greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Lakes Water Quality and Ecology monitoring programme

Annual data report, 2015/16

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Contents

1. Introduction

This report summarises the key results of the Lakes Water Quality and Ecology (LWQE) monitoring in the Wellington Region for the period 1 July 2015 to 30 June 2016 inclusive. The LWQE programme typically involves monthly monitoring of water quality and/or periodic assessments of submerged macrophyte (plant) community structure and composition in selected lakes.

Information on lake water levels during 2015/16 is presented in Harkness (2016).

2. Overview of Lakes Water Quality and Ecology monitoring programme

Greater Wellington Regional Council (GWRC) routinely monitors water quality in two lakes in the Wellington Region, Lake Wairarapa and Lake Onoke. Monitoring in Lake Wairarapa commenced in 1994 and the programme remained largely unchanged until 2012/13 when changes in monitoring frequency and some site locations and variables were implemented (see Cockeram & Perrie 2013 and Cockeram & Perrie 2014). In August 2009, water quality monitoring programmes were established for two additional lakes, Onoke and Waitawa (Figure 2.1). Monitoring of Lake Onoke is ongoing while monitoring of Lake Waitawa is restricted to 12-month periods every five years (initially in 2009/10 and then again in 2014/15).

In 2011 assessments of ecological condition, based on submerged macrophyte community structure and composition, were introduced for Lakes Kohangapiripiri, Kohangatera and Pounui (Figure 2.1). Assessments of macrophytes in all three of these lakes, as well as an inaugural assessment in Lake Waitawa, occurred in early 2016 (with results reported herein).

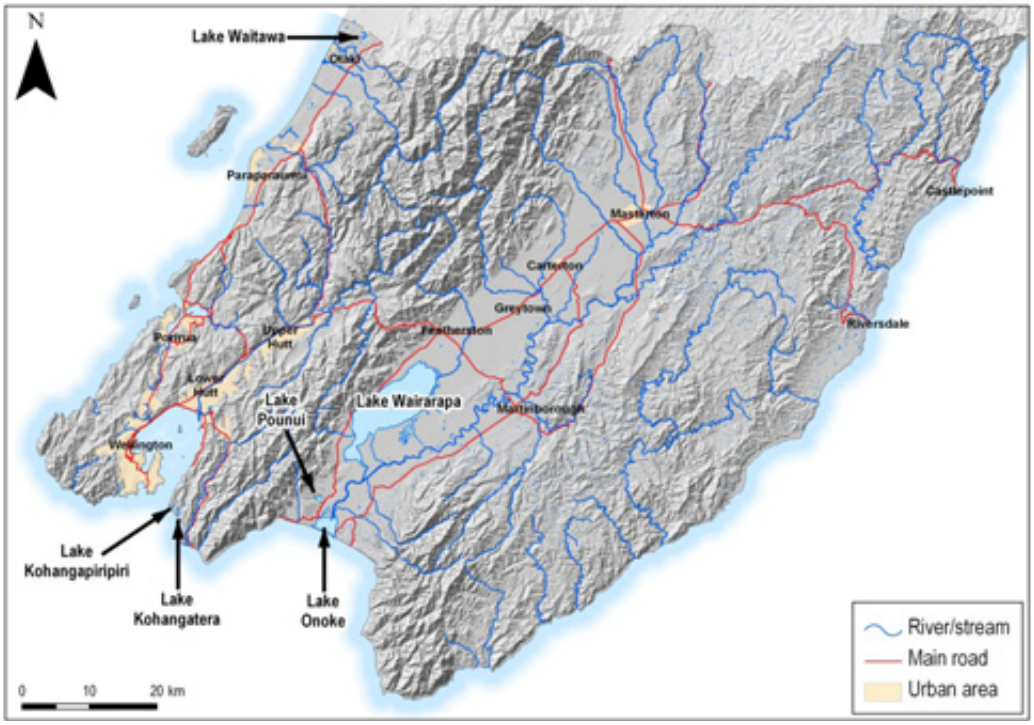

Figure 2.1: Locations of lakes routinely monitored in the Wellington Region

2.1 Monitoring objectives

The aims of GWRC's LWQE monitoring programme are to:

1. Assist in the detection of spatial and temporal changes in the condition of selected lakes;
2. Contribute to our understanding of freshwater biodiversity in the Wellington Region;
3. Determine the suitability of lakes for designated uses;
4. Provide information to assist in targeted investigations where remediation or mitigation of poor water quality or ecosystem health is desired; and
5. Provide information required to determine the effectiveness of regional plans and policies.

2.2 Monitoring sites, variables and protocol

Two types of lake monitoring are undertaken in the Wellington Region:

- Monthly analysis of water samples for a variety of physico-chemical variables (eg, dissolved oxygen, water temperature, pH, conductivity, visual clarity (Secchi depth), turbidity, suspended solids, chlorophyll *a* and dissolved and total nutrients) and monthly assessment of the phytoplankton community (taxa presence, relative abundance and, where potentially toxic cyanobacteria are present, cell counts and potentially cyanotoxin analysis); and

- Periodic assessments of macrophyte community structure and composition – as an indicator of ecological condition – in selected lakes (using the LakeSPI (Submerged Plant Index) methodology). These assessments are typically undertaken every five years.

2.2.1 Monitoring in 2015/16

During 2015/16, monitoring was limited to routine monthly water quality sampling in Lakes Wairarapa and Onoke (and associated sites[1]), and LakeSPI surveys in Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa. No notable changes to the monitoring programme occurred during this period.

Lake locations are shown in Figure 2.1, sampling sites on Lakes Onoke and Wairarapa are shown in Figure 2.2 and site coordinates can be found in Appendix 1. Note that as the monitoring site in Lake Onoke is located where the Ruamahanga River enters the lake, it is unlikely to be representative of water quality across the whole lake (see Perrie & Milne 2012). Further information on LakeSPI transects in each lake assessed is provided in de Winton (2016).

[1] Two monitoring sites were added to the Lake Onoke sampling programme in July 2014. These sites are located upstream of Lake Onoke and were selected to provide further information on the relative effects of the discharges from Lake Wairarapa and the Ruamahanga River on the water quality in Lake Onoke

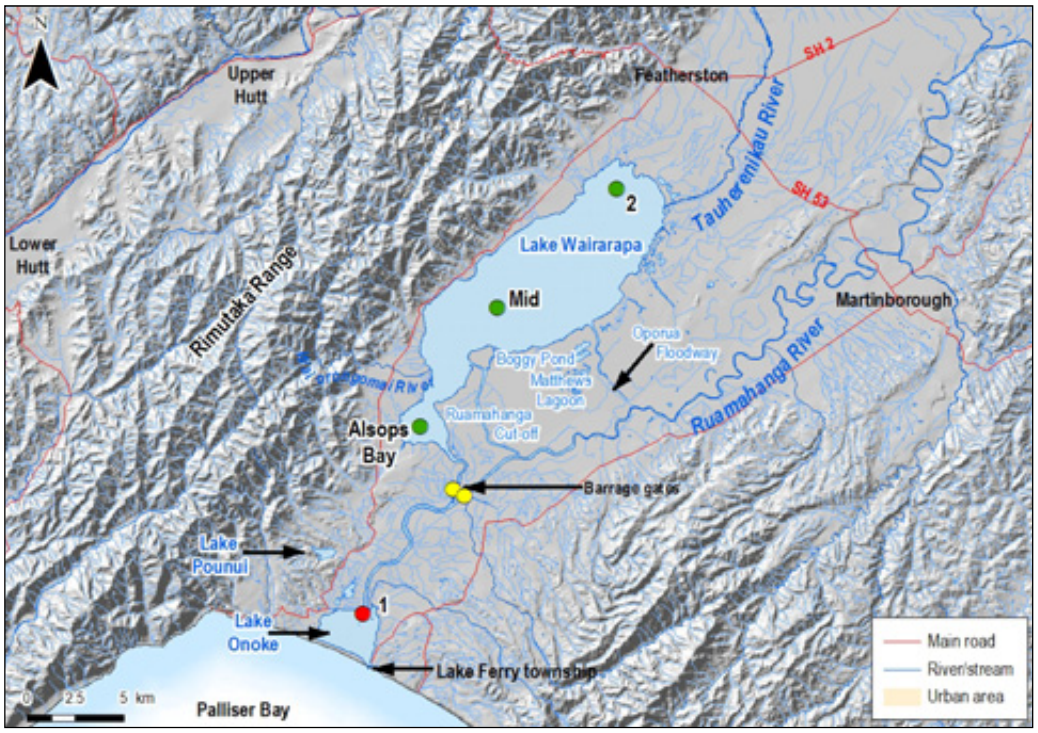

Figure 2.2: Lake Wairarapa and Lake Onoke sites monitored during 2015/16. Green circles = Lake Wairarapa sites, red circles = Lake Onoke main site and yellow circles = sites sampled to help inform the relative effects of the discharges from Lake Wairarapa and the Ruamahanga River on water quality in Lake Onoke.

2.3 Data analysis and reporting

2.3.1 Water quality

Water quality data collected from Lakes Wairarapa and Onoke are summarised and assessed using the trophic level index (TLI). The TLI was developed by Burns et al. (2000) for assessing the water quality status of New Zealand lakes. The TLI is calculated using four key variables of lake water quality (chlorophyll *a*, Secchi depth, total phosphorus and total nitrogen) and is based on the following four regression equations:

1. TLc = 2.22 + 2.54 log(Chlorophyll *a*)
2. $$TLs = 5.10 + 2.27 \log\left(\frac{1}{\text{Secchi depth}} - \frac{1}{40}\right)$$
3. TLp = 0.218 + 2.92 log(Total phosphorus)
4. TLn = -3.61 + 3.01 log(Total nitrogen)

TLI scores are calculated for each individual sampling occasion and then averaged (mean) over the reporting period, although note that this TLI calculation approach differs slightly to that outlined in Burns et al. (2000) and that used in some earlier reporting (eg, Cockeram & Perrie 2013)[2]. Lake water quality is assigned an overall trophic level status according to this mean TLI score (Table 2.1). TLI scores (and hence trophic level status) are calculated and reported for an annual and, where data are available, a three-year (rolling mean) period. For lakes with multiple monitoring sites (Lake Wairarapa), TLI scores are calculated for each individual site and then averaged to provide an overall TLI score for the lake. To aid interpretation, Trophic Level scores and corresponding trophic values for each of the four key variables are also presented. These Trophic Level scores are calculated from the mean value of each variable over the reporting period.

Table 2.1: Classification of lake trophic status using the TLI (after Burns et al. 2000) and nutrient enrichment descriptions described in Burns et al. (1999)

Trophic status (nutrient enrichment)	TLI	Chlorophyll *a* (mg/m^3)	Secchi depth (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
Ultra-microtrophic (practically pure)	0.0–1.0	0.13–0.33	33–25	0.00084–0.0018	0.016–0.034
Microtrophic (very low)	1.0–2.0	0.33–0.82	25–15	0.0018–0.0041	0.034–0.073
Oligotrophic (low)	2.0–3.0	0.82–2.0	15–7.0	0.0041–0.009	0.073–0.157
Mesotrophic (medium)	3.0–4.0	2.0–5.0	7.0–2.8	0.0090–0.0200	0.157–0.337
Eutrophic (high)	4.0–5.0	5.0–12	2.8–1.1	0.0200–0.0430	0.337–0.725
Supertrophic (very high)	5.0–6.0	12–31	1.1–0.4	0.0430–0.0960	0.725–1.558
Hypertrophic (extremely high)	>6.0	>31	<0.4	>0.0960	>1.558

During data processing, any water quality variables reported as less than or greater than detection limits were replaced by values one half of the detection limit or the detection limit respectively (eg, a value of <2 became 1, a value of >400 became 400). The exceptions are minimum and maximum values presented in the tabulated summaries in Sections 3–5 and Appendix 3 (eg, if a value was reported as <2 the minimum value presented is <2).

[2] See Cockeram and Perrie (2014) for a summary of the changes to previous TLI reporting.

2.3.2 Submerged aquatic plant community assessments

Submerged aquatic plant communities are assessed using the nationally accepted LakeSPI (Submerged Plant Index) methodology developed by Clayton and Edwards (2006; refer Appendix 2). Application of the LakeSPI method results in three indices expressed as a percentage of expected pristine state:

- A native condition index (ie, the diversity and quality of the indigenous flora);
- An invasive condition index (ie, the degree of impact by invasive weed species); and
- An overall LakeSPI index that synthesises components of both the native condition and invasive condition indices to provide an overall indication of lake ecological condition.

The LakeSPI index is used to place the lake vegetation into one of five categories of lake condition (Table 2.2; Verburg et al. 2010).

Table 2.2: Classification of lake ecological condition using the LakeSPI index (from Verburg et al. 2010)

Lake ecological condition	LakeSPI index (% of expected pristine state)
Non-vegetated	0
Poor	>0–20
Moderate	>20–50
High	>50–75
Excellent	>75

3. Lake Wairarapa

Water samples were collected from Lake Wairarapa on 12 occasions during 2015/16. However, due to intermittent access to the Alsops Bay site, this site was only sampled on eight occasions[3]. A summary of water quality for each site is presented in Table 3.1.

Trophic level classes based on mean values for each variable, overall TLI scores at each site for the 2015/16 year and a three-year period (July 2013 to June 2016) are presented in Table 3.2. Annual mean TLI scores for each site ranged from 4.8 (eutrophic) to 5.0 (supertrophic) and mean TLI scores for the three-year period were 5.0 (supertrophic) at Alsops Bay and 5.1 (supertrophic) at both Site 2 and at Middle site (Table 3.2). Overall, based on the average (mean) of the three sites assessed over the three-year period, the lake can be classed as supertrophic with a TLI score of 5.1.

[3]The Alsops Bay site cannot be accessed when lake levels are low. This site was not sampled in February, March, April and June of 2016.

Table 3.1: Summary of water quality in Lake Wairarapa at each site, based on 12 sampling occasions (except at Alsops Bay, *n*=8) between July 2015 and June 2016 (D.L. = detection limit)

Variable	Site 2 (*n*=12)					Middle (*n*=12)					Alsops Bay (*n*=8)				
	Mean	Med	Min	Max	% *n* <D.L.	Mean	Med	Min	Max	% *n* <D.L.	Mean	Med	Min	Max	% *n* <D.L.
Water temperature (°C)	14.3	14.0	7.8	21.9	-	14.2	14.2	7.4	21.8	-	12.7	12.1	7.6	19.2	-
Dissolved oxygen (% saturation)	101.3	100.2	86.3	113.4	-	102.2	102.0	87.3	114.6	-	103.9	103.8	85.1	125.9	-
Dissolved oxygen (mg/L)	10.4	10.2	8.7	12.4	-	10.5	10.2	9.0	12.7	-	11.0	11.1	9.6	13.0	-
pH	7.8	7.8	7.4	9.0	-	7.8	7.7	7.0	9.0	-	7.6	7.6	6.8	8.6	-
Conductivity (µS/cm)	816	530	306	2,522	-	921	552	424	2,601	-	1,160	603	461	2,794	-
Secchi depth (m)	0.31	0.24	0.15	0.95	-	0.30	0.24	0.18	0.97	-	0.40	0.35	0.23	0.83	-
Turbidity (NTU)	57.9	63.0	8.7	110	0	54.6	55.5	12.4	93	0	34.3	27.0	12.0	66	0
Total suspended solids (mg/L)	57.5	62.0	5.0	125.0	0	51.7	56.5	4.0	88.0	0	31.0	24.0	9.0	62.0	0
Volatile suspended solids (mg/L)[1]	5.6	6.0	<2.0	11.0	17	4.3	3.0	<2.0	14.0	50	2.4	2.3	<2.0	4.0	50
Total nitrogen (mg/L)	0.553	0.485	0.190	1.210	0	0.462	0.425	0.150	0.920	0	0.516	0.445	0.260	1.040	0
Total Kjeldahl nitrogen (mg/L)	0.397	0.400	0.190	0.570	0	0.337	0.345	0.150	0.520	0	0.285	0.270	0.130	0.400	0
Nitrite-nitrate nitrogen (mg/L)	0.157	0.001	<0.002	0.820	58	0.126	0.002	<0.002	0.580	50	0.231	0.106	<0.002	0.770	38
Ammoniacal nitrogen (mg/L)	0.005	0.005	<0.010	0.005	100	0.005	0.005	<0.010	0.005	100	0.0095	0.005	<0.010	0.035	75
Total phosphorus (mg/L)	0.055	0.059	0.023	0.080	0	0.050	0.042	0.022	0.106	0	0.035	0.030	0.014	0.076	0
Dissolved reactive phosphorus (mg/L)	0.006	0.005	<0.004	0.011	42	0.006	0.005	<0.004	0.010	25	0.004	0.002	<0.004	0.013	75
Chlorophyll *a* (mg/m^3)[1]	14.9	8.5	<3.0	79.0	33	15.0	5.5	<3.0	111.0	17	11.7	10.5	<3.0	40.0	13
Pheophytin *a* (mg/m^3)[1]	2.7	2.3	<3.0	5.0	92	2.6	2.0	<3.0	5.0	92	2.3	1.5	<3.0	4.5	100
Absorbance at 340 nm (AU/cm)	0.041	0.043	0.008	0.060	0	0.040	0.043	0.007	0.056	0	0.033	0.028	0.017	0.059	0
Absorbance at 440 nm (AU/cm)	0.015	0.016	<0.002	0.024	8	0.015	0.017	<0.002	0.023	8	0.011	0.011	0.003	0.024	0
Absorbance at 780 nm (AU/cm)	0.003	0.004	<0.002	0.008	42	0.003	0.003	<0.002	0.006	17	0.003	0.003	<0.002	0.005	38

[1] The detection limits for chlorophyll *a*, pheophytin *a* and volatile suspended solids (see Appendix 2) could not always be achieved by the laboratory.

Table 3.2: Trophic level values for each of the four TLI variables as well as an overall mean TLI score for Lake Wairarapa, based on both July 2015 to June 2016 and the three-year period July 2013 to June 2016 (note variable *n* between sites). Trophic level classes are provided in brackets

Site 2		
	Annual mean (*n*=12)	**Three-year mean (*n*=33)**
Chlorophyll *a*	4.5 (eutrophic)	4.0 (eutrophic)
Secchi depth	6.4 (hypertrophic)	6.6 (hypertrophic)
Total phosphorus	5.2 (supertrophic)	5.5 (supertrophic)
Total nitrogen	4.5 (eutrophic)	4.6 (eutrophic)
Overall TLI score	**5.0 (supertrophic)**	**5.1 (supertrophic)**
Middle site		
	Annual mean (*n*=12)	**Three-year mean (*n*=28)**
Chlorophyll *a*	4.3 (eutrophic)	4.2 (eutrophic)
Secchi depth	6.4 (hypertrophic)	6.5 (hypertrophic)
Total phosphorus	5.0 (supertrophic)	5.3 (supertrophic)
Total nitrogen	4.3 (eutrophic)	4.4 (eutrophic)
Overall TLI score	**4.8 (eutrophic)**	**5.1 (supertrophic)**
Alsops Bay		
	Annual mean (*n*=8)	**Three-year mean (*n*=22)**
Chlorophyll *a*	4.4 (eutrophic)	4.0 (eutrophic)
Secchi depth	6.1 (hypertrophic)	6.3 (hypertrophic)
Total phosphorus	4.6 (eutrophic)	5.0 (supertrophic)
Total nitrogen	4.4 (eutrophic)	4.5 (eutrophic)
Overall TLI score	**4.9 (eutrophic)**	**5.0 (supertrophic)**

4. Lake Onoke

Water samples were collected from one site on Lake Onoke on 11 occasions during 2015/16 and the results are summarised in Table 4.1. Trophic level classes based on mean values generated for the three-year period July 2013 to June 2016 ranged from mesotrophic (chlorophyll *a*) to supertrophic (Secchi depth). Overall, based on the three-year assessment, the lake can be classed as eutrophic with a TLI score of 4.5 (Table 4.2). Water quality summaries for the two sites sampled upstream of Lake Onoke are provided in Appendix 3.

Table 4.1: Summary of water quality in Lake Onoke, based on 11 sampling occasions between July 2015 and June 2016 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	13.8	14.0	7.7	20.6	-
Dissolved oxygen (% saturation)	99	101	88	109	-
Dissolved oxygen (mg/L)	10.2	9.6	7.9	12.8	-
pH	7.5	7.3	7.1	8.5	-
Conductivity (µS/cm)	3,788	1,886	144	11,222	-
Secchi depth (m)	0.57	0.54	0.16	>1.00[1]	-
Turbidity (NTU)	20.8	15.3	1.7	76.0	0
Total suspended solids (mg/L)	26.2	14.0	<3.0	111.0	17
Volatile suspended solids (mg/L) [2]	2.3	1.5	<2.0	6.0	92
Total nitrogen (mg/L)	0.422	0.300	<0.3	0.990	17
Total Kjeldahl nitrogen (mg/L)	0.187	0.190	<0.2	0.320	25
Nitrite-nitrate nitrogen (mg/L)	0.217	0.166	0.020	0.740	17
Ammoniacal nitrogen (mg/L)	0.020	0.020	<0.01	0.049	58
Total phosphorus (mg/L)	0.035	0.025	0.008	0.092	0
Dissolved reactive phosphorus (mg/L)	0.011	0.010	<0.004	0.019	17
Chlorophyll *a* (mg/m^3)	6.2	1.5	<3.0	45.0	83
Absorbance at 340 nm (AU/cm)	0.026	0.027	0.005	0.046	0
Absorbance at 440 nm (AU/cm)	0.006	0.006	<0.002	0.015	33
Absorbance at 780 nm (AU/cm)	0.001	0.001	<0.002	0.003	100

[1] On one sampling occasions the Secchi disc was visible on the lake bottom (>1.00).

[2] The typical detection limit for volatile suspended solids could not be achieved by the laboratory on all sampling occasions.

Table 4.2: Trophic level values for each of the four TLI variables as well as an overall TLI score for Lake Onoke based on both July 2015 to June 2016 (*n*=11) and the three-year period July 2013 to June 2016 (*n*=35). Trophic level classes are provided in brackets

Variable	TLI score	
	Annual mean (July 2015 to June 2016, *n*=11)	**Three-year mean (July 2013 to June 2016, *n*=35)**
Chlorophyll *a*	3.2 (mesotrophic)	3.2 (mesotrophic)
Secchi depth	5.8 (supertrophic)	5.8 (supertrophic)
Total phosphorus	4.5 (eutrophic)	4.7 (eutrophic)
Total nitrogen	4.1 (eutrophic)	4.4 (eutrophic)
Overall TLI score	**4.4 (eutrophic)**	**4.5 (eutrophic)**

5. Lake macrophyte (aquatic plant) surveys

Table 5.1 summarises the results from the LakeSPI (Submerged Plant Index) surveys undertaken by NIWA in February 2016 in Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa. The results from these surveys are documented in full in de Winton (2016). Overall LakeSPI scores ranged from 82 in Lake Kohangatera to 10 in Lake Waitawa, which places these lakes in the "excellent" and "poor" ecological condition classes, respectively. LakeSPI scores for both Lake Kohangapiripiri and Lake Pounui placed them in the "moderate" ecological condition class (Table 5.1).

Table 5.1: Summary of LakeSPI results for Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa from surveys undertaken in February 2016 (adapted from de Winton 2016)

Lake	Native condition index (%)	Invasive condition index (%)	Overall LakeSPI index (%)	Lake ecological condition class (LakeSPI rank[1])
Kohangapiripiri	36	61	40	Moderate (119th)
Kohangatera	81	16	82	Excellent (15th)
Pounui	45	65	38	Moderate (126th)
Waitawa	0	90	10	Poor (197th)

[1] Ranks are based on a comparison against 259 lakes that have been assessed across New Zealand using LakeSPI methodology. Ranks are ordered from best to worst (in terms of overall LakeSPI scores).

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Appendix 1: Monitoring sites

Table A1.1 provides site information for Lake Wairarapa and Lake Onoke routine sampling sites. Further information on LakeSPI transects in each lake assessed in 2016 is provided in de Winton (2016).

Table A1.1: Monitoring site information for routine water quality sampling sites

Lake	Site no./name	Monitoring variables[1]	NZTM site coordinates		Lake characteristics
			Easting	Easting	
Wairarapa	2 (stump)	Monthly sampling: typical water quality suite plus phytoplankton (relative abundance)	1791644	5439152	Max depth: ~2.5 m; Lake area: 7,850 ha; Catchment area: 57,245 ha; Landcover: indigenous forest and scrub 43.9%, pasture 54%, urban 0.4% and other 1.7%.
	Middle	Monthly sampling: typical water quality suite	1785607	5433715	
	Alsops Bay	Monthly sampling: typical water quality suite plus occasional phytoplankton	1781568	5427654	
Onoke	1	Monthly sampling: typical water quality suite plus phytoplankton (relative abundance)	1778829	5417842	Max depth: ~5.5 m; Lake area: 622 ha; Catchment area: 341,744 ha; Landcover: indigenous forest and scrub 27.5%, pasture 64%, horticulture 1%, exotic forest 3.7%, urban 0.7% and other 3.1%
	Ruamahanga River at Boat Ramp[2]	Monthly sampling: typical water quality suite	1783984	5423866	
	Lake Wairarapa downstream of Barrage Gates[2]	Monthly sampling: typical water quality suite	1783638	5423977	

[1] The 'typical' water quality suite varies slightly between sites/lakes but for all sites that are sampled regularly (monthly), water samples are, at minimum, analysed for core lake water quality variables (eg, dissolved and total nutrients, chlorophyll *a* and water clarity (Secchi depth).
[2] These sites are located upstream of Lake Onoke and were selected to provide information on the relative effects of the discharges from Lake Wairarapa and the Ruamahanga River on water quality in Lake Onoke.

Appendix 2: Monitoring variables and methods

Physico-chemical water quality (monthly spot measurements)

Lake Wairarapa monitoring sites are accessed by boat and the Lake Onoke monitoring sites (including the two upstream monitoring sites) are accessed by wading from the lake or river edge. Water samples are collected in accordance with the sub-surface grab method for sampling isothermal lakes described in Smith et al. (1989) and in the case of Lake Onoke, a 'grab pole' is used to collect water samples in an effort to minimise the potential effects of re-suspension of lakebed sediments (caused by wading) on the samples. Note that the sub-surface grab method differs from protocols outlined in Burns et al. (2000) for the sampling of isothermal lakes.

Field measurements (conductivity, dissolved oxygen, pH and temperature) are generally taken using a YSI 556 field meter which is calibrated on the day of sampling. Secchi disc measurement methodology is consistent with the procedure outlined in Burns et al. (2000) except that an underwater viewer is not used. Note that all field measurements collected from Lake Onoke (and upstream sites) are made from a 'wading position', although care is taken to minimise any disturbance of lakebed sediments.

Water samples requiring laboratory analysis are stored on ice upon collection and couriered overnight to RJ Hill Laboratories in Hamilton. The variables monitored and current analytical methods are summarised in Table A2.1. All lake water samples collected for dissolved nutrient analysis are filtered in the laboratory.

Table A2.1: Laboratory analytical methods for lake water samples

Variable	Method	Detection limit
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 22nd Ed. 2012	0.05 NTU
Total suspended solids	Filtration using Whatman 934 AH, Advantec GC-50 or 1-2 equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 22nd Ed. 2012	2 mg/L
Volatile suspended solids[1]	Filtration (GF/C, 1.2 µm). Ashing 550°C, 30 min. Gravimetric. APHA 2540 E 22nd Ed. 2012	2 mg/L
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N	0.002 mg/L
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3 - I (modified) 22nd Ed. 2012	0.002 mg/L
Nitrate-N + Nitrite-N (NNN)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3 - I (modified) 22nd Ed. 2012	0.002 mg/L
Ammoniacal nitrogen	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4+-N + NH_3-N) APHA 4500-NH_3 F (modified from manual analysis) 22nd Ed. 2012	0.01 mg/L
Total Kjeldahl nitrogen	Kjeldahl digestion, phenol/hyperclorite colorimetry (Discrete Analysis). APHA 4500-N Org C. (modified) 4500- F (modified) 22nd Ed. 2012	0.1 mg/L
Total nitrogen	Calculation: TKN + Nitrate-N +Nitrite-N	0.1 mg/L
Dissolved reactive phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22nd Ed. 2012	0.004 mg/L
Total phosphorus	Total Phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22nd Ed. 2012	0.004 mg/L
Chlorophyll *a* (mg/m^3) [1]	Acetone extraction. Spectroscopy. APHA 10200 H (modified) 22nd Ed. 2012	0.003 mg/L
Pheophytin *a* (mg/m^3) [1]	Acetone extraction. Spectroscopy. APHA 10200 H (modified) 22nd Ed. 2012	0.003 mg/L
Absorbance at 340 nm	Filtered sample. Spectrophotometry, 1cm cell. APHA 5910 B 22nd Ed. 2012	0.002 AU/cm
Absorbance at 440 nm	Filtered sample. Spectrophotometry, 1cm cell. APHA 5910 B 22nd Ed. 2012	0.002 AU/cm
Absorbance at 740 nm	Filtered sample. Spectrophotometry, 1cm cell. APHA 5910 B 22nd Ed. 2012	0.002 AU/cm
Faecal coliforms	APHA 9222D 22nd Ed. 2012	1 cfu/100mL
E. coli	APHA 9222G 22nd Ed. 2012	1 cfu/100mL

[1] Note the detection limit for these variables is not always achieved (ie, is often higher than indicated here).

Submerged aquatic plants

Surveys of submerged aquatic plants follow the nationally accepted LakeSPI (Submerged Plant Index) methodology developed by Clayton and Edwards (2006). This involves scuba divers assessing 11 metrics over a 2 m wide transect from the shore to the deepest vegetation limit at several sites which are representative of the lake. Metrics include measures of diversity, the presence of key plant communities, the depth of vegetation growth, and the extent that invasive weeds are represented.

Appendix 3: Water quality data from sites located upstream of Lake Onoke

Tables A3.1 and A3.2 summarise monthly water quality data collected from two sites located upstream of Lake Onoke during 2015/16. These sites, Lake Wairarapa downstream of Barrage Gates and Ruamahanga River at Boat Ramp, were selected to provide information on the relative effects of the discharges from Lake Wairarapa and the Ruamahanga River (respectively) on water quality in Lake Onoke.

Table A3.1: Summary of water quality for Lake Wairarapa downstream of Barrage Gates, based on 11 sampling occasions between July 2015 and June 2016 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	13.7	14.2	7.1	21.0	-
Dissolved oxygen (% saturation)	96	98	80	110	-
Dissolved oxygen (mg/L)	9.8	9.7	5.3	12.3	-
pH	7.4	7.2	7.0	8.3	-
Conductivity (µS/cm)	1,755	1,155	171	7,495	-
Secchi depth (m)	0.52	0.47	0.13	1.07[1]	-
Turbidity (NTU)	44.1	22.0	0.9	178.0	0
Total suspended solids (mg/L)	61.8	19.0	<2.0	350.0	9
Volatile suspended solids (mg/L)	4.5	1.0	<2.0	23.0	55
Total nitrogen (mg/L)	0.532	0.540	0.120	1.100	0
Total Kjeldahl nitrogen (mg/L)	0.295	0.220	<0.1	0.700	9
Nitrite nitrogen (mg/L)	0.002	0.001	<0.002	0.005	64
Nitrate nitrogen (mg/L)	0.232	0.058	<0.002	0.880	18
Nitrite-nitrate nitrogen (mg/L)	0.232	0.059	<0.002	0.880	18
Ammoniacal nitrogen (mg/L)	0.012	0.005	<0.010	0.036	64
Total phosphorus (mg/L)	0.060	0.032	0.007	0.290	0
Dissolved reactive phosphorus (mg/L)	0.007	0.006	<0.004	0.016	27
Chlorophyll *a* (mg/m^3)	5.9	4.0	<3.0	14.0	36

[1] On three sampling occasions the Secchi disc was visible on the bottom.

Table A3.2: Summary of water quality for Ruamahanga River at Boat Ramp, based on 11 sampling occasions between July 2015 and June 2016 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	13.5	14.4	7.3	21.0	-
Dissolved oxygen (% saturation)	98	99	83	109	-
Dissolved oxygen (mg/L)	10.2	9.9	8.2	12.5	-
pH	7.2	7.1	6.6	7.8	-
Conductivity (µS/cm)	172	125	56	572	-
Secchi depth (m)	0.74	0.84	0.16	1.03[1]	-
Turbidity (NTU)	15.8	7.1	1.1	85.0	0
Total suspended solids (mg/L)	25.6	6.0	<2.0	197.0	18
Volatile suspended solids (mg/L)	1.8	1.0	<2.0	8.0	73
Total nitrogen (mg/L)	0.460	0.420	0.160	0.740	0
Total Kjeldahl nitrogen (mg/L)	0.169	0.170	<0.1	0.270	9
Nitrite nitrogen (mg/L)	0.002	0.001	<0.002	0.005	55
Nitrate nitrogen (mg/L)	0.286	0.230	0.059	0.560	0
Nitrite-nitrate nitrogen (mg/L)	0.287	0.230	0.060	0.560	0
Ammoniacal nitrogen (mg/L)	0.022	0.022	<0.010	0.043	18
Total phosphorus (mg/L)	0.035	0.026	0.010	0.132	0
Dissolved reactive phosphorus (mg/L)	0.013	0.013	0.006	0.022	0
Chlorophyll *a* (mg/m^3) [2]	1.6	1.5	<3.0	2.5	100

[1] On four sampling occasions the Secchi disc was visible on the bottom.

[2] The typical detection limit for chlorophyll *a* could not be achieved by the laboratory on all sampling occasions.