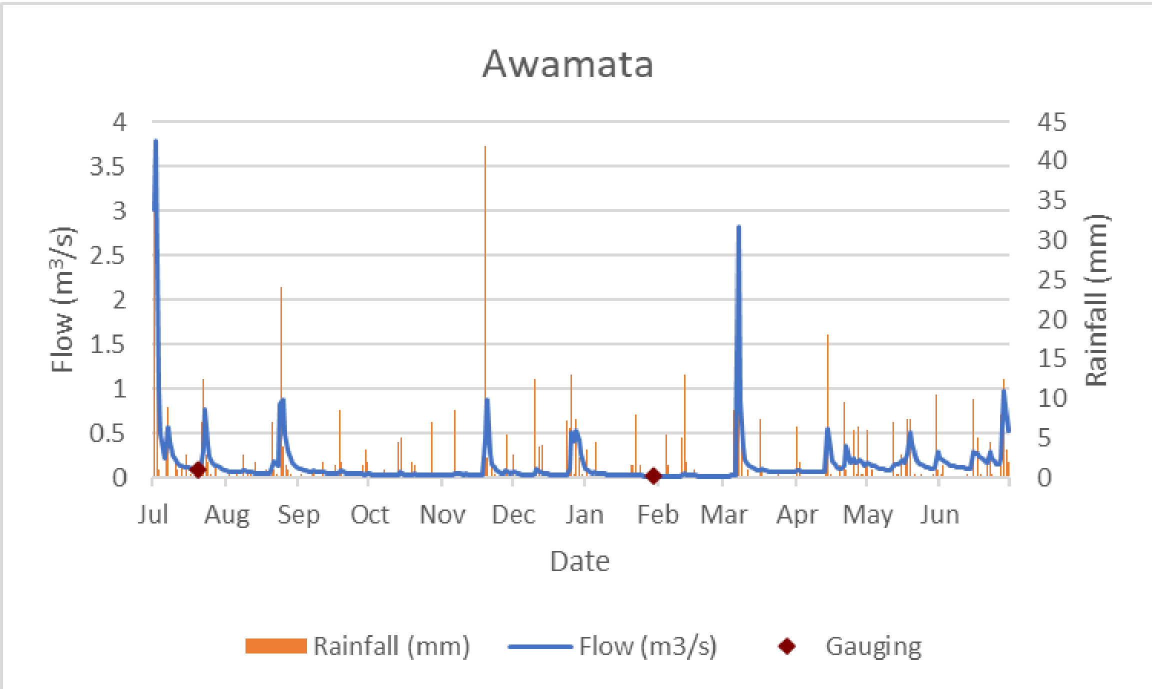

Figure 4-10: Daily mean flow at the Awamata flow recorder over the 2020 hydrological year with the associated rainfall station

4.7 Tuku a Tamatea River

There is no rainfall station associated with the Tuku a Tamatea flow recorder. The seven-day average low flow for the Tuku recorder was 0.066 m^3/s which occurred early February. The maximum annual flow was 8.48 m^3/s with an average rate of 0.50 m^3/s (Figure 4-11 and Table 4-1).

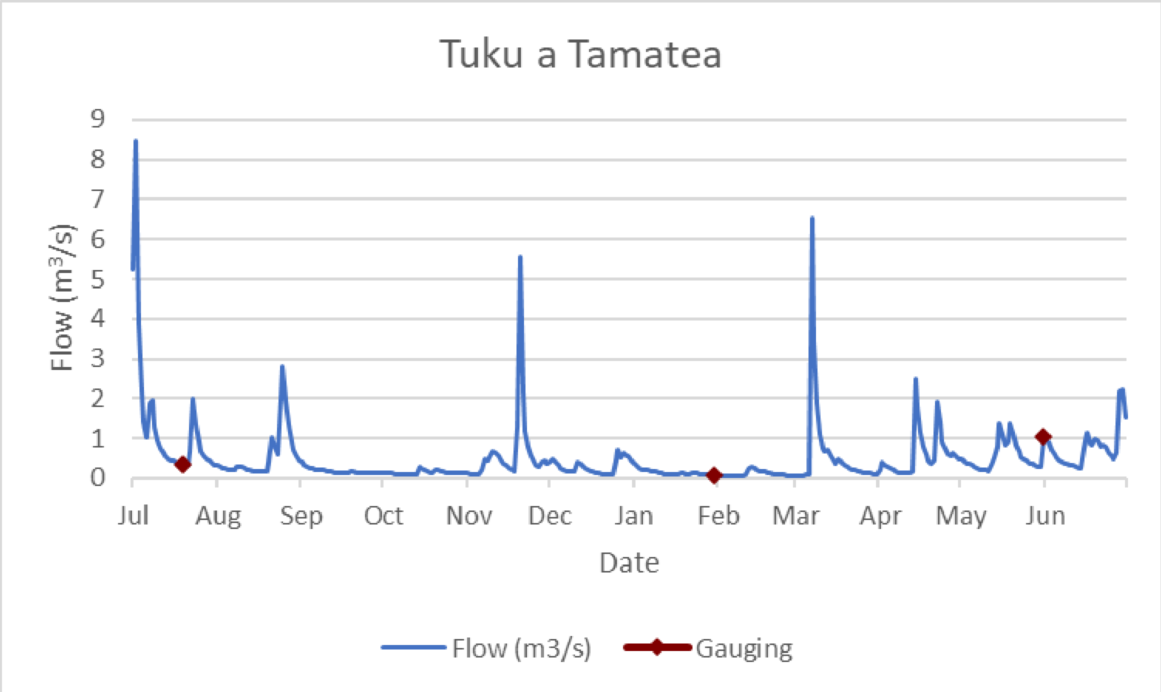

Figure 4-11: Daily mean flow at the Tuku a Tamatea flow recorder over the 2020 hydrological year

5 Discussion

An understanding of the climate, particularly rainfall, of Chatham Island is an important determinant. This is because like many island communities, rainfall runoff collection is particularly important as a collected domestic water source and as a diffuse stockwater resource. Rainfall is generally considered to be regularly distributed throughout the year, but at times it varies greatly and can be considered to reflect regular drought periods. Previously these may have been associated with decadal or ENSO cycles and weather patterns, but there is now concern whether we must now project forward for assessing possible further climate change patterns. It is therefore important to maintain an understanding of past, present and future rainfall patterns to maintain and manage community resilience.

Unfortunately, there have been considerable changes in the maintenance of weather stations on the island. In particular, the long-term weather station at the main town Waitangi was disestablished. It was subsequently recommended by PDP (2020) that the rainfall monitor was re-established in the Waitangi area, and while now re-established it will take some time to re-establish adequate records to determine a consistency with the historic long-term records.

In addition to this, PDP (2020) also recommended a rainfall sensor could be established within the southern uplands as this is likely to be the highest rainfall zone. This was rationalised to better understand the rainfall patterns in that area noting that the logistics would need to be discussed. However, the resources (population, roading, infrastructure etc.) are minimal in the southern uplands and so this information may be of little practical use. This recommendation therefore remains unactioned.

As illustrated in this report there are several weather stations across the island. The rainfall patterns recorded at these are similar, though generally reflect higher rainfall in the south and lower rainfall in the north of the island. There appears to be little consistent difference east to west. Chatham Island has a higher average rainfall during the winter period compared to the summer period, but overall rainfall is generally well spread and periods without rain are short (days to weeks).

The 2020-21 year illustrated a year of lower-than-average rainfall with particularly lower rainfall in late winter/spring (August, September, October) and summer (January, February) across all weather stations on the island. Periods such as this can cumulatively be considered droughts as water supplies are sourced from roof collection systems, small shallow aquifers or shallow lakes, all with limited yield or storage. Such droughts can also be cumulative over subsequent years if rainfall deficits are not made up by higher-than-average rainfall. The previous year (2019-20) was also a lower-than-average rainfall year recording periods of below average rainfall. Not surprisingly, the monitoring described here reflect a cumulative drought period with lower-than-average rainfall that contributes to lower-than-average river flows, low lake levels, and pressure on water storage and availability. Some lakes were of much lower level than usually observed (Lakes Marakapia and Tenant's Lake) and particularly Lake Rangitai that was heavily drawn on for stock water and domestic supply for the town of Kaingaroa. In these conditions rivers such as Tutuiri experienced periods where it ceased to flow at the surface, and smaller creeks ceased to flow as well-defined channels. These may partly explain the poor state and trends in decreasing flow and water quality seen over the 2020/21 year.

The four main river flow recorder sites illustrate that only the Te Awainanga River has an appreciable base flow (a MALF of approximately 300 l/s). The other three rivers have base flows (MALF) of only 2 - 66 l/s. Corresponding annual floods recorded in 2020 ranged from only 3.5 to 22.8 m^3/s. While the Awamata Stream has historically supported a small hydro-electric structure only the Te Awainanga River has the hydraulic capacity for a community sized hydro-electric facility. It has been proposed in the past for a combined hydro-electric wind turbine battery facility but has to date failed to secure the necessary financial support. Therefore, there is good reason to maintain a strong hydrological record for the Te Awainanga River to support future assessments or initiatives.

The Nairn River flow recorder site has been closed in recent years and the upper reaches of the Nairn River catchment border the Te Awainanga, the Tuku a Tamatea, and the Awamata catchments. The Nairn River flow correlated most strongly with the Tuku a Tamatea catchment ($r^2 = 0.98$). Therefore, although it would be nice to have flow recorder data on the Nairn River it is not currently considered necessary. The management issues for the Nairn River are also in its lower reaches that are also fed by wetlands and Lake Huro, and so headwater catchment hydrology may be of lesser relevance to the required monitoring and management of the catchment.

In future it may be necessary to review whether this intensity of climate (rainfall) monitoring and hydrological monitoring is necessary as there appear to be good relationships between the different sites. It is further necessary to consider whether the logistics and investment in monitoring some remote sites such as the Tuturiri River is still necessary. Other recorder sites such as Awamata and Tuku a Tamatea Rivers are relatively close together on one part of the island and could be rationalised to a single site if the rivers themselves do not warrant explicit monitoring. Only the Te Awainanga River warrants explicit ongoing resource monitoring given its potential for future development.

Many of the notable changes in water quality state and trend across the island all relate to the developing climate drought period, including physico-chemical features such as decreasing dissolved oxygen concentration, higher water temperatures, higher DOC concentrations and lower water clarity. The waters of Chatham Island are particularly sensitive to such climactic patterns because catchments are relatively small and so flow recessions and lake level reductions can occur quite rapidly.

The low intensity livestock land uses can also operate in tandem with climate patterns, as the effects of increasingly difficult access to stock water from natural streams and lakes can lead to increasing riparian pugging effects. An extreme effect of this can be higher casualty stock issues with stock becoming bogged or trapped within stream and lake peat margins. This has been noted in our reports in the past and become most conspicuous during sustained droughts. The Chatham Islands are not covered by the national low slope maps for stock exclusion from waterways regulations but are still required to avoid adverse effects such as pugging, compaction and casualty issues in riparian areas. While stock exclusion is not explicitly required, it would be prudent to prioritise actions addressing stock exclusion from waterway reaches adjacent to the roading network particularly leading to infrastructure such as the airport and between towns.

Care will always be needed in interpreting the significance of water quality state and trends on the Chatham Islands because of the high incidence of deep peat soils and the properties they impart to the waterways and lakes. The nutrient state can be misinterpreted if significant concentrations arise from stable organic peat materials such as tannins and lignins that are not generally available for driving primary production (i.e., algal growth or macrophyte growth).

We have previously identified that Chatham Island has seen a significant shift from sheep farming to drystock beef farming. This increase in cattle numbers has resulted in increased pugging and soil compaction, and a significant change in the vegetation state (lower plant height and increase in cover such as bracken fern) of scrub or poorly developed grazing land. All these changes can affect the water quality of island waterways and lakes through reduced shading, increased pugging and sediment runoff and altered drainage rate and patterns.

Overall, the identified changes (degradation) in water quality on the island are likely to be caused by a number of interacting influences. The climate patterns (and in this case a sustained drought) may be the biggest influence, but the changes in farming type strongly interact with the climate influences when cattle as larger and heavier livestock have higher water requirements and have greater effect on riparian environments. Particularly where the peat soils are poor at supporting heavy animals.

There are also particular sites within the water quality network worthy of comment, that illustrate these broader water quality issues more clearly.

Blind Jims Creek on the north of Te Whanga Lagoon is very conspicuous from the road and shows visible impacts of extensive pugging by cattle and corresponding increase in both DOC and nitrogen concentrations. Phosphorus concentrations are all decreasing. However, the nearby monitoring of Te Whanga Lagoon at Blind Jims shows widespread degradation trends in all water quality parameters. This therefore indicates that creeks such as Blind Jims are not only significant conspicuous indicators of creek water quality but also contribute to at least localised degradation of valued water bodies such as Te Whanga Lagoon. As recommended earlier, waterways such as this deserve added attention/priority in reaches close to roads to address the conspicuous and water quality effects of livestock entering these waterways.

Mangape Creek, that flows between Lake Huro the Nairn River is another creek that is showing a significant range of adverse effects. Many effects may be partly a result of the drought conditions and sluggish flows contributing to stagnant or anoxic conditions. However, the significant livestock densities in this wetland area are directly contributing to increasing nutrient concentrations, high levels of ammonia and high microbiological concentrations. These then flow into the Nairn River on the edge of Waitangi township and show similar degraded water quality conditions. The Nairn River is probably the highest recreationally used water body on the island but with the greatest risk profile. The land use in the wetlands and waterways associated with these water bodies deserve much closer scrutiny and management.

Lake Rangitai also stands out in this report. The degrading water quality is highly likely to be a result of the greatly reducing area of this lake as it is highly abstracted from for stockwater and domestic water use for the township of Kaingaroa. These water resources are largely being mined under sustained drought conditions, and as the lake becomes relatively small and shallow the water quality deteriorates. More careful or strategic management of this water resource is warranted.

Te Whanga Lagoon is a highly valued taonga and community resource but is very sensitive to its contributing catchment. The Te Awainanga River and its tributaries contribute 85% of the freshwater to the lagoon (PDP 2020) and so its flow and water quality are fundamental to the health of the lagoon. The very likely increasing trends in nitrogen, phosphorus and DOC to the lagoon are therefore of some notable concern. However, as illustrated above the remaining 15% from small creeks can also have at least localised effects on lagoon water quality if left unmanaged. This is especially true as the norther basins are much shallower and lesser flushed by the south-eastern outfall to the ocean. Scrutiny of these water quality results and trends for freshwaters in and flowing into Te Whanga lagoon should not be ignored.

6 Conclusion

Quality assured rainfall records are needed to maintain and manage community resilience. Therefore, maintaining consistent rainfall monitoring sites particularly at Waitangi and the Airport are necessary for maintaining long term trends. Rainfall records indicate 2020/21 (and the previous 2019/20) had lower than average rainfall with cumulative drought periods over spring and summer. these can put pressure on limited water supplies on the island.

Flow regimes of the major river systems are now well understood and characterised for both low flow and flood conditions. Flow monitoring of the rivers could be rationalised to monitoring priority rivers such as Te Awainanga and Nairn Rivers.

Degrading water quality of waters across the island are likely caused by a number of influences. Climate patterns (drought) appears to be the biggest influence, although changing farming emphasis to heavier livestock (sheep to cattle) appear to strongly interact with climate particularly where organic (peat) soils are poor at supporting heavier animals and contribute to erosion, pugging, compaction and casualty animal effects.

Reduction in state or degrading trends were particularly notable at key sites. Blind Jims Creek exhibited both degrading water quality, impacted riparian habitats and an accompanying poor water quality in the Te Whanga receiving environment. Mangape Creek and the lower reaches of the Nairn River it discharges to were both showing effects of anoxic water, increasing nutrient concentrations and high microbiological concentrations. These catchments show conspicuous effects and a high water quality risk profile and deserve closer scrutiny of land and stream management effects.

Lake Rangitai also stands out in this report. The degrading water quality is highly likely to be a result of the greatly reducing area of this lake as it is highly abstracted from for stockwater and domestic water use for the township of Kaingaroa. These water resources are largely being mined under sustained drought conditions, and as the lake becomes relatively small and shallow the water quality deteriorates. More careful or strategic management of this water resource is warranted.

Te Whanga lagoon is a highly visible and important taonga or community asset. The very likely increasing trends in nitrogen, phosphorus and DOC to the lagoon are therefore of some notable concern. Scrutiny of these water quality results and trends for freshwaters in and flowing into Te Whanga lagoon should not be ignored.

Closer attention to monitoring the limited domestic and potable water resources of the island are warranted including scoping monitoring of the groundwater resources and assessing the capacity of potential water resources.

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Appendix A - Current State of the Chatham Islands Water Quality Monitoring Sites

Figure A1: Current state of dissolved oxygen for monitored sites on the Chatham Islands

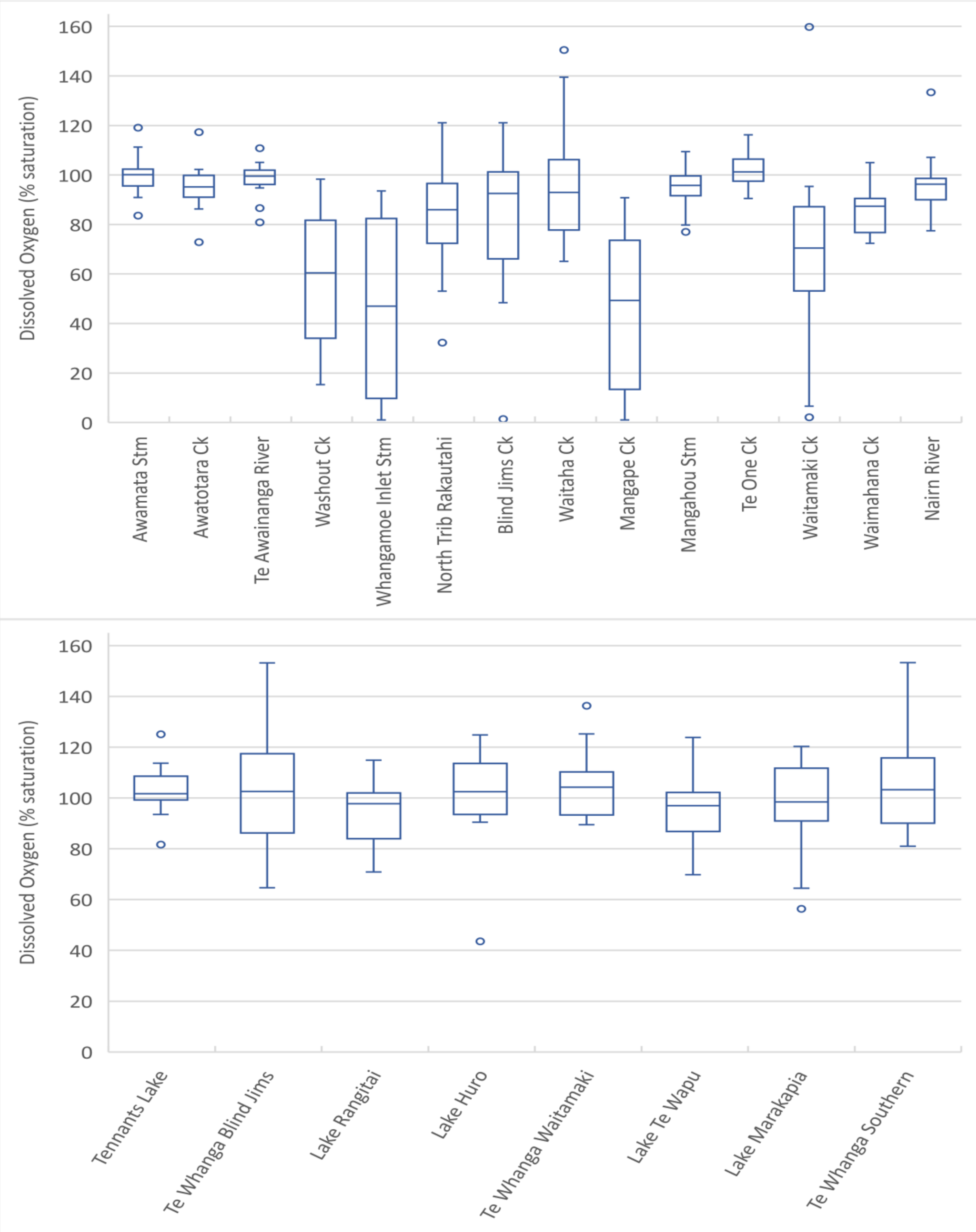


Figure A2: Current state of temperature for monitored sites on the Chatham Islands

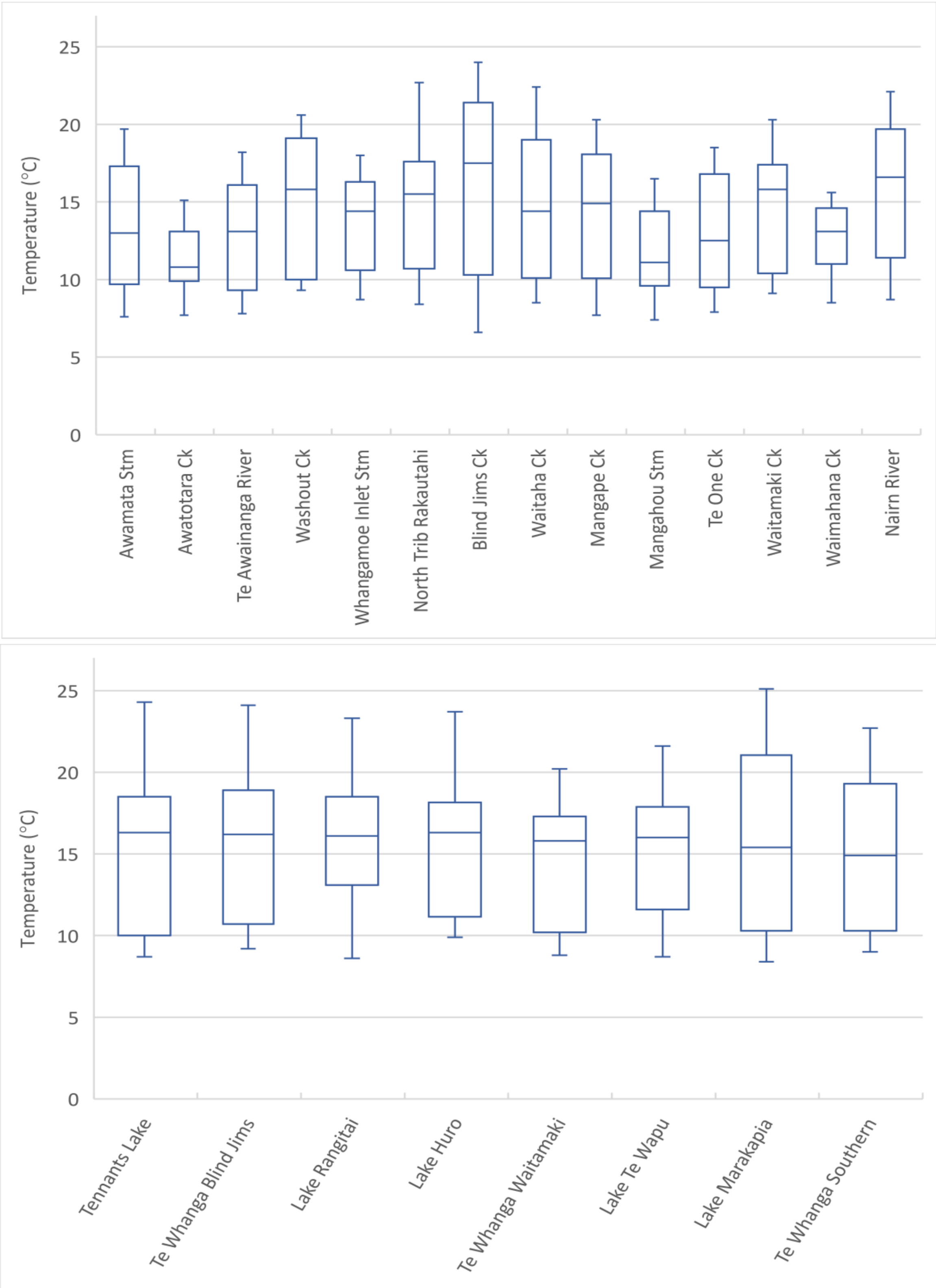


Figure A3: Current state of pH for monitored sites on the Chatham Islands

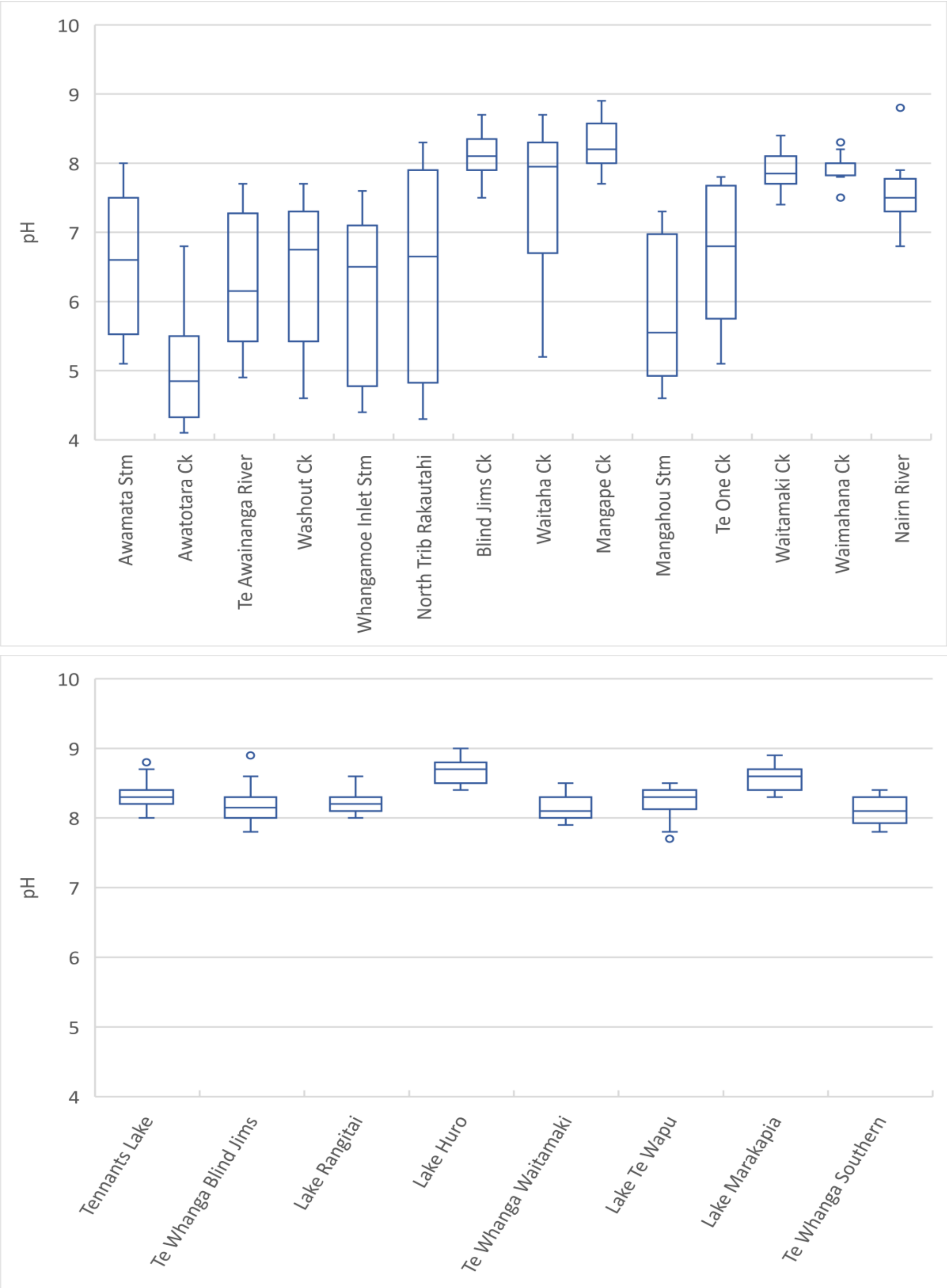
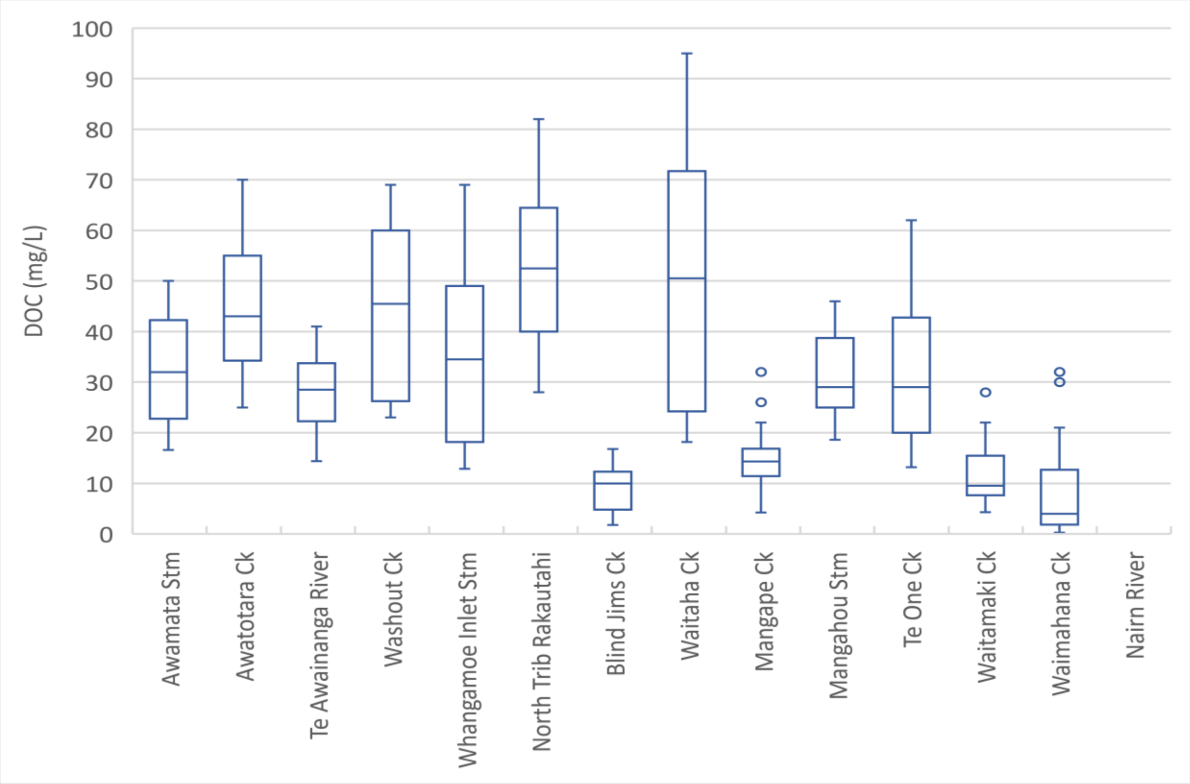


Figure A4: Current state of dissolved organic carbon (DOC) for monitored sites on the Chatham Islands



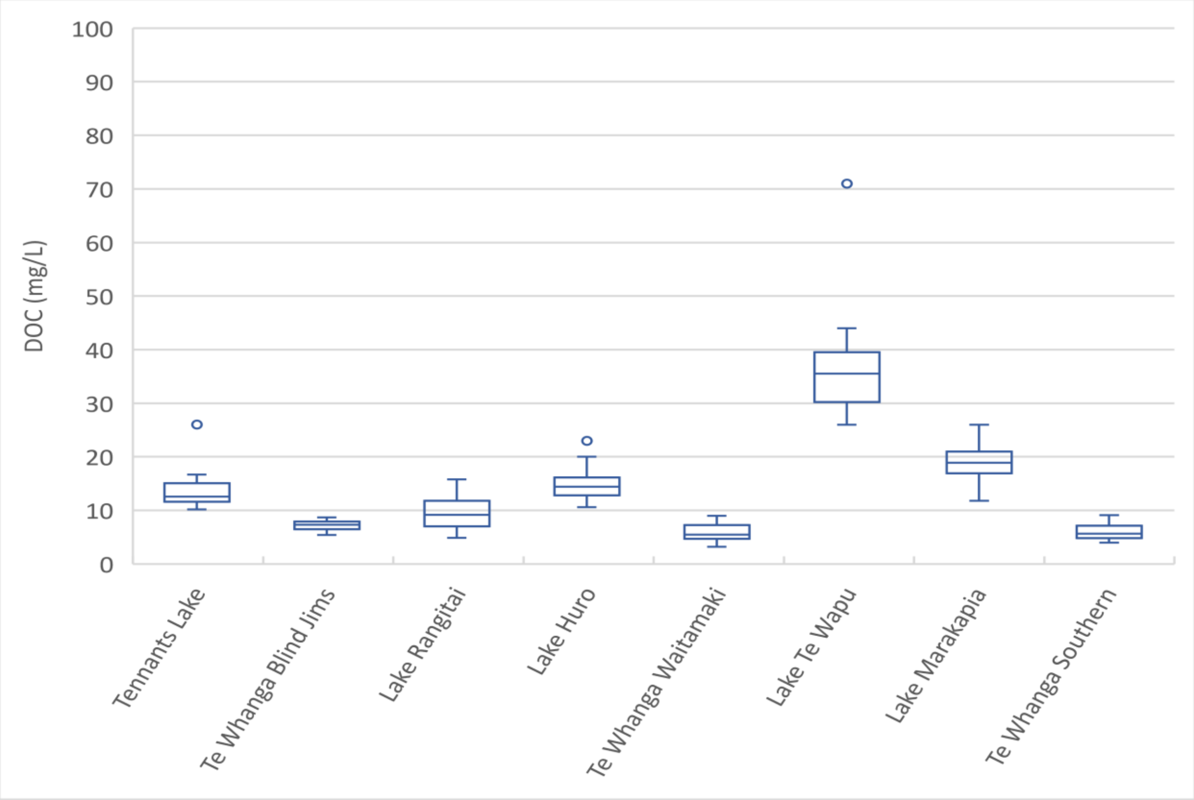
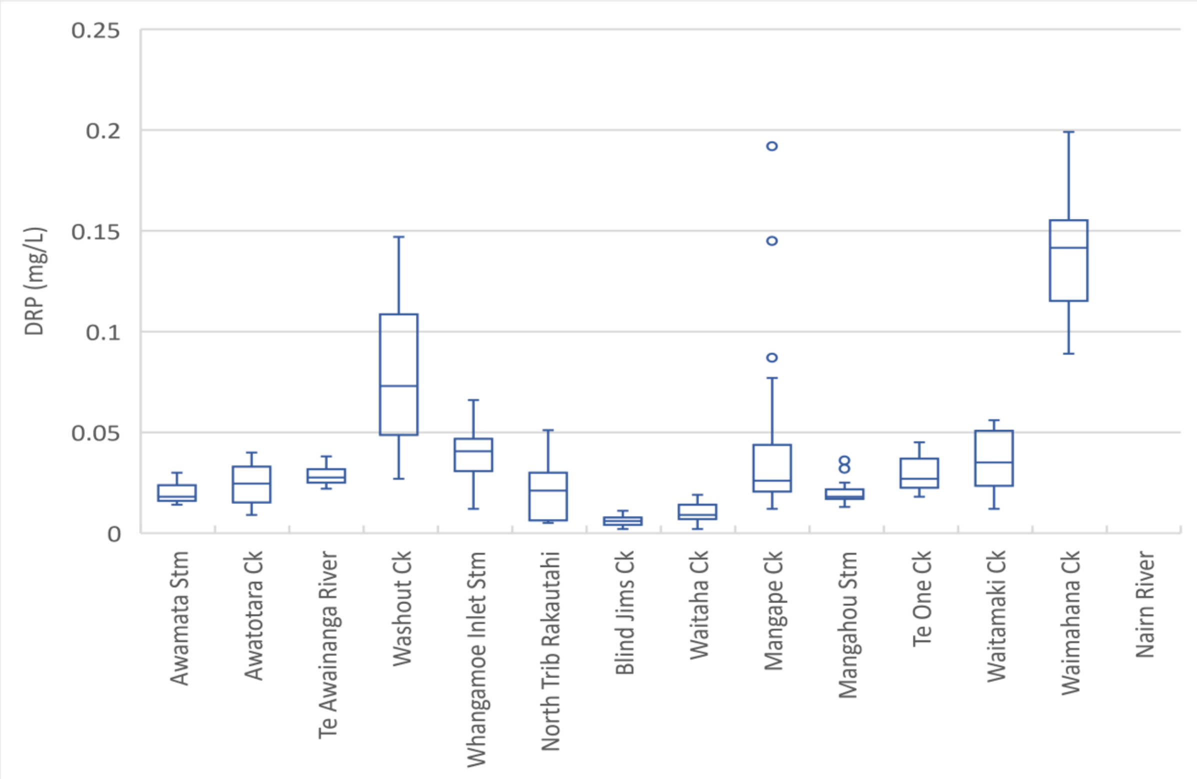


Figure A5: Current state of dissolved reactive phosphorus for monitored sites on the Chatham Islands



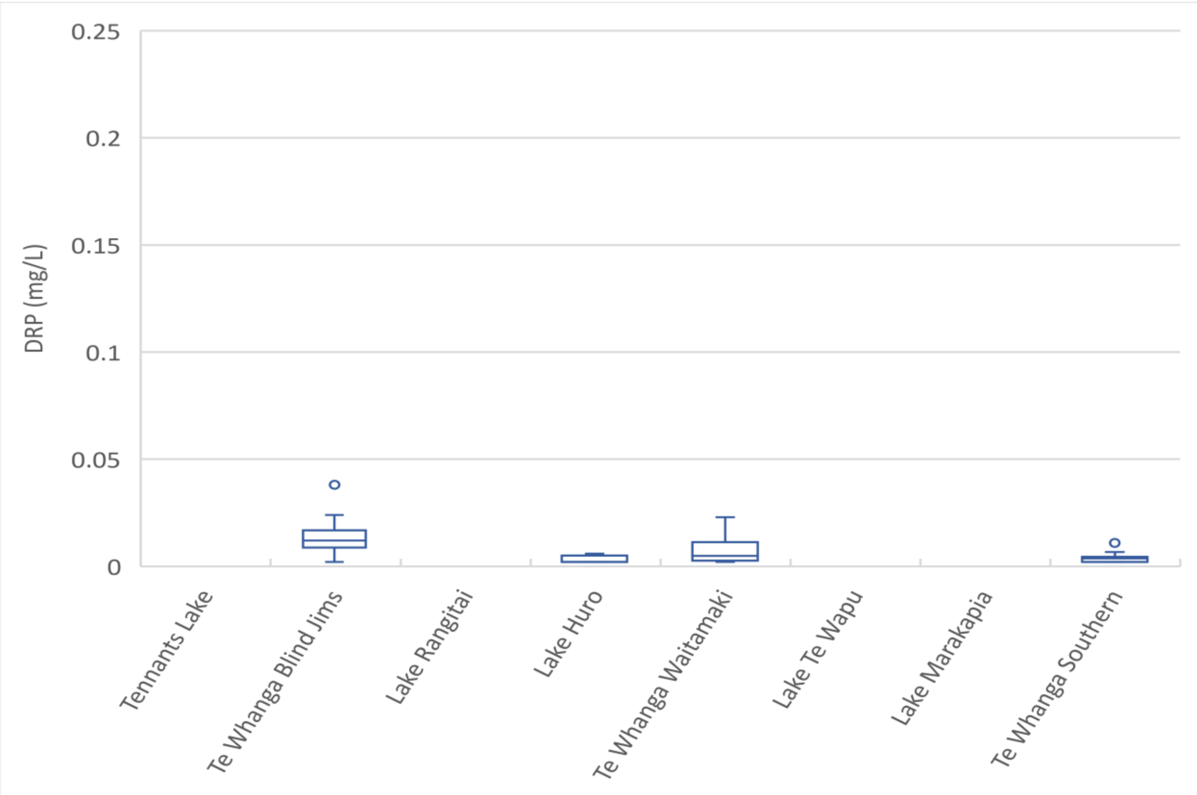


Figure A6: Current state of total phosphorus for monitored sites on the Chatham Islands

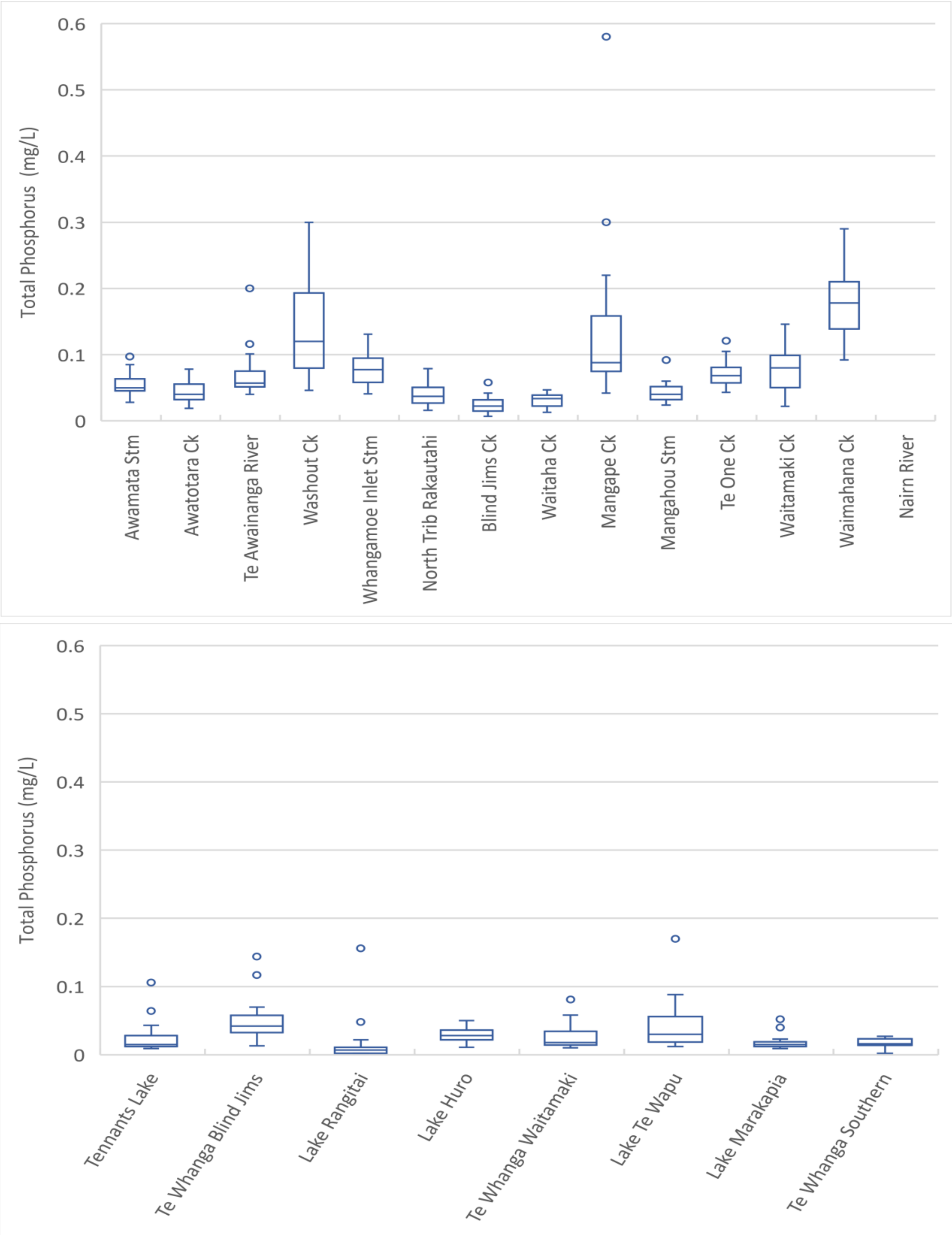
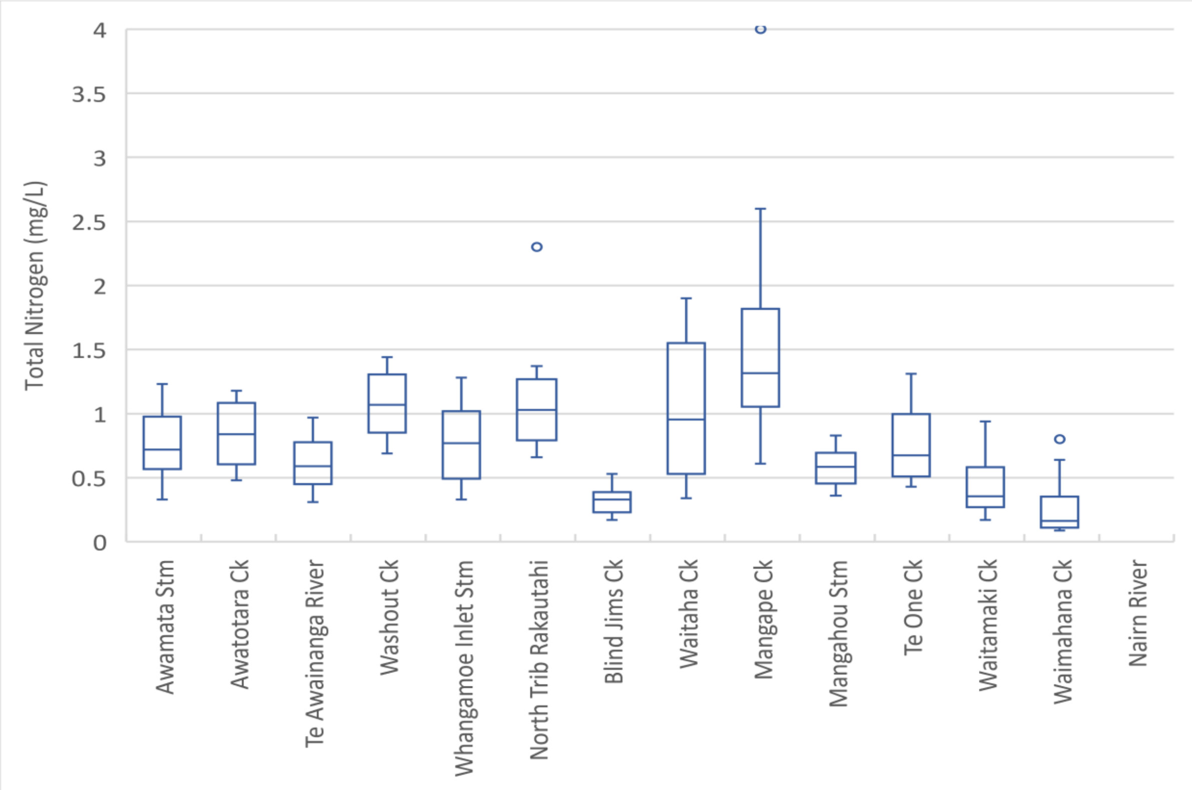


Figure A7: Current state of total nitrogen for monitored sites on the Chatham Islands



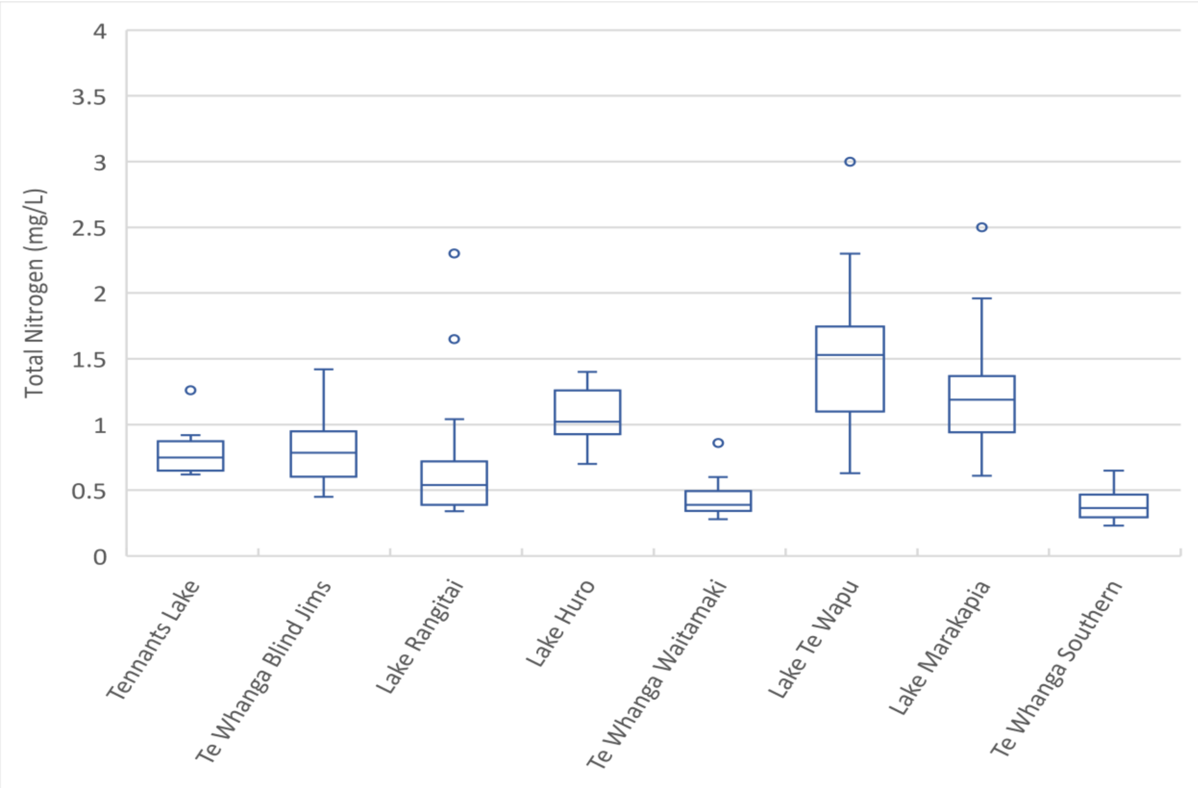


Figure A8: Current state of chlorophyll a at monitored sites on the Chatham Islands

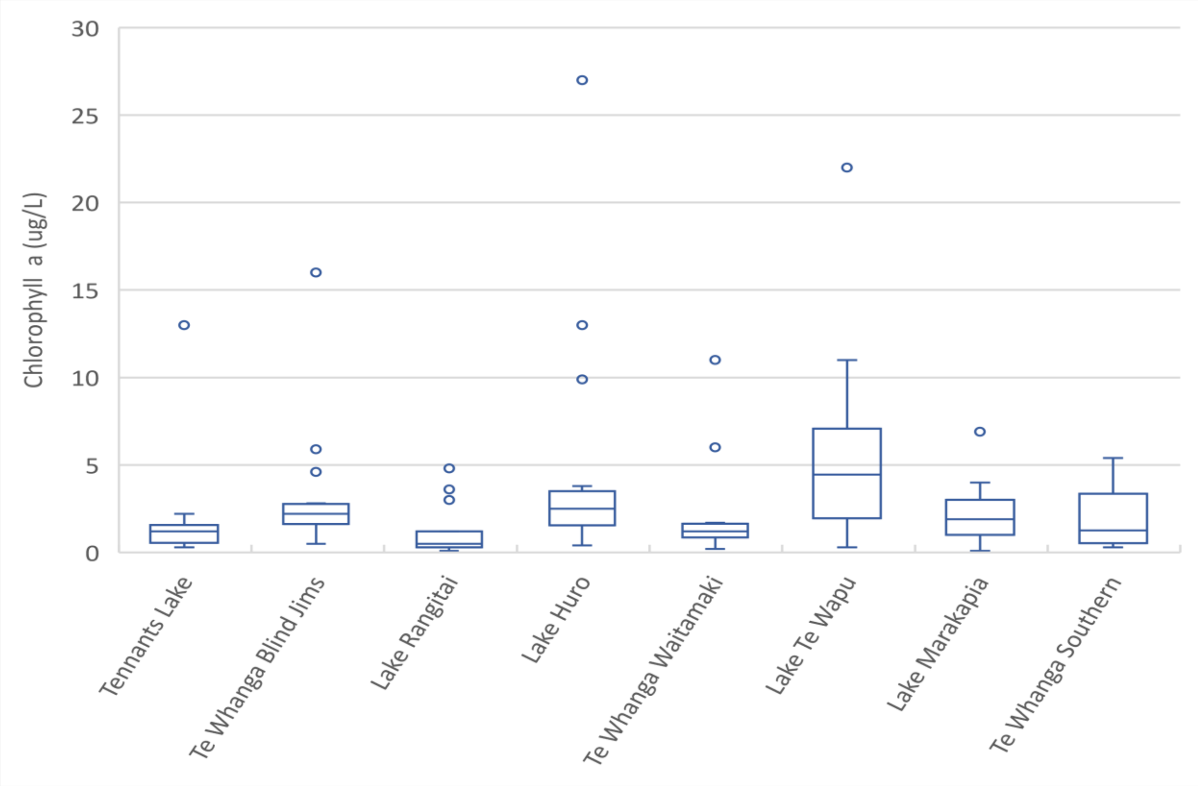
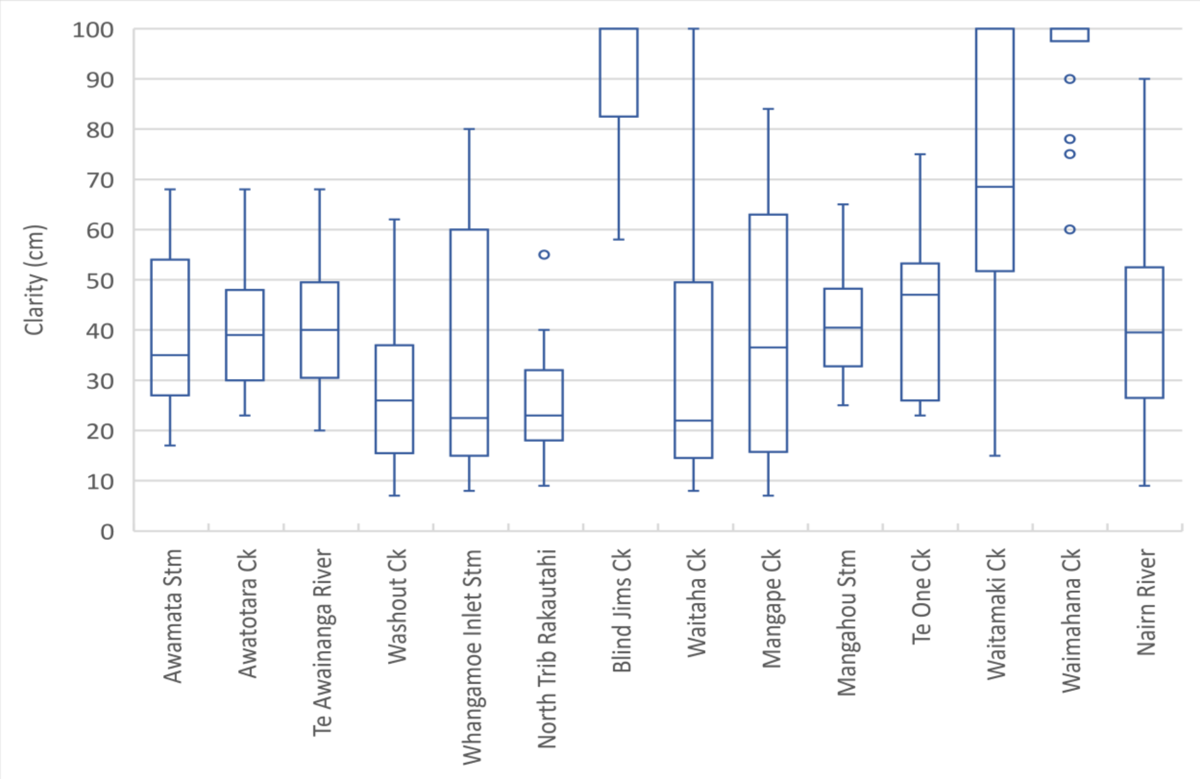


Figure A9: Current state of clarity for monitored sites on the Chatham Islands



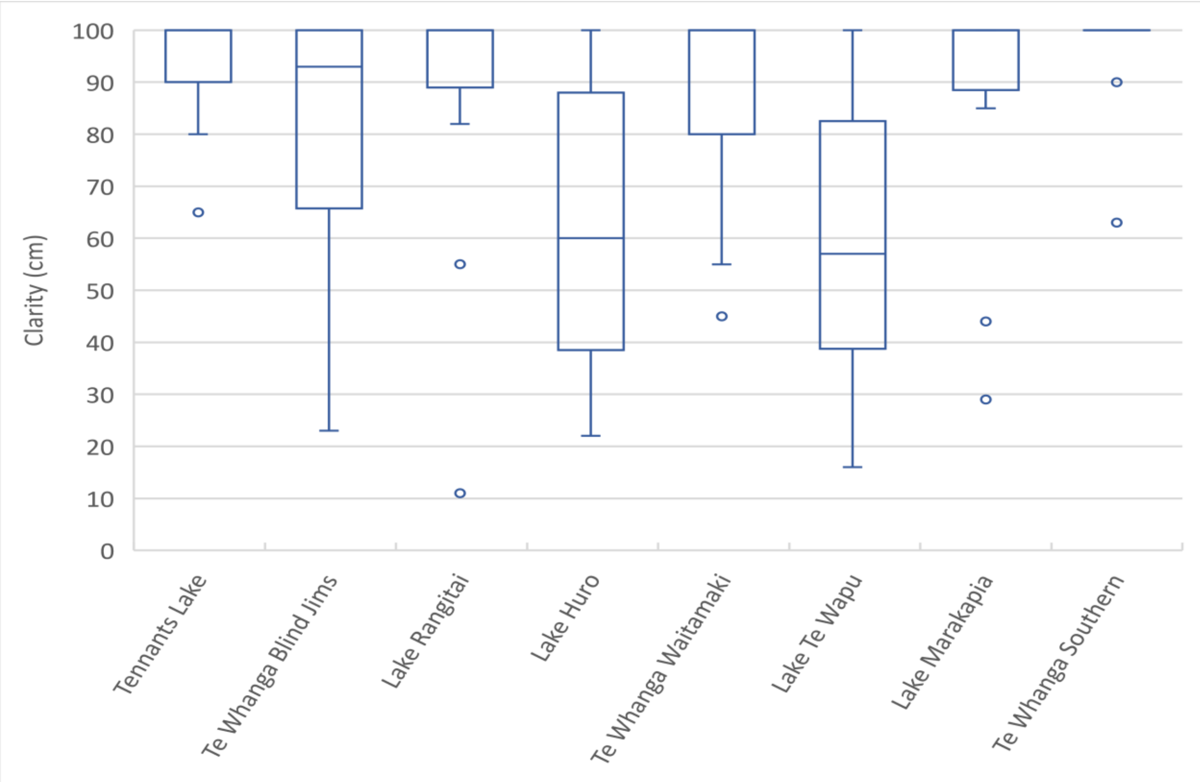


Figure A10: Current state of *E. coli* for monitored sites on the Chatham Islands

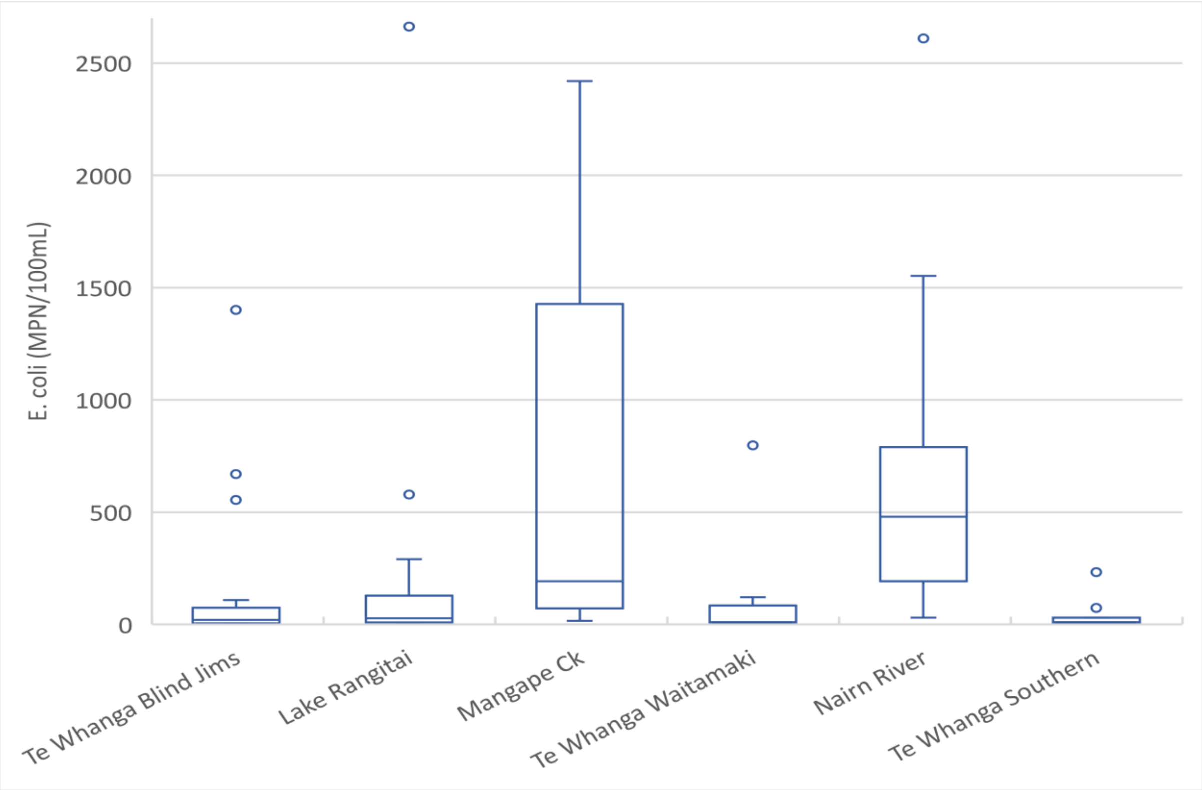
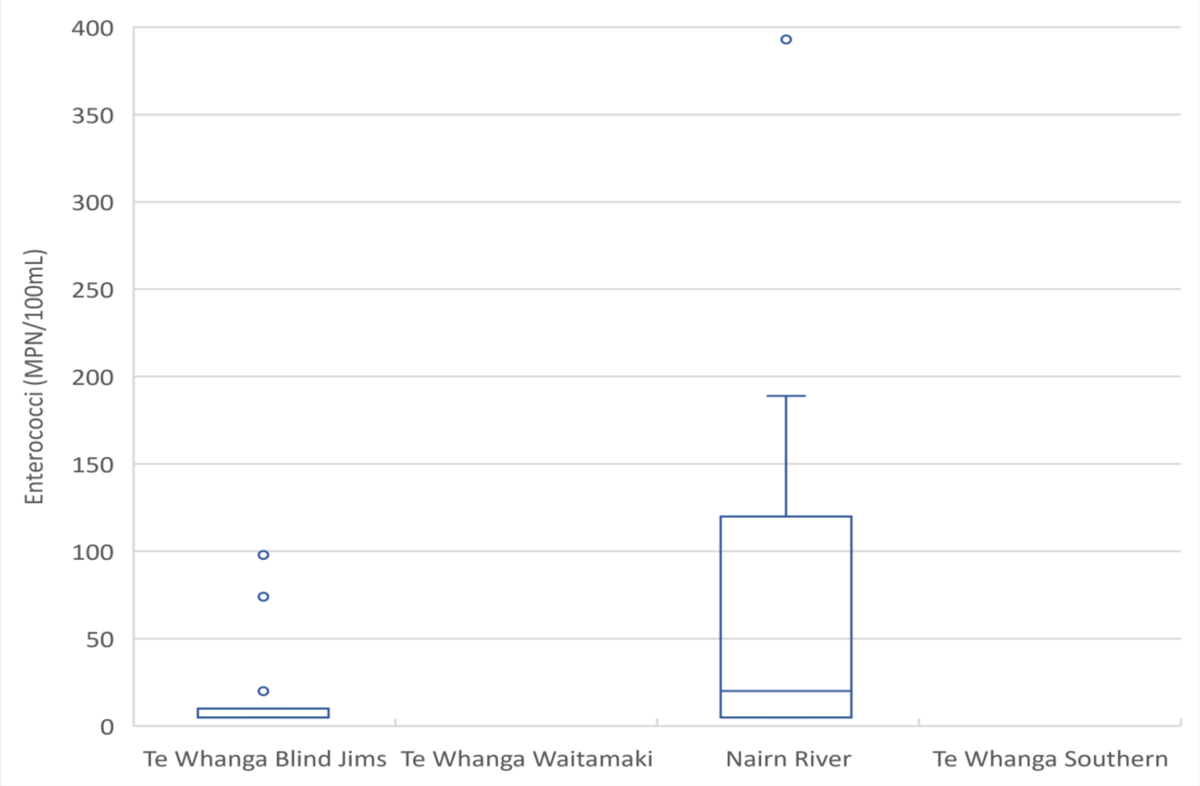


Figure A11: Current state of enterococci for monitored sites on the Chatham Islands



Appendix B – Long Term Trends of the Chatham Islands Water Quality Monitoring Sites

Figure B1: Long Term Trends of Chatham Island Water Quality monitoring sites

Site	Dissolved oxygen %	Water Temperature	pH	DOC	DRP	TP	NH_4N
Awamata Stm	NS	Very Likely Increasing	NS	Very Likely Increasing	Very Likely Decreasing	Very Likely Increasing	NS
Awatotara Ck	NS	Very Likely Increasing	NS	Likely Increasing	Likely Decreasing	NS	NS
Blind Jims Ck	NS	NS	NS	Likely Increasing	Very Likely Decreasing	Very Likely Decreasing	NS
Lake Huro	NS	NS	NS	NS	NS	Likely Decreasing	NS
Lake Marakapia	NS	Very Likely Increasing	NS	Very Likely Increasing	NS	Very Likely Increasing	NS
Lake Rangitai	NS	Very Likely Increasing	NS	Very Likely Increasing	NS	NS	NS
Lake Te Wapu	NS	Very Likely Increasing	NS	Very Likely Decreasing	NS	Very Likely Decreasing	NS
Mangahou Stm	NS	NS	NS	Very Likely Increasing	NS	NS	NS
Mangape Ck	Very Likely Decreasing	NS	NS	NS	Very Likely Increasing	Likely Increasing	Very Likely Increasing
Nairn River	ID	ID	ID	-	-	-	-
North Trib Rakautahi	Very Likely Decreasing	Very Likely Increasing	NS	Very Likely Increasing	Indeterminate	Indeterminate	NS
Te Awainanga River	NS	NS	NS	Very Likely Increasing	Very Likely Increasing	Very Likely Increasing	NS
Te One Ck	NS	NS	NS	Likely Increasing	NS	Very Likely Increasing	NS
Te Whanga Southern	NS	Very Likely Increasing	NS	Likely Decreasing	NS	Likely Decreasing	NS
Te Whanga Blind Jims	Very Likely Decreasing	Very Likely Increasing	NS	Very Likely Increasing	Very Likely Increasing	Likely Increasing	NS
Te Whanga Waitamaki	NS	NS	NS	Very Likely Increasing	NS	Likely Decreasing	NS
Tennants Lake	NS	Very Likely Increasing	NS	Very Likely Increasing	NS	Very Likely Increasing	NS
Waimahana Ck	NS	NS	NS	Likely Decreasing	Likely Decreasing	NS	NS
Waitaha Ck	NS	Very Likely Increasing	NS	Very Likely Increasing	Very Likely Decreasing	Likely Decreasing	NS
Waitamaki Ck	Likely Decreasing	NS	NS	Likely Increasing	Likely Increasing	Likely Decreasing	Very Likely Decreasing
Washout Ck	Indeterminate	Very Likely Increasing	NS	Very Likely Increasing	Indeterminate	Likely Increasing	NS
Whangamoe Inlet Stm	Likely Decreasing	Very Likely Increasing	NS	Very Likely Increasing	Very Likely Decreasing	NS	NS

Site	NNN	TN	Chl a	Clarity Tube	*E. coli*	*Enterococci*
Awamata Stm	NS	Very Likely Increasing	-	Very Likely Decreasing	-	-
Awatotara Ck	NS	Very Likely Increasing	-	Very Likely Decreasing	-	-
Blind Jims Ck	NS	Very Likely Increasing	-	NS	-	-
Lake Huro	NS	Likely Decreasing	NS	Very Likely Increasing	-	-
Lake Marakapia	NS	Very Likely Increasing	NS	NS	-	-
Lake Rangitai	NS	Very Likely Increasing	NS	NS	Very Likely Increasing	-
Lake Te Wapu	NS	Likely Decreasing	Likely Decreasing	Very Likely Decreasing	-	-
Mangahou Stm	NS	Very Likely Increasing	-	Likely Decreasing	-	-
Mangape Ck	Likely Decreasing	NS	-	NS	Indeterminate	-
Nairn River	-	-	-	ID	Likely Increasing	NS
North Trib Rakautahi	NS	Very Likely Increasing	-	Very Likely Decreasing	-	-
Te Awainanga River	Very Likely Increasing	Very Likely Increasing	-	Very Likely Decreasing	-	-
Te One Ck	NS	Very Likely Increasing	-	Likely Decreasing	-	-
Te Whanga Southern	NS	NS	NS	NS	NS	NS
Te Whanga Blind Jims	Very Likely Decreasing	Likely Increasing	NS	NS	NS	NS
Te Whanga Waitamaki	NS	Likely Increasing	NS	NS	NS	NS
Tennants Lake	NS	Very Likely Increasing	NS	Very Likely Decreasing	-	-
Waimahana Ck	Very Likely Increasing	Very Likely Increasing	-	NS	-	-
Waitaha Ck	Very Likely Increasing	Very Likely Increasing	-	Likely Decreasing	-	-
Waitamaki Ck	NS	Likely Increasing	-	Likely Decreasing	-	-
Washout Ck	Very Likely Increasing	Very Likely Increasing	-	Very Likely Decreasing	-	-
Whangamoe Inlet Stm	NS	Very Likely Increasing	-	Very Likely Decreasing	-	-

- = not sampled
NS = not significant
ID = insufficient data

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