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REGIONAL COUNCIL
Te Pane Matua Taiao

Lakes State of the Environment Monitoring programme

Annual data report, 2013/14

B Cockeram
A Perrie

Environmental Science Department

For more information, contact the Greater Wellington Regional Council:

Wellington
PO Box 11646

T 04 830 4021
F 04 385 6960
www.gw.govt.nz

Masterton
PO Box 41

T 04 830 4021
F 06 378 2146
www.gw.govt.nz

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www.gw.govt.nz
info@gw.govt.nz

Report prepared by:	B Cockeram A Perrie	Senior Environmental Monitoring Officer Environmental Scientist	
Report reviewed by:	J R Milne	Team Leader, Aquatic Ecosystems & Quality	
Report approved for release by:	G Sevicke-Jones	Manager, Environmental Science	 **Date**: December 2014

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Contents

1. Introduction

This report summarises the key results of Lakes State of the Environment (LSoE) monitoring in the Wellington region for the period 1 July 2013 to 30 June 2014 inclusive. The LSoE programme involves monthly monitoring of water quality on two lakes and periodic assessments of submerged plant community structure and composition in additional lakes.

Information on lake water levels during 2013/14 is presented in Harkness (2014).

2. Overview of Lakes SoE 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 June 2012 when changes in monitoring frequency and some site locations and variables were implemented (see Cockeram & Perrie 2013). 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 was restricted to an initial year-long investigation (see Perrie & Milne 2012) and is due to be re-assessed in 2014/15.

In 2011 assessments of ecological condition, based on submerged plant community structure and composition, were introduced for Lakes Kohangapiripiri, Kohangatera and Pounui (Figure 2.1). Lake Kohangatera vegetation was assessed again in 2013 (see de Winton 2013 and Cockeram & Perrie 2013) and vegetation in all three lakes is scheduled to be re-assessed in early 2016.

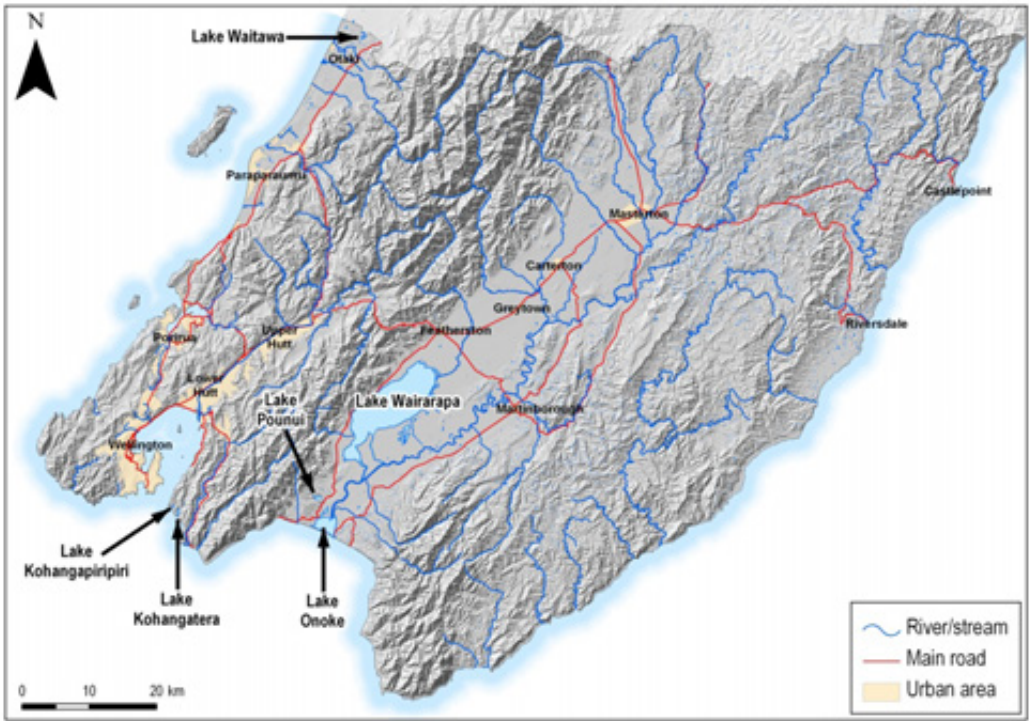

Figure 2.1: Locations of lakes monitored in the Wellington region to date

2.1 Monitoring objectives

The aims of GWRC's Lakes SoE 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 surface water samples for a variety of physico-chemical variables (eg, total and dissolved nutrients, dissolved oxygen, Secchi depth, etc.) in Lake Wairarapa and Lake Onoke; and
- Periodic assessments of macrophyte community structure and composition (as an indicator of ecological condition) in lakes that support submerged aquatic plant communities (eg, Lake Kohangatera).

2.2.1 Physico-chemical water quality monitoring

Water quality is assessed monthly at three sites on Lake Wairarapa and at one site on Lake Onoke (Figure 2.2, Appendix 1) by measuring a range of physico-chemical variables: dissolved oxygen, water temperature, pH, conductivity, visual clarity (Secchi depth), turbidity, suspended solids, chlorophyll *a* and dissolved and total nutrients. The full list of variables monitored, together with details of field and analytical methods, is provided in Appendix 2.

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).

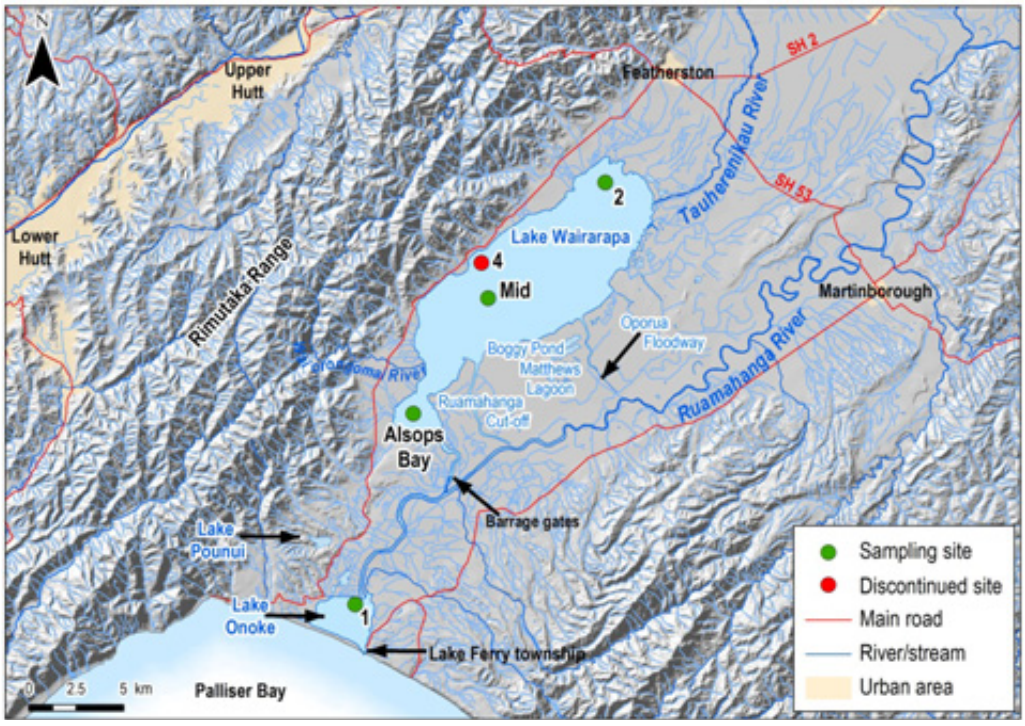

Figure 2.2: Lake Wairarapa and Lake Onoke sites monitored over 2013/14

(a) Changes to the monitoring programme in 2013/14

As a result of recommendations from a 'shallow lake expert panel workshop' held in late 2013 (see Milne et al. 2014 for details), the following programme changes were implemented in January 2014:

- Monitoring of site 4 on Lake Wairarapa was discontinued and a new monitoring site located more centrally in the lake ('Lake Wairarapa Middle site'; see Figure 2.2) was added. It was considered that this new site would be more representative of the lake when compared to site 4 which was located relatively close to the western shore of the lake.

- Nitrite-nitrogen (nitrite) was dropped from the suite of variables monitored (for both Lake Onoke and Lake Wairarapa); nitrite concentrations are consistently low in both lakes and comprise a very minor proportion of the soluble inorganic nitrogen component present.

(b) Data analysis and reporting

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

Lake water quality is then assigned an overall trophic level status according to the mean score of these four TLI variables (Table 2.1) (see Burns et al. 2000 for full details).

Based on recommendations from a shallow lake expert panel workshop (see Milne et al. 2014), changes in how TLI scores are calculated and reported (cf. earlier reports, eg, Cockeram & Perrie 2013) have been implemented from July 2014 (Table 2.2).

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, 4 and Appendix 3 (eg, if a value was reported as <2 the minimum value presented is <2).

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

Table 2.2: Summary of TLI calculation and reporting changes

TLI	Previous reporting (eg, Cockeram & Perrie 2013)	New reporting
Reporting period and statistic	12-monthly mean	Three-year rolling mean
Calculation method	TLI score calculated based on the means of the four TLI variables over the reporting period Data pooled across sites	TLI score calculated for each individual sampling occasion and then averaged (mean) over the reporting period Scores determined for individual sites

2.2.2 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). The first LakeSPI surveys were carried out in autumn 2011 and are intended to be repeated at five-yearly intervals except where more frequent surveys are warranted.

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 2.3; Verburg et al. 2010).

Table 2.3: 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

No LakeSPI surveys were undertaken in 2013/14.

3. Lake Wairarapa

Water samples were collected from Lake Wairarapa on nine occasions[1] during 2013/14. However, due to monitoring site changes and the intermittent access to the Alsops Bay site, only site 2 was sampled on every one of these occasions[2]. A summary of water quality for this site is presented in Table 3.1 (summary statistics for the other sites are provided in Appendix 3).

Trophic level classes based on the mean TL value generated for the two-year period available (July 2012 to June 2014) ranged from eutrophic (chlorophyll *a* and total nitrogen) to hypertrophic (Secchi depth). Overall, based on the two-year period assessed[3], the lake can be classed as supertrophic with a TLI score of 5.2 (Table 3.2).

Table 3.1: Summary of water quality in Lake Wairarapa, based on nine sampling occasions at site 2 between July 2013 and June 2014 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	15.4	15.7	8.0	20.6	0
Dissolved oxygen (% saturation)	102	100	95	115	0
Dissolved oxygen (mg/L)	10.2	10.3	8.8	12.4	0
pH	7.3	7.4	6.1	7.9	0
Conductivity (µS/cm)	277	249	139	536	0
Secchi depth (m)[1]	0.19	0.19	0.08	0.30	0
Turbidity (NTU)	133	106	42.0	320	0
Total suspended solids (mg/L)	127	99	38	300	0
Volatile suspended solids (mg/L)	10.4	10.0	3.0	22.0	22
Total nitrogen (mg/L)	0.779	0.610	0.290	1.580	0
Total Kjeldahl nitrogen (mg/L)	0.539	0.490	0.290	0.790	0
Nitrite-nitrate nitrogen (mg/L)	0.239	0.004	<0.002	0.830	33
Ammoniacal nitrogen (mg/L)	0.015	0.005	<0.010	0.062	67
Total phosphorus (mg/L)	0.135	0.091	0.054	0.340	0
Dissolved reactive phosphorus (mg/L)	0.010	0.009	<0.004	0.020	33
Chlorophyll *a* (mg/m^3)	6.6	7.0	<3.0[2]	14	44
Pheophytin *a* (mg/m^3)	8.2	3.5	<3.0	36	89
Absorbance at 340 nm (AU/cm)	0.086	0.082	0.057	0.133	0
Absorbance at 440 nm (AU/cm)	0.033	0.029	0.018	0.055	0
Absorbance at 740 nm (AU/cm)	0.008	0.008	<0.002	0.014	11

[1] On one sampling occasion Secchi depth was not recorded so summary statistics presented are based on *n*=8.
[2] On three occasions the typical detection limit for chlorophyll *a* (<3.0 mg/m^3) could not be achieved by the laboratory. In these cases the detection limits ranged from <5 mg/m^3 to <14 mg/m^3.

[1] Sampling sites on Lake Wairarapa could not be accessed on three occasions (September 2013 and April and June 2014) because strong winds prevented safe access.
[2] Due to site location changes that took effect in January 2014 (refer Section 2.2.1), site 4 was sampled on five occasions and the new Lake Wairarapa middle site was sampled on four occasions. The Alsops Bay site, which cannot be accessed at low lake levels, was sampled on six occasions during 2013/14.
[3] Calculation over a 3-year period (of monthly sampling) as recommended in Section 2.2.1 will not be possible until the end of 2014/15 given changes to the existing sampling frequency and sites only took effect in July 2012 (see Cockeram & Perrie 2013).

Table 3.2: Trophic level values for each of the four TLI variables as well as an overall mean TLI score for both July 2013 to June 2014 (*n*=9) and the two-year period July 2012 to June 2014 (*n*=19). All values are based on data from only site 2. Trophic level classes are also provided in brackets

Variable	TLI score	
	Annual mean (July 2013 to June 2014, *n*=9)	Two-year mean[1] (July 2012 to June 2014, *n*=19)
Total nitrogen	4.9 (eutrophic)	4.5 (eutrophic)
Total phosphorus	6.2 (hypertrophic)	5.7 (supertrophic)
Secchi depth	6.8 (hypertrophic)	6.4 (hypertrophic)
Chlorophyll *a*	4.1 (eutrophic)	4.3 (eutrophic)
Overall TLI score	**5.5 (supertrophic)**	**5.2 (supertrophic)**

[1] Calculation over a rolling 3-year period is recommended – see Section 2.2.1.

4. Lake Onoke

Water quality samples were collected from one site on Lake Onoke on 12 occasions during 2013/14 and the results are summarised in Table 4.1. Trophic level classes based on the mean TL value generated for the three-year period (July 2011 to June 2014) ranged from mesotrophic (chlorophyll *a*) to hypertrophic (Secchi depth). Overall, based on the three-year assessment, the lake can be classed as eutrophic with a TLI score of 4.8 (Table 4.2).

Table 4.1: Summary of water quality in Lake Onoke, based on 12 sampling occasions between July 2013 and June 2014 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	13.2	11.8	8.2	21.0	0
Dissolved oxygen (% saturation)	107	107	91	128	0
Dissolved oxygen (mg/L)	11.0	10.8	9.7	13.5	0
pH[1]	7.3	7.2	6.6	8.0	0
Conductivity (µS/cm)	2,364	1,336	74	7,137	0
Secchi depth (m)	0.45	0.37	0.16	>1.12[2]	0
Turbidity (NTU)	58.1	27.5	3.5	146	0
Total suspended solids (mg/L)	70	32	3	200	0
Volatile suspended solids (mg/L)	4.6	1.8	<2.0	13	50
Total nitrogen (mg/L)	0.689	0.550	0.220	1.340	0
Total Kjeldahl nitrogen (mg/L)	0.311	0.255	<0.200	0.580	8
Nitrite-nitrate nitrogen (mg/L)	0.373	0.330	<0.200	0.860	8
Ammoniacal nitrogen (mg/L)	0.011	0.005	<0.010	0.025	58
Total phosphorus (mg/L)	0.072	0.046	0.013	0.184	0
Dissolved reactive phosphorus (mg/L)	0.012	0.013	<0.004	0.020	17
Chlorophyll *a* (mg/m^3)[3]	3.8	2.3	<3.0	10.0	75
Absorbance at 340 nm (AU/cm)	0.048	0.039	0.008	0.106	0
Absorbance at 440 nm (AU/cm)	0.017	0.012	<0.002	0.045	8
Absorbance at 740 nm (AU/cm)	0.004	0.002	<0.002	0.011	50

[1] On two sampling occasions pH was measured in water samples sent to the laboratory.

[2] On one sampling occasion the Secchi disc was visible on the lake bottom (>1.12 m).

[3] On three occasions the typical detection limit for chlorophyll *a* (<3.0 mg/m^3) could not be achieved by the laboratory. In these cases the detection limits ranged from <6mg/m^3 to <15 mg/m^3.

Table 4.2: Trophic level values for each of the four TLI variables as well as an overall TLI score for both July 2013 to June 2014 (*n*=12) and the three-year period July 2011 to June 2014 (*n*=36). Trophic level classes are provided in brackets

Variable	TLI score	
	Annual mean (July 2013 to June 2014, *n*=12)	Three-year mean (July 2011 to June 2014, *n*=36)
Total nitrogen	4.8 (eutrophic)	4.6 (eutrophic)
Total phosphorus	5.2 (supertrophic)	5.1 (supertrophic)
Secchi depth	6.1 (hypertrophic)	6.0 (hypertrophic)
Chlorophyll *a*	3.4 (mesotrophic)	3.5 (mesotrophic)
Overall TLI score	**4.9 (eutrophic)**	**4.8 (eutrophic)**

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Juliet Milne reviewed a draft version of this report.

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Appendix 1: Lake SoE water quality monitoring sites

Lake	Site no./name	NZTM site coordinates	
		Easting	Northing
Lake Wairarapa	2 (stump)	1791644	5439152
	4 (west)	1785175	5435526
	Middle	1785607	5433715
	Alsops Bay	1781568	5427654
Lake Onoke	1	1778829	5417842

Appendix 2: Monitoring variables and methods

Physico-chemical water quality

All monitoring sites are accessed by boat, except in the case of Lake Onoke, where sampling is carried out by wading from the lake's 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 'grabber 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 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 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*	Filtration (GF/C, 1.2 µm). Ashing 550°C, 30 min. Gravimetric. APHA 2540 E 22nd Ed. 2012	2 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
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) 21st Ed. 2005	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
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)**	Acetone extraction. Spectroscopy. APHA 10200 H (modified) 22nd Ed. 2012	0.003 mg/L
Pheophytin *a* (mg/m^3)**	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

* These variables were dropped from the monitoring programme in January 2014.

** 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 from the presence of key of plant communities, the depth of vegetation growth, and the extent that invasive weeds are represented.

Appendix 3: Additional Lake Wairarapa water quality monitoring data

Table A3.1: Water quality summary statistics for Lake Wairarapa monitoring sites sampled between July 2013 and June 2014 and not presented in Table 3.1 (D.L. = detection limit)

Variable	Site 4 (*n*=5)					Middle (*n*=4)					Alsops Bay (*n*=6)				
	Mean	Median	Minimum	Maximum	%*n* <D.L.	Mean	Median	Minimum	Maximum	%*n* <D.L.	Mean	Median	Minimum	Maximum	%*n* <D.L.
Water temperature (°C)	14.0	13.6	7.7	20.2	0	16.9	17.1	13.0	20.3	0	14.5	14.5	7.7	20.2	0
Dissolved oxygen (% saturation)	102	103	94	110	0	102	102	102	103	0	100	99	94	110	0
Dissolved oxygen (mg/L)	10.5	10.1	9.1	13.1	0	9.8	9.6	9.2	10.7	0	10.3	9.8	9.0	13.2	0
pH	7.2	7.2	6.8	7.4	0	7.6	7.6	7.3	8.0	0	7.2	7.2	6.7	7.8	0
Conductivity (µS/cm)	264	216	155	440	0	347	280	152	676	0	482	405	202	964	0
Secchi depth (m)	0.32	0.19	0.13	0.90	0	0.17	0.19	0.08	0.23	0	0.18	0.18	0.08	0.29	0
Turbidity (NTU)	142.6	134.0	67.0	240	0	181	148	57	370	0	122.8	93.0	57.0	250	0
Total suspended solids (mg/L)	141.4	127.0	61.0	270	0	187	151	56	390	0	121.0	95.5	43.0	250	0
Volatile suspended solids (mg/L)	6.4	3.5	<5	18.0	80	18.8	18	7	32	0	9.3	7.5	5.0	17.0	17
Nitrite-nitrate nitrogen (mg/L)	0.364	0.400	<0.002	0.730	40	0.024	0.024	<0.002	0.045	50	0.276	0.206	<0.002	0.640	33
Ammoniacal nitrogen (mg/L)	0.007	0.016	<0.010	0.016	80	0.022	0.022	<0.010	0.022	75	0.006	0.005	<0.010	0.012	83
Total Kjeldahl nitrogen (mg/L)	0.564	0.600	0.330	0.800	0	0.673	0.670	0.310	1.040	0	0.575	0.555	0.360	0.780	0
Total nitrogen (mg/L)	0.924	1.190	0.330	1.280	0	0.685	0.690	0.310	1.050	0	0.852	0.855	0.360	1.430	0
Dissolved reactive phosphorus (mg/L)	0.012	0.017	<0.004	0.020	40	0.009	0.010	<0.004	0.011	25	0.009	0.008	<0.004	0.018	50
Total phosphorus (mg/L)	0.130	0.105	0.081	0.187	0	0.139	0.073	0.059	0.350	0	0.105	0.101	0.061	0.180	0
Chlorophyll *a* (mg/m^3)	6.1	12	<6	12	80	13	13	<3	18	50	7.2	8.5	7.0*	10	67
Pheophytin *a* (mg/m^3)	9.3	4	<6	28	80	<3	<3	<3	<3	100	<5	<5	<5	<12	100
Absorbance at 340 nm (AU/cm)	0.111	0.113	0.059	0.156	0	0.077	0.072	0.069	0.093	0	0.092	0.087	0.055	0.148	0
Absorbance at 440 nm (AU/cm)	0.045	0.046	0.019	0.070	0	0.031	0.030	0.026	0.039	0	0.037	0.034	0.020	0.065	0
Absorbance at 740 nm (AU/cm)	0.011	0.011	0.004	0.020	0	0.007	0.008	0.004	0.010	0	0.009	0.008	0.005	0.017	0

* A result of <8 mg/m^3 was also recorded on one occasion.