Water Quality Monitoring Report for Te Roto o Wairewa – Lake Forsyth: January – December 2022

Prepared to meet the Requirements of CRC134849

Christchurch City Council

March 2023

Report: Water Quality Monitoring Report for Te Roto o Wairewa – Lake Forsyth: January – December 2022

Document control	
Document location	FOLDER09/2440: Lake Forsyth / Wairewa
Related documents	CRC134849 consent document (16/515158)

Version control	
Version number	1
Prepared by and date	Dr Belinda Margetts, Principal Waterways Ecologist, Three Waters and Waste, Christchurch City Council Laura Drummond, Technical Director - Ecology, Pattle Delamore Partners 07/03/22
Reviewed by and date	Vanessa Irvine, Resource Consent Compliance Coordinator, Three Waters and Waste, Christchurch City Council 07/03/22
Approved by and date	Veronica Zefferino, Team Leader Quality & Compliance, Three Waters and Waste, Christchurch City Council 08/03/22
Changes/updates to the new version	N/A

Executive Summary

This report briefly summarises the surface water quality monitoring of Te Roto o Wairewa – Lake Forsyth for the 2022 calendar year and provides an analysis of long-term trends. The results are in line with previous annual reports since 2016.

Conductivity, salinity, turbidity, nitrogen and phosphorus levels, as well as phytoplankton and cyanobacteria unit counts, all recorded statistically significant decreases since monitoring began. Trophic Level Index (TLI) also decreased over time, which is not surprising as this index is calculated from total nitrogen and total phosphorus (as well as chlorophyll a). There was no change in temperature over time. However, the guideline level for temperature (19°C) was exceeded on two occasions during the 2022 monitoring year.

The cyanobacteria biovolume alert and action levels were exceeded on ten and six occasions, respectively. This number of exceedances is within the range recorded since monitoring began in 2008. As a result of these exceedances, health warnings were issued from 19 October 2021–15 February 2022, 18 February - 6 July 2022, 14 July -1 September, and 13 October – 29 November 2022. The decrease in salinity is probably partially driving the change in phytoplankton composition from *Nodularia* spp., to *Dolichospermum* spp. and *Aphanizomenon* spp..

These results show that water quality continues to improve within the lake, most likely due to the canal opening regime. Most notably, there has been a significant decrease in the TLI over time. However, the water quality is still poor at times, and additional lake and catchment management practices that improve water quality (e.g., planting) should therefore continue.

Contents Page

1. Introduction

In accordance with the requirements of Condition 11c (monitoring and reporting) of consent CRC134849 (to take and divert water from, and dam, Te Roto o Wairewa – Lake Forsyth), this report briefly summarises the surface water quality results of Te Roto o Wairewa – Lake Forsyth for the 2022 calendar year and provides an analysis of long term trends. The data used in this report was provided by Environment Canterbury (ECan).

2. Methods

Samples were taken at least monthly from the lake and analysed for conductivity, salinity, temperature, turbidity, Dissolved Inorganic Nitrogen (DIN), Dissolved Reactive Phosphorus (DRP), Trophic Level Index (TLI), phytoplankton unit counts, and cyanobacteria unit counts and biovolume. The TLI is calculated using chlorophyll a, total nitrogen and total phosphorus. Cyanobacteria are a subset of phytoplankton, and unit counts and biovolumes were assessed for particular species of potentially toxic cyanobacteria.

Water quality parameters were analysed from when the monitoring began in 1993 until December 2022. Phytoplankton and cyanobacteria unit counts were assessed from 2004, and cyanobacteria biovolumes from 2008. Samples were typically collected from the ECan water level recorder site (hereafter referred to as 'Recorder'), with the exception of salinity, which was also recorded at two additional sites (Figure 1). As conductivity and salinity are related, these are presented together in this report.

Long-term data trends were analysed using Time Trends software (NIWA, 2014[1]). The Seasonal Kendall trend test was used to test the significance, magnitude and direction of trends, providing an average annual percent change. Water quality parameters were analysed as independent data. Total phytoplankton data, including the subsets of cyanobacteria and potentially toxic cyanobacteria, were analysed as dependent data, due to the potential for species numbers to impact replication between sampling events. Long-term data trends for cyanobacteria biovolume were not analysed, due to the sampling methodology varying between state of environment monitoring and samples collected during blooms to assess human health risks.

[1] NIWA, 2014. Trend and equivalence analysis. Software Version 9.0. NIWA. https://www.jowettconsulting.co.nz/home/time-1.

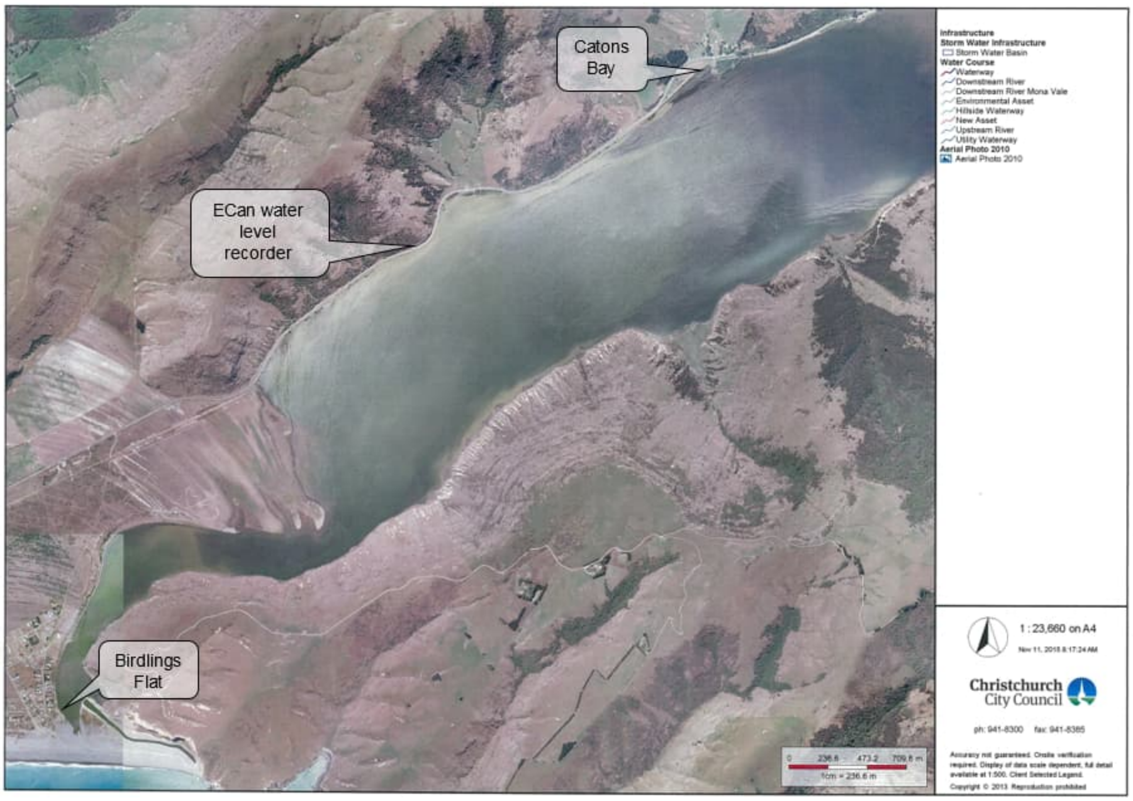

Figure 1. Water quality monitoring sites in Te Roto o Wairewa – Lake Forsyth.

3. Results

3.1. Conductivity and salinity

- A general decreasing trend was recorded over time for both parameters (Figures 2 – 3 in Appendix A).
- Following the implementation of the canal opening regime, median conductivity and salinity concentrations have decreased by nearly 80%, while mean concentrations decreased by over 70% (Table 1).
- There was a significant decrease (5% per annum) in conductivity at the Recorder site since monitoring began in July 1993.
- There was a significant decrease (7% per annum) in salinity at the Recorder site since monitoring began in November 1998. A significant decrease of 16% was recorded at the Catons Bay site and a 13.5% decrease at Birdlings Flat since monitoring began in December 2006.

3.2. Temperature

- Following the implementation of the canal opening regime, median temperature increased by 18% and mean temperatures by 9% (Table 1).
- No significant change over time was recorded for temperature since monitoring began in August 1993, with seasonal variations in levels as expected (Figure 4 in Appendix A).

- Frequent exceedances of the Land and Water Regional Plan guideline (LWRP) level (19°C; Environment Canterbury, 2015[2]) have occurred since monitoring began. Two of the 12 samples taken during the 2022 monitoring year exceeded this guideline (January and December).

3.3. Turbidity

- Following the implementation of the canal opening regime, turbidity decreased by 20% (median) and 31% (mean) (Table 1).
- There was a significant per annum decrease in turbidity of 2% since monitoring began in July 1993, with fewer large peaks in levels over time (Figure 5 in Appendix A).
- Compared to the rest of the 2022 data, a spike in turbidity was recorded in November 2022 of 154 NTU (Figure 5 in Appendix A).

3.4. Dissolved Inorganic Nitrogen

- Following the implementation of the canal opening regime, DIN decreased by 63% (median) and 37% (mean) (Table 1).
- There was a significant decreasing trend in DIN since monitoring began in July 1993, with an annual percent change of 2.4% (Figure 6 in Appendix A).
- Compared to the rest of the 2022 data, a spike in DIN concentrations was recorded in July (0.461 mg/L). This spike exceeded the LWRP guideline of 0.34 mg/L (Environment Canterbury, 2015[2]), and was due to a high concentration of Nitrate-Nitrite Nitrogen, which is a component of DIN.

3.5. Dissolved Reactive Phosphorus

- Following the implementation of the canal opening regime, median DRP did not change; however, mean DRP decreased by 38% (Table 1). This may be due to an increase in low levels of DRP concentrations that affect the mean, but not the median until a bigger change occurs.
- There was a significant decrease in DRP of 4% per annum since monitoring began in July 1993 (Figure 7 in Appendix A).
- There were fewer peak concentrations after approximately 2010.
- For the 2022 calendar year, no peaks were observed. No DRP records exceeded the LWRP guideline of 0.02 mg/L (Environment Canterbury, 2015[2]).

3.6. Trophic Level Index

- Following the implementation of the canal opening regime, median and mean TLI decreased by 7% (Table 1).
- A significant decrease in TLI of 0.44% per annum was recorded since monitoring began in September 1999 (Figures 8a - 8c in Appendix A).
- Prior to the canal opening there was an increasing trend (Figure 8b); however, levels have been decreasing since the initiation of the canal opening (Figure 8c).

3.7. Phytoplankton and cyanobacteria unit counts

- Total phytoplankton counts significantly decreased by 7% per annum, since monitoring began in 2004 (Figure 9 in Appendix A).

---

[2] Environment Canterbury, 2015. Canterbury Land and Water Regional Plan - Volume 1. February 2017. Environment Canterbury, Christchurch.

- Total cyanobacteria counts significantly decreased by 19% per annum, since monitoring began in 2004 (Figure 9 in Appendix A).
- There was a reduction in large peaks in concentrations for both parameters since monitoring began. A comparatively small spike in total phytoplankton was recorded in January 2022, due to high counts of the diatom *Chaetoceros* sp. (Figure 9 in Appendix A).
- With respect to counts of potentially toxic cyanobacteria:
    - Following the implementation of the canal opening regime, cyanobacteria counts decreased by 100% (median) and 79% (mean).
    - *Merismopedia* spp. counts were high when monitoring first began in 2004, but since 2011 counts have reduced to occasional numbers, with a significant per annum decrease of 282% since monitoring began (Figure 10 in Appendix A). These lower numbers are potentially due to this species not tolerating freshwater conditions.
    - Large counts of *Nodularia* spp. were recorded when monitoring first commenced, but only occasional re-occurrences have been recorded since 2010 (Figure 10 in Appendix A). A comparatively low spike in concentrations (1,500 units/ml) was recorded in April 2022, although this is not visible on the graph. The decline in *Nodularia* spp. is likely due to the decrease in lake salinity, as optimal growth occurs between 7–18 ppt[3]. With one exception, salinities in the lake have not exceeded 5 ppt since 2010. Although a significant decrease was recorded since monitoring began, the percent change was zero, likely due to a small number of peaks recorded at the beginning of the dataset and predominantly no records thereafter.
    - *Dolichospermum* spp. and *Aphanizomenon* spp. have generally been present in low numbers, as was the case this monitoring year; however, one comparatively low spike in *Aphanizomenon* spp. concentration (3,700 units/ml) was recorded in September (Figure 10 in Appendix A). A significant increasing trend was recorded for both cyanobacteria species; however, a zero percent change over time was recorded, due to a high proportion of zero abundance, particularly early in the dataset. It is probable that the increasing abundance of these two cyanobacteria is a result of lower salinity in the lake, with both species able to grow in freshwater[4]. Rosen et al (2018)[5] concluded that salinities greater than 7.5 ppt were not tolerated by *Dolichospermum circinale*.

3.8. Cyanobacteria biovolume

- A comparison of the pre and post canal opening regime is not provided for biovolume, as the metric is impacted by low samples taken pre-opening (only 19).
- With respect to the biovolume of potentially toxic cyanobacteria species (Figure 11 in Appendix A):
    - *Merismopedia* sp. biovolume was occasionally high when monitoring first began, but levels are now generally low year-round, as was the case this monitoring year.

---

[3] Mazur-Marzec, H., Żeglińska, L. & Pliński, M. 2005. The effect of salinity on the growth, toxin production, and morphology of Nodularia spumigena isolated from the Gulf of Gdańsk, southern Baltic Sea. Journal of Applied Phycology 17, 171–179.
[4] Halinen, K., Jokela, J., Fewer, D., Wahlsten, M., & Sivonen, K. 2007. Direct evidence for production of microcystins by Anabaena strains from the Baltic Sea. Applied Environmental Microbiology, 73(20), 6543–6550.
[5] Rosen, B., Loftin, K., Graham, J., Stahlhut, K., Riley, J., Johnston, B., and Senegal, S. 2018. Understanding the effect of salinity tolerance on cyanobacteria associated with a harmful algal bloom in Lake Okeechobee, Florida: U.S. Geological Survey Scientific Investigations Report 2018–5092, 32 p.

- Nodularia spp. biovolume was occasionally high when monitoring first began but was particularly high in the 2016 monitoring year. During the 2022 monitoring year, one spike of *Nodularia* spp. was recorded, otherwise small volumes on many occasions were recorded, as was the case for the last several years.
- *Dolichospermum* spp. have generally been present in low volumes; however, spikes in concentrations are typically recorded a couple of times a year. Two spikes were recorded in 2022.
- Low numbers of *Aphanizomenon* spp. are typically recorded; however, small peaks of biovolume have occurred every spring/summer since December 2016. In 2022, peaks were recorded in September.

- Of the 26 samples taken in 2022, the biovolume alert guideline level for all potentially toxic cyanobacteria (0.5 mm^3/L) was exceeded on ten occasions and the action guideline level (1.8 mm^3/L) was exceeded on six occasions (Ministry for the Environment and Ministry of Health, 2009[6]; Figure 12a in Appendix A). Most exceedances of the alert level were due to *Nodularia* spp. and all action level exceedances were due to this cyanobacteria species, apart from one exceedance as a result of *Aphanizomenon* spp. This number of exceedances per annum is within the range previously recorded since monitoring began in 2008 (Figure 12b in Appendix A).
- Consequently, the Canterbury District Health Board advised the public to avoid contacting the water, and eating fish or shellfish from the lake, and recommended to keep livestock and pets away from the lake. These warnings were in place from 19 October 2021–15 February 2022, 18 February - 6 July 2022, 14 July -1 September, and 13 October – 29 November 2022.

3.9. Lake openings

The lake was opened on the 7th June, 15th July, and 25th July. A smaller opening for tuna (eel) migration occurred on 21st March, this small area was re-opened on 26th and 28th March for continued migration (Figures 2 and 13 in Appendix A).

4. Conclusion

- Since the canal opening was instigated in 2009, there have been significant improvements in water quality within the lake. Conductivity, salinity, turbidity, nitrogen, phosphorus, phytoplankton, cyanobacteria, and TLI have all decreased. This was highlighted in the Commissioner's decision on the lake opening consent, based on the evidence presented by a number of experts (Collins et al, 2016)[7]. The monitoring from 2022 is still showing continual improvements in water quality.
- Lake openings likely improve water quality by allowing water to flow out to sea and disallowing significant flows of salt water back into the lake, which previously occurred with the former mid-beach opening regime. This has resulted in a decrease in lake salinity.

[6] Ministry for the Environment and Ministry of Health. 2009. New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters – Interim Guidelines. Prepared for the Ministry for the Environment and the Ministry of Health by SA Wood, DP Hamilton, WJ Paul, KA Safi and WM Williamson. Wellington: Ministry for the Environment.

7 Collins, D., Cowie, B. & Langsbury, H. 2016. Decisions of hearings commissioners, in the matter of applications to the Christchurch City Council (RMA92021940 and RMA92030265), and the Canterbury Regional Council (CRC134837, CRC134839, CRC134864, CRC135060 and CRC 160434) made jointly by the Christchurch City Council and Wairewa Rūnanga Incorporated for consents to carry out activities associated with the artificial opening and closing of Te Roto o Wairewa/Lake Forsyth to the sea. Little River, Banks Peninsula, New Zealand.

- The decrease in salinity is probably partially driving the change in phytoplankton composition from *Nodularia* spp., to *Dolichospermum* spp. and *Aphanizomenon* spp..
- However, the water quality is still poor at times, and additional lake and catchment management practices that improve water quality (e.g., planting) should therefore continue.

Table 1. Percent change of parameters at the Environment Canterbury Recorder Site at Te Roto o Wairewa – Lake Forsyth, before (various dates for each parameter from 1993 – September 2009) and after (October 2009 – December 2022) the implementation of the canal opening regime.

Parameter	Count (n)		Median		Mean		Percentage change	
	Pre	Post	Pre	Post	Pre	Post	Median	Mean
Conductivity (µS/cm)	587	194	920	206.3	987	243	-78%	-75%
Salinity (ppt)	496	267	5.2	1.1	5.1	1.5	-79%	-71%
Temperature °C	694	285	13.0	15.3	13.2	14.4	18%	9%
Turbidity (NTU)	599	159	14.0	11.2	31.2	21.4	-20%	-31%
DIN (mg/L)	512	155	0.043	0.016	0.112	0.071	-63%	-37%
DRP (mg/L)	504	151	0.004	0.004	0.028	0.017	0%	-38%
TLI	121	145	5.99	5.58	6.17	5.71	-7%	-7%
Potentially toxic cyanobacteria - counts (unit/ml)	137	199	47500	105.5	171,471	36,448	-100%	-79%

5. Appendix A: Graphs

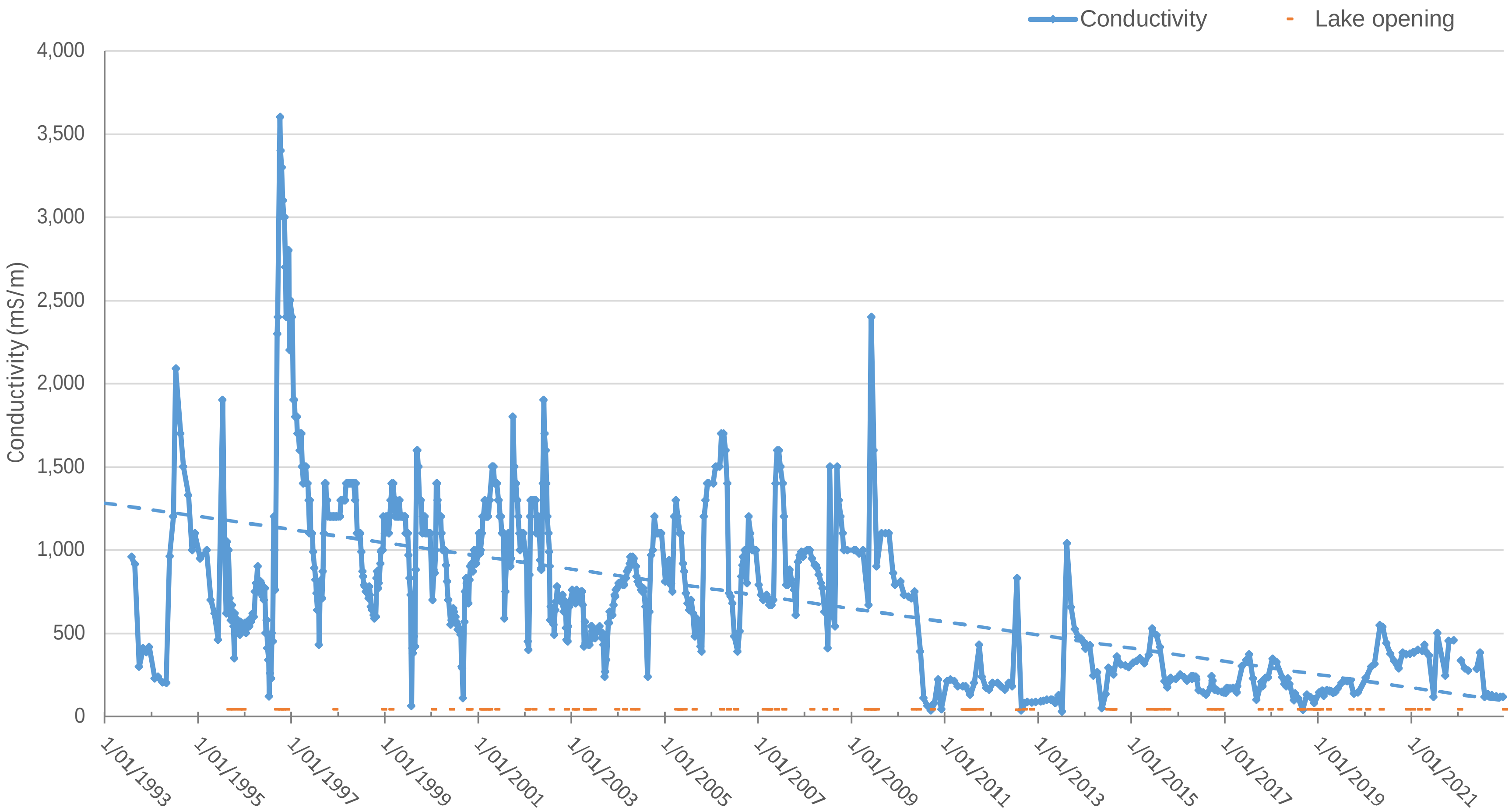

Figure 2. Conductivity of water at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site July 1993 - December 2022. The dashed line is a linear trendline.

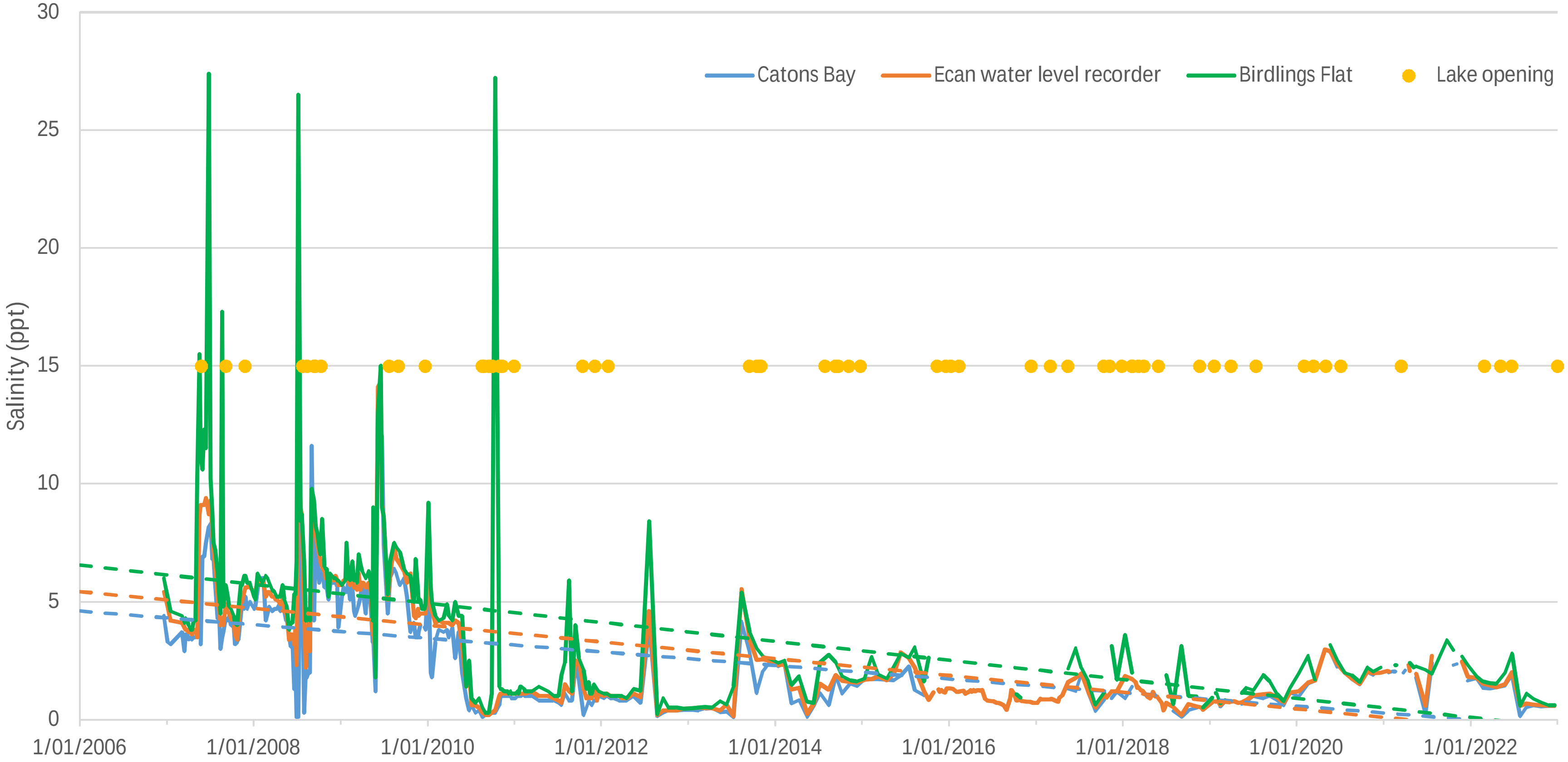

Figure 3. Salinity of water at Te Roto o Wairewa – Lake Forsyth at three sites (ECan Water Level Recorder, Catons Bay and Birdlings Flat) December 2006 - December 2022. The dashed lines are linear trendlines.

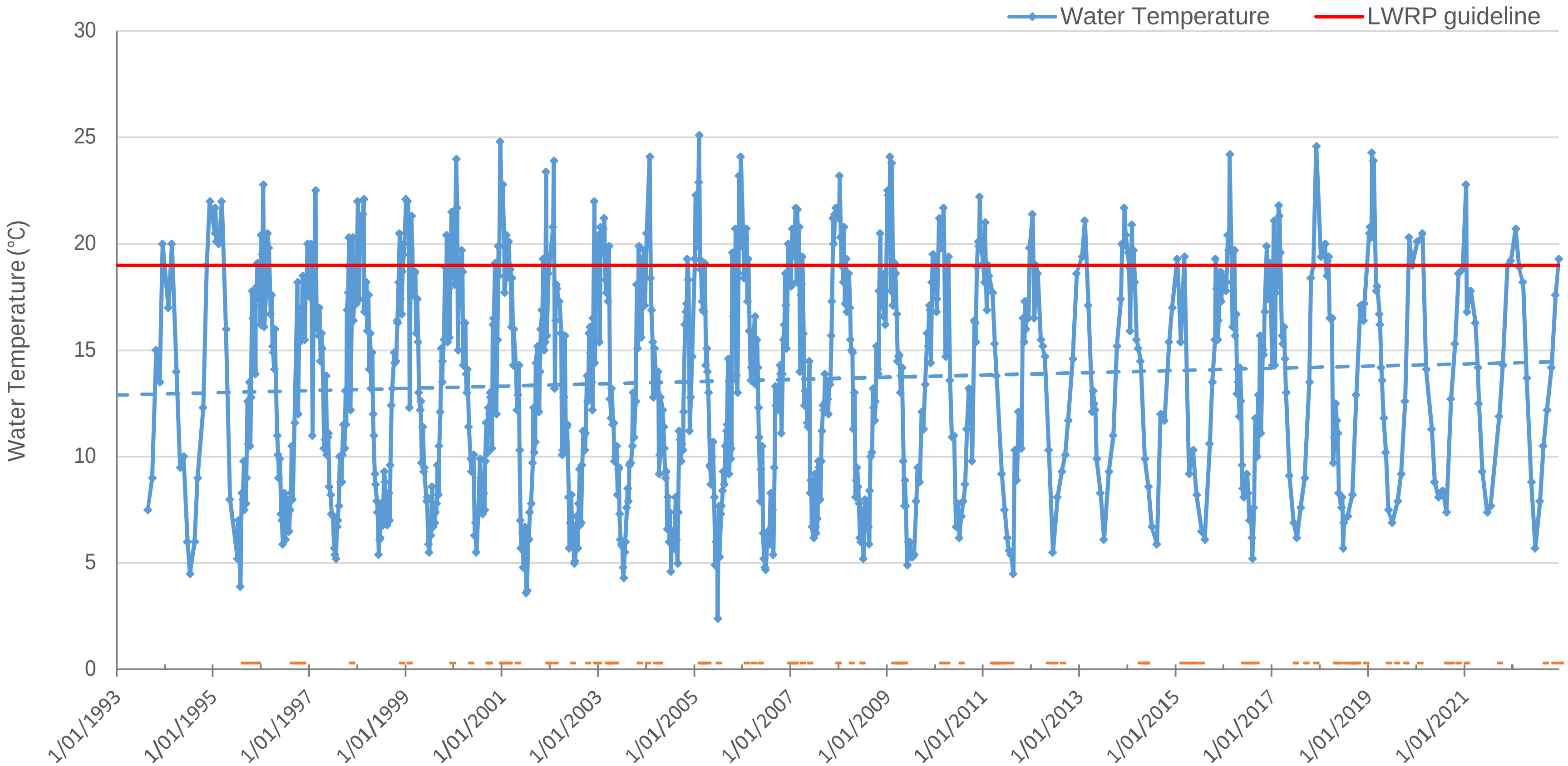

Figure 4. Water Temperature at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site August 1993 - December 2022. The dashed line is a linear trendline. Red line = Land and Water Regional Plan (LWRP) guideline for coastal lakes (19°C).

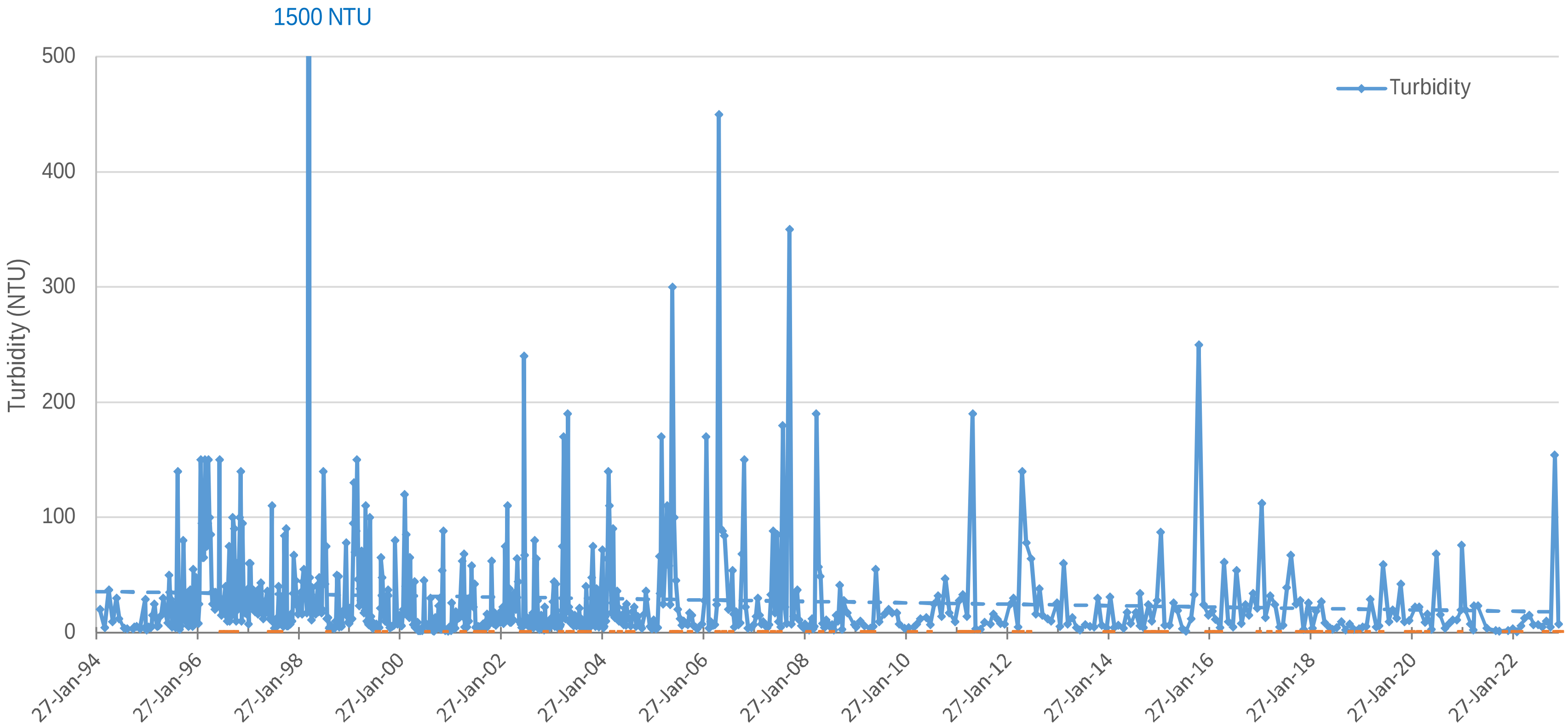

Figure 5. Turbidity of water at Te Roto o Wairewa – Lake Forsyth at the water level recording site July 1993 - December 2022. The dashed line is a linear trendline. One data point is substantially higher than the other data points and is therefore off the scale of the graph – the number above the graph details the concentration.

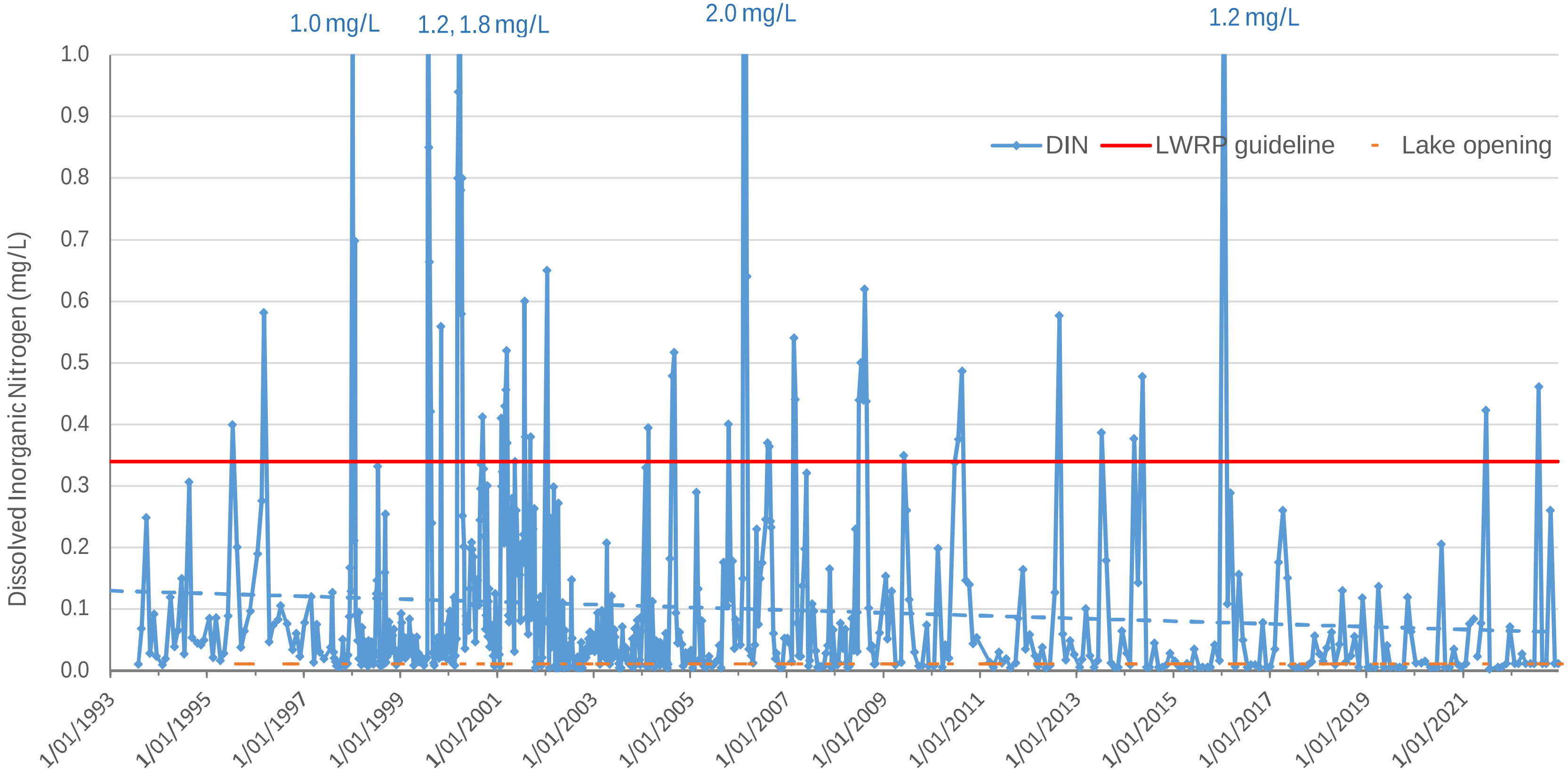

Figure 6. DIN at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site July 1993 – December 2022. The dashed line is a linear trendline. Five data points are substantially higher than the other data points and are therefore off the scale of the graph – the numbers above the graph detail their concentrations.

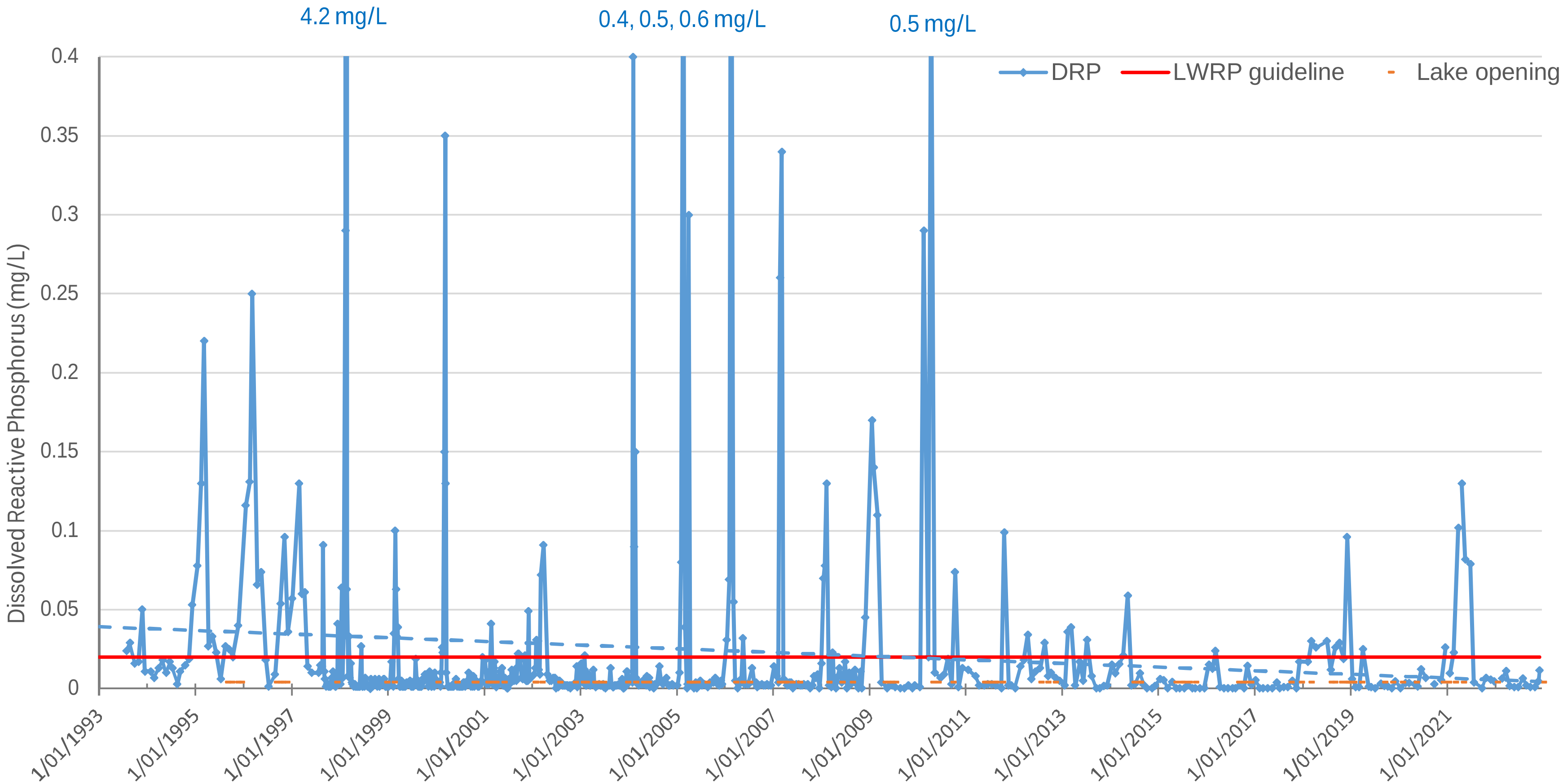

Figure 7. DRP at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site July 1993 – December 2022. The dashed line is a linear trendline. Five data points are substantially higher than the other data points and are therefore off the scale of the graph – the numbers above the graph detail their concentrations.

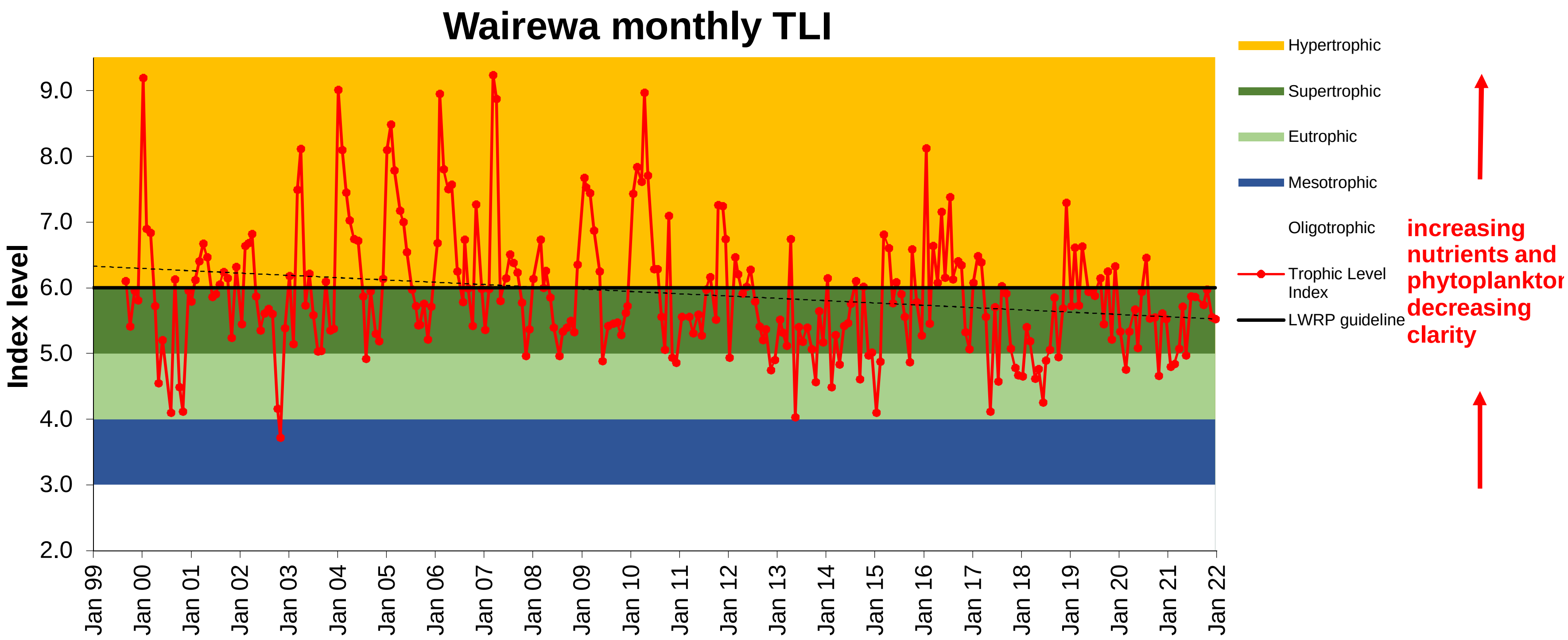

Figure 8a. Trophic Level Index (TLI) at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site for the entire dataset (September 1999 – December 2022). The dashed line is a linear trendline. Solid black line = Land and Water Regional Plan (LWRP) guideline for coastal lakes (6 TLI). Graph modified from ECan versions.

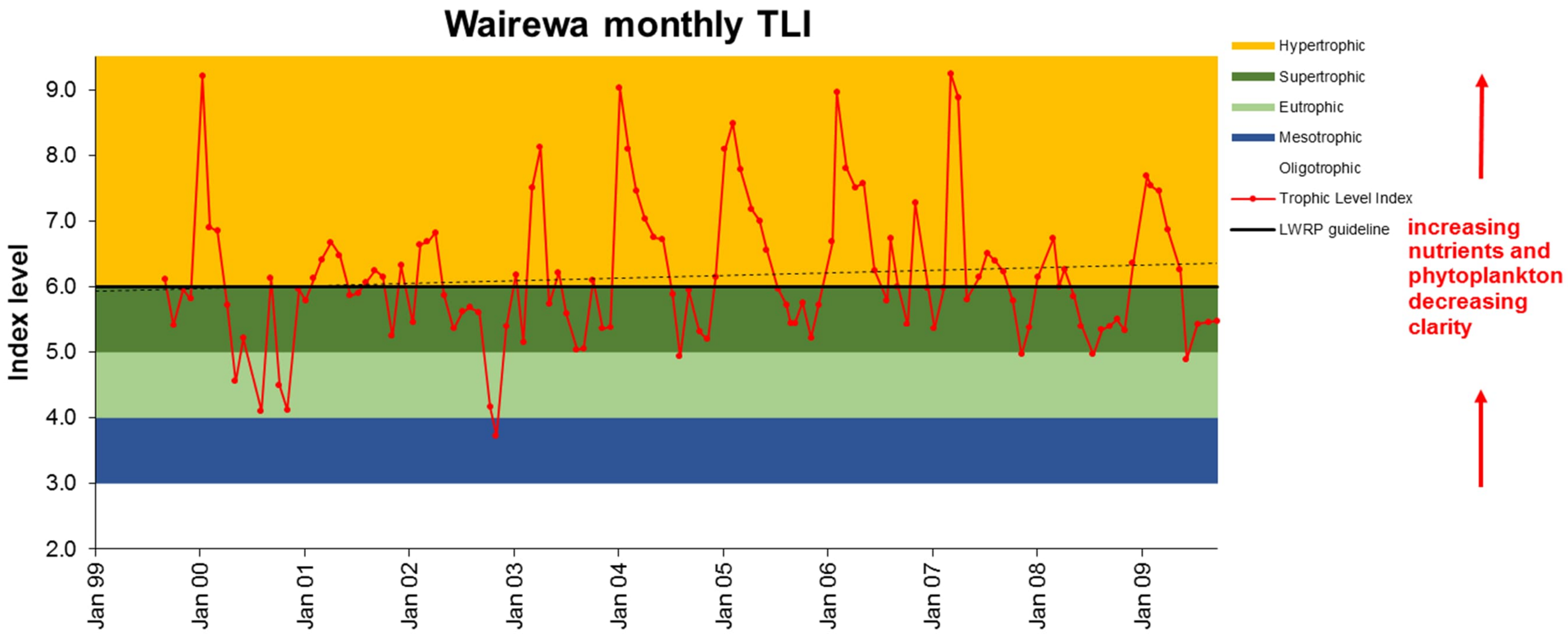

Figure 8b. Trophic Level Index (TLI) at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site prior to the construction of the canal opening (September 1999 –September 2009). The dashed line is a linear trendline. Solid black line = Land and Water Regional Plan (LWRP) guideline for coastal lakes (6 TLI). Graph modified from ECan versions.

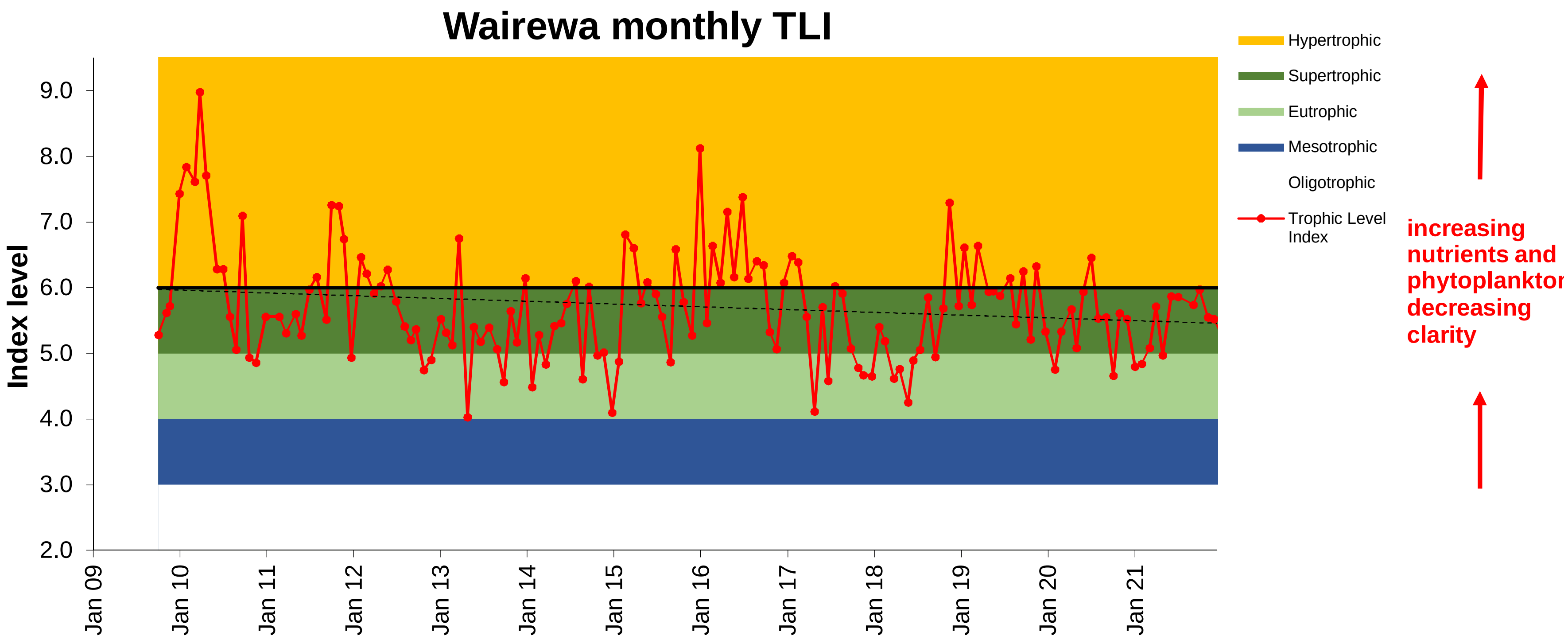

Figure 8c. Trophic Level Index (TLI) at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site after the construction of the canal opening (October 2009– December 2022). The dashed line is a linear trendline. Solid black line = Land and Water Regional Plan (LWRP) guideline for coastal lakes (6 TLI). Graph modified from ECan versions.

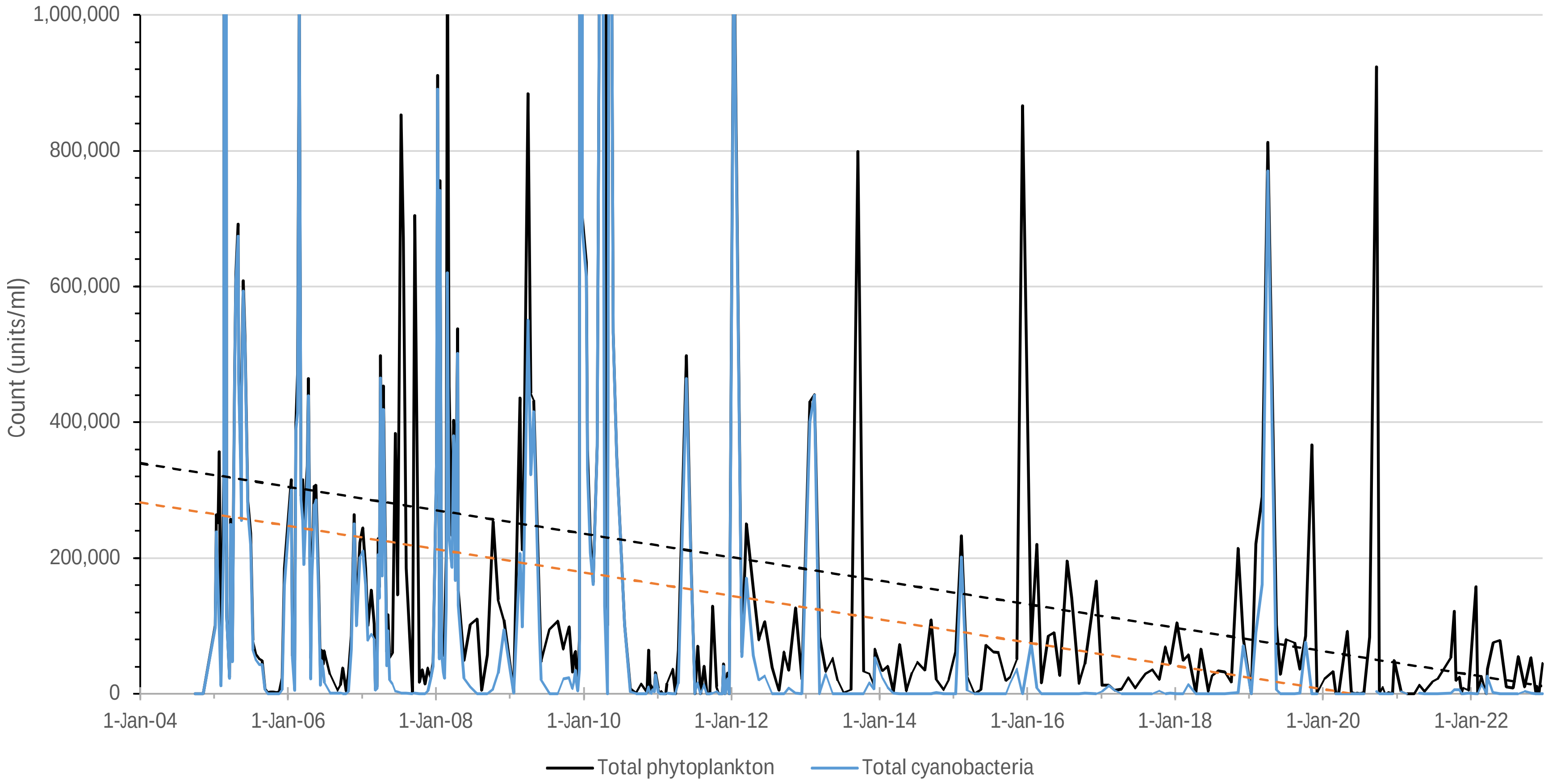

Figure 9. Total phytoplankton and cyanobacteria unit counts at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site from September 2004 to December 2022. The dashed lines are linear trendlines. Due to the large number of records above the y-axis cut-off, concentrations above this value have not been provided.

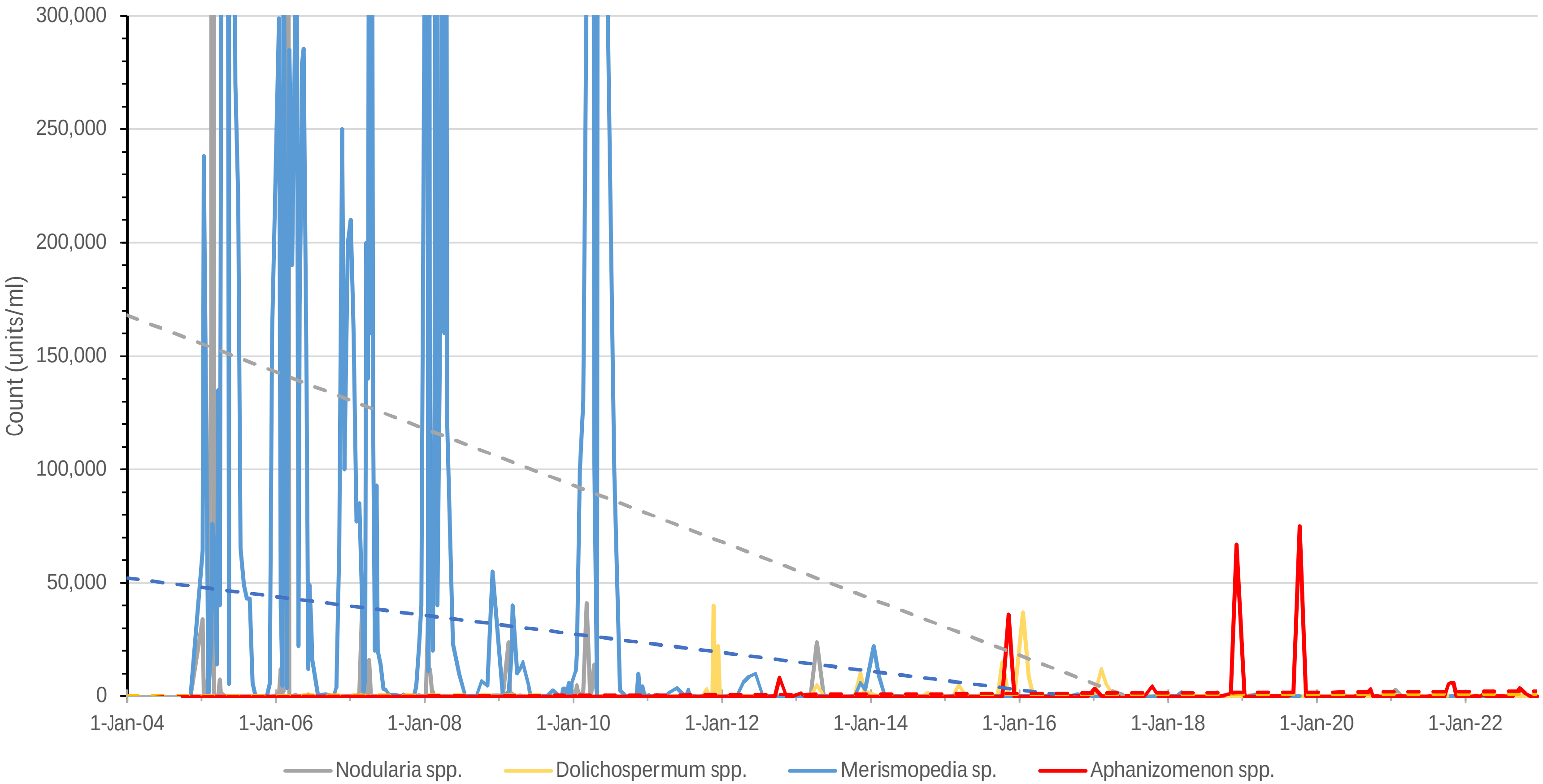

Figure 10. Unit counts at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site for the potentially toxic cyanobacteria *Nodularia* spp., *Dolichospermum* spp., *Merismopedia* spp. and *Aphanizomenon* spp. from September 2004 to December 2022. The dashed lines are linear trendlines. Due to the number of records above the y-axis cut-off, concentrations above this value have not been provided.

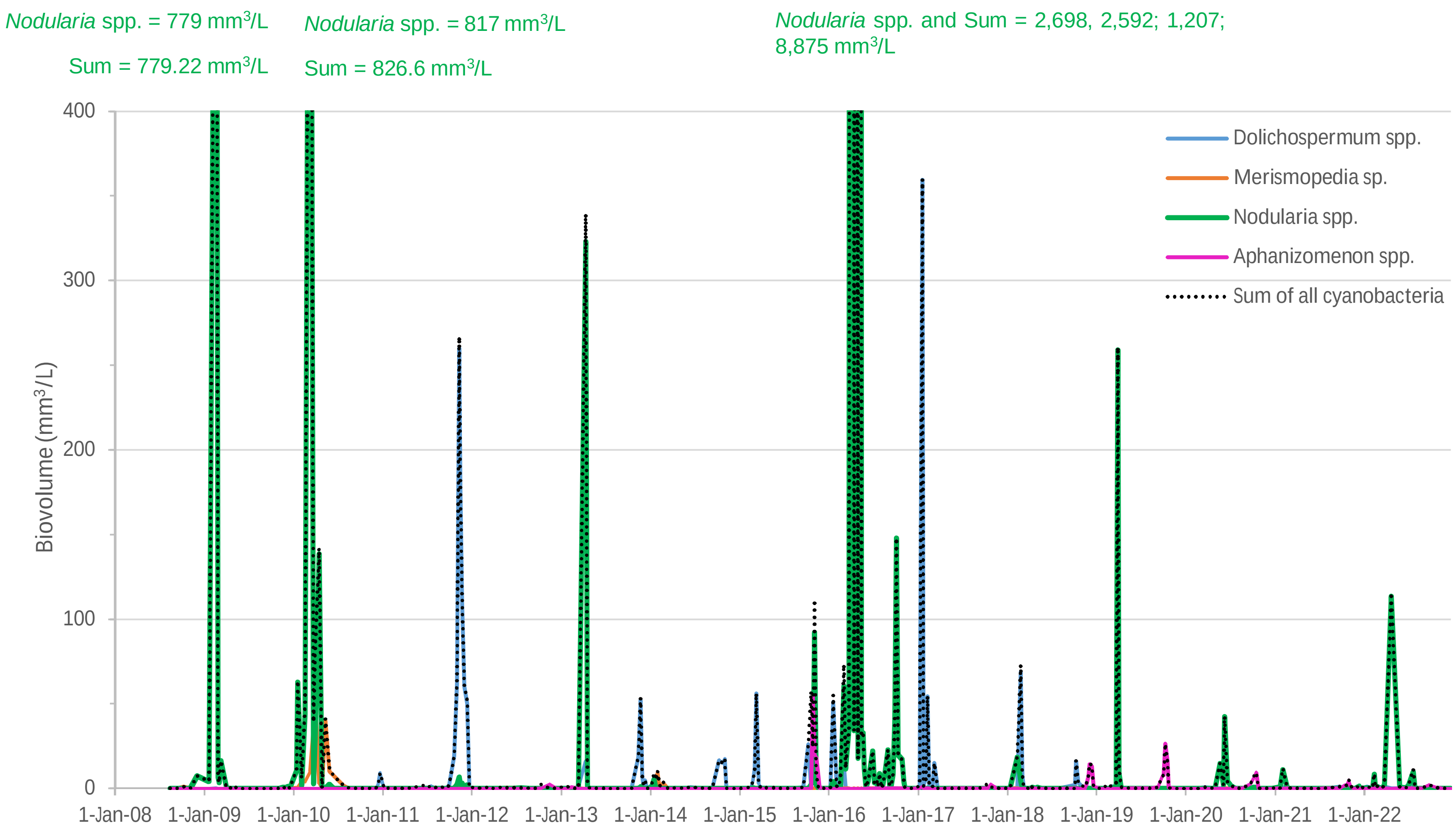

Figure 11. Biovolumes of potentially toxic cyanobacteria *Nodularia* spp., *Dolichospermum* spp., *Merismopedia* spp., *Aphanizomenon* spp. and the sum of all cyanobacteria at Te Roto o Wairewa – Lake Forsyth at the ECan Water Level Recorder site from August 2008 – December 2022. Several data points are significantly higher than the other data points and are therefore off the scale of the graph – the numbers above the graph detail their concentrations.

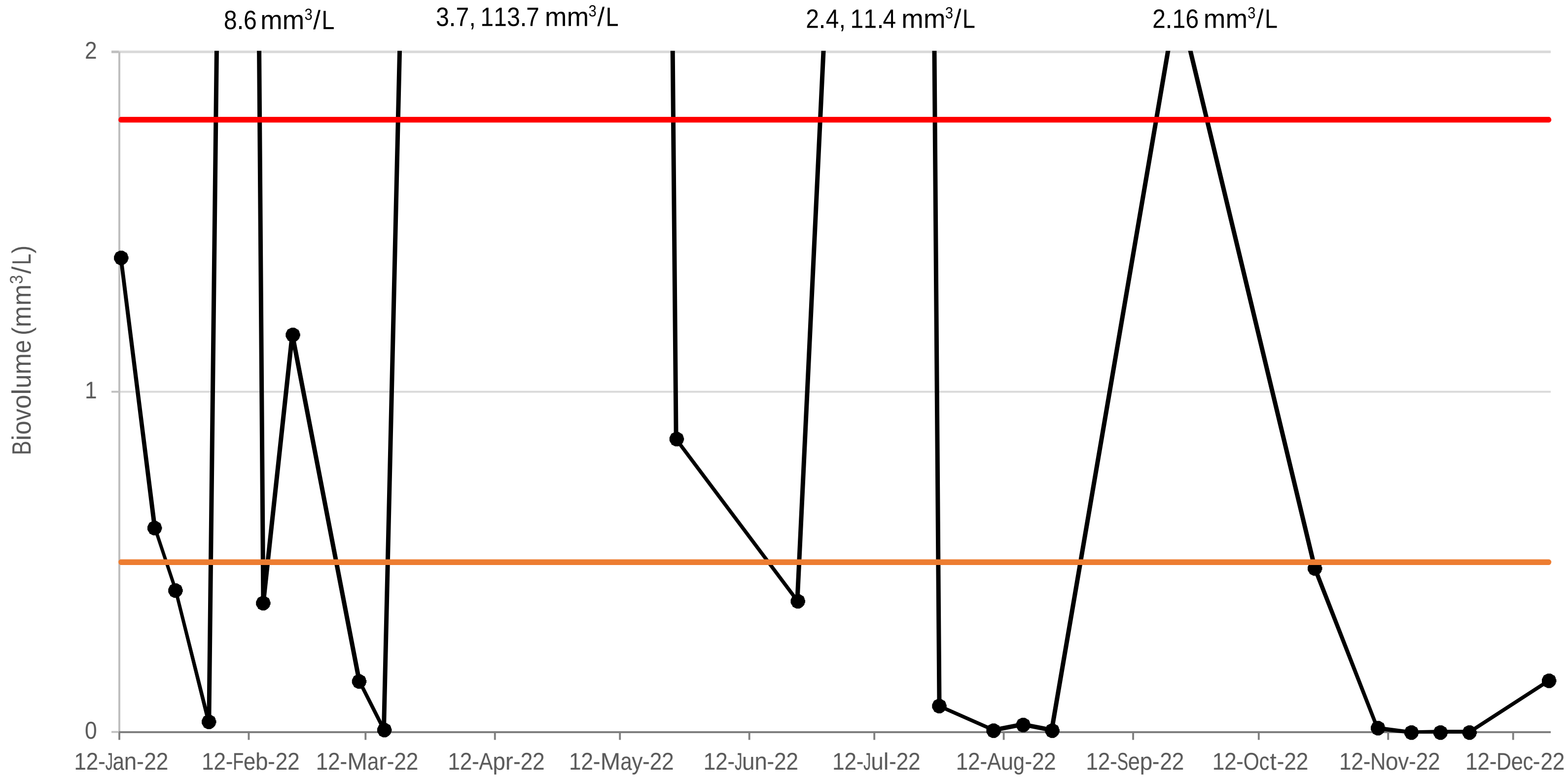

Figure 12a. Biovolume of the sum of all potentially toxic cyanobacteria (*Nodularia* spp., *Dolichospermum* spp., *Merismopedia* spp., and *Aphanizomenon* spp.) at the ECan Water Level Recorder monitoring site in Te Roto o Wairewa – Lake Forsyth in 2022. Orange line = alert guideline level of 0.5 mm^3/L; red line = action guideline level of 1.8 mm^3/L (Ministry for the Environment and Ministry of Health, 2009).

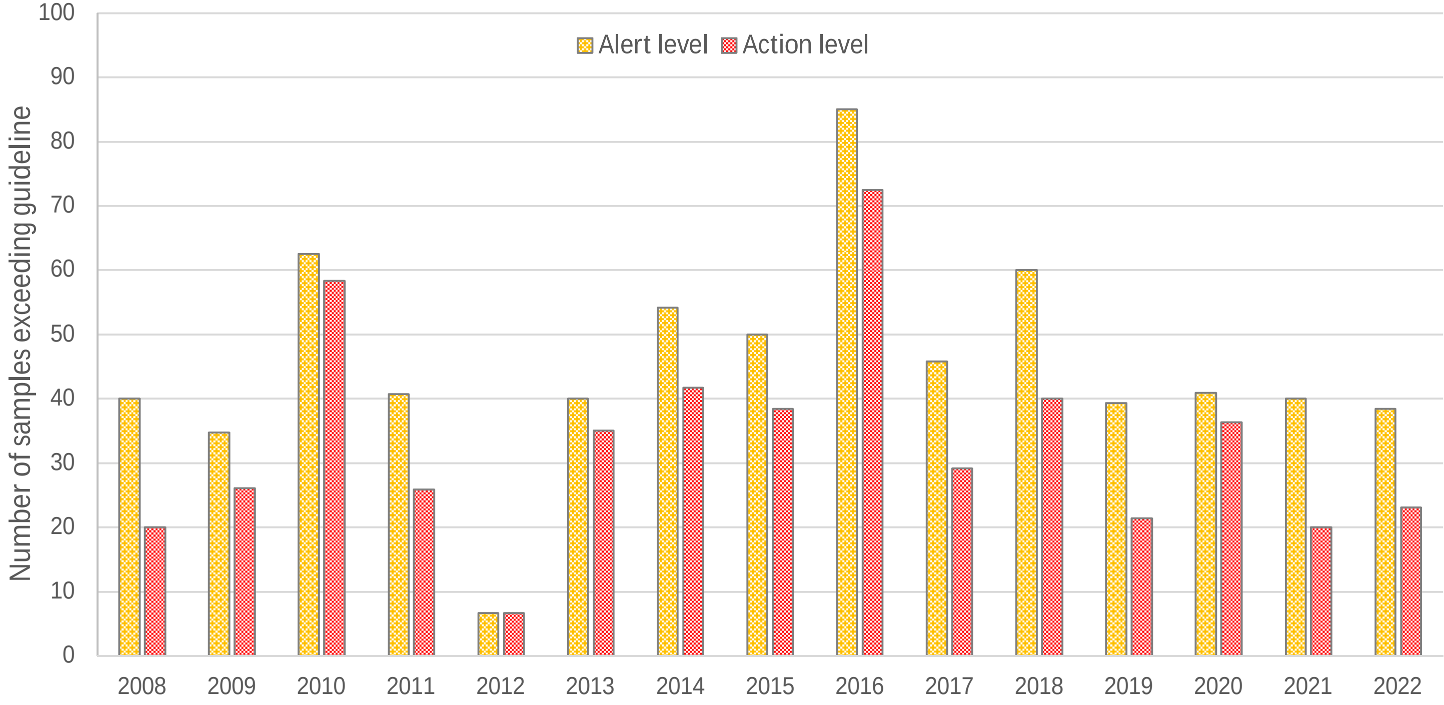

Figure 12b. Number of samples of potentially toxic cyanobacteria (*Nodularia* spp., *Dolichospermum* spp., *Merismopedia* spp., and *Aphanizomenon* spp.) that exceeded either the alert (0.5 mm^3/L) or action (1.8 mm^3/L) level at the ECan Water Level Recorder site in Te Roto o Wairewa – Lake Forsyth from 2008 – 2022 (Ministry for the Environment and Ministry of Health, 2009).

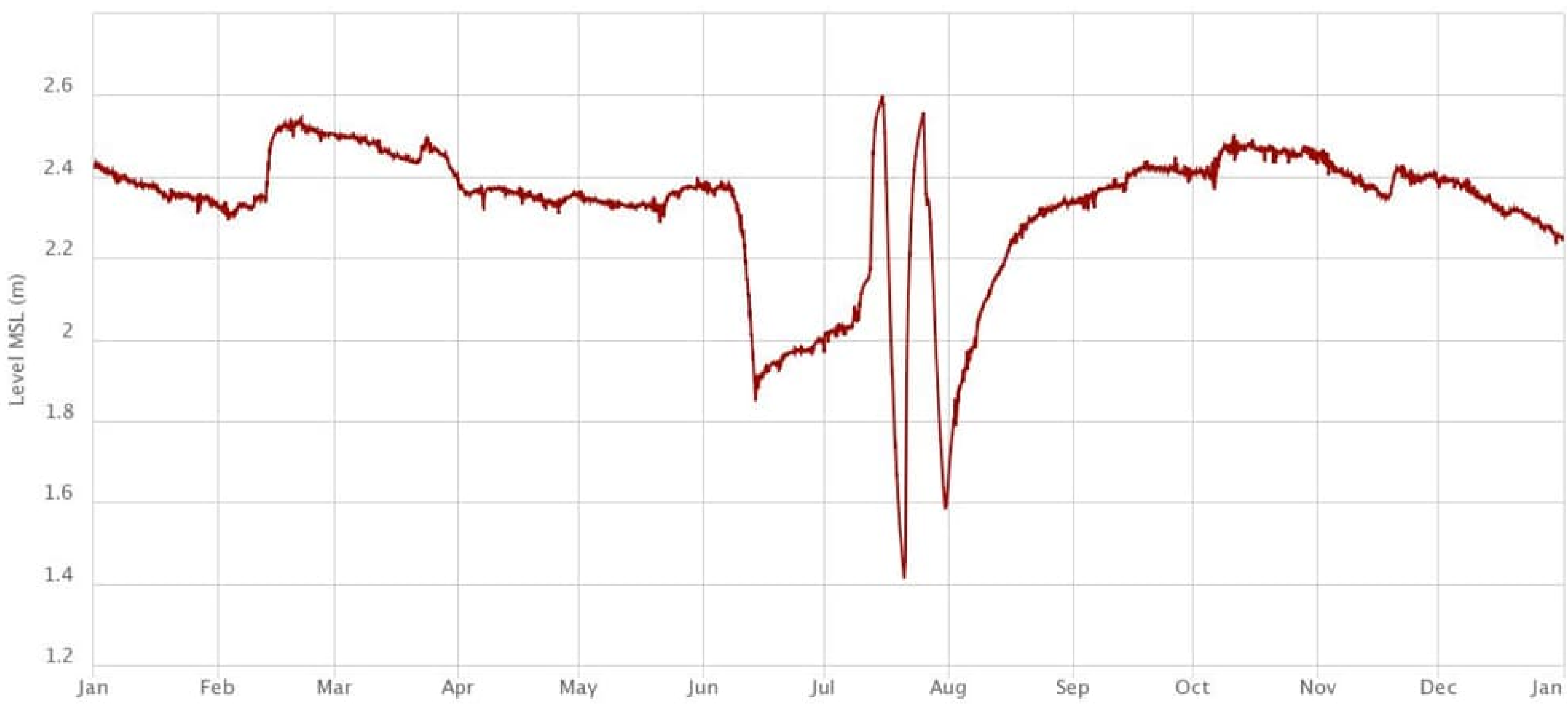

Figure 13. Water level in Te Roto o Wairewa – Lake Forsyth January – December 2022. The sharp drops in water levels indicate when the lake was opened.