A method for managing the alum dosing of Lake Rotorua

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1 Introduction

Alum dosing of the Utuhina Stream and the Puarenga Stream has become an important method for remediation of Lake Rotorua. In 2012, Lake Rotorua reached its objective quality set as a Trophic Level Index (TLI) of 4.2 in the Bay of Plenty Regional Council's Water & Land Plan.

The occurrence of blue-green algal blooms in Lake Rotorua, the Ohau Channel, the Okere Arm of Lake Rotoiti and the Kaituna River are related to the nutrient status of Lakes Rotorua and Rotoiti. The potential adverse health effects, of blue-green algal blooms in these waters are to some extent manageable by alum dosing of Lake Rotorua and by the effectiveness of the Ohau diversion wall. The proposal to cap the sediments of Lake Rotorua with an alum dose to the hypolimnion was partly based on the objective of lessening blue-green algal blooms in the Okere Arm of Rotoiti and the Kaituna River. This action appears now unnecessary due to the quality objective for Lake Rotorua being met. Because of the apparent effectiveness of the stream dosing, a management system for alum dosing is proposed in this report so that the quality of the lake can be maintained at a level where adverse health effects do not re-occur.

In the first instance it is assumed that if Lake Rotorua meets or betters the Water & Land Plan objective TLI of 4.2, blue-green algal blooms are unlikely to occur. The parameters from which the TLI is derived were proposed by Rutherford *et al* (1989). An average in-lake total phosphorus concentration of 0.020 g/m^3 was proposed (Rutherford *et al* 1989) in conjunction with an average total nitrogen concentration of 0.300 g/m^3, an average chlorophyll *a* concentration of 10 mg/m^3 and an average Secchi disc depth of 2.5 – 3 m. The annual TLI calculation does not provide a sensitive enough mechanism to act as a trigger to control the stream alum dose rate and maintain phosphorus levels in Lake Rotorua on a month to month basis. A mechanism derived around the monthly lake phosphorus concentration could provide a suitable mechanism with the annual TLI acting as a longer term control.

Alum dosing started at the Utuhina Stream site in 2006 and at the Puarenga site in April 2010 and this approximately tripled the alum dose to Rotorua inflows and to the lake as shown in Table 1.

Table 1 Aluminium dose to the Utuhina and Puarenga Streams, Lake Rotorua.

Year	Tonnes aluminium Utuhina Stream	Tonnes aluminium Puarenga Stream	Tonnes aluminium total
2007	23		23
2008	16		16
2009	22		22
2010	19	52	71
2011	29	68	97
2012	6	58	64

2 Monthly phosphorus concentration

Water quality monitoring of Lake Rotorua is carried out at two sites on a monthly basis. In Figures 1, the average monthly total phosphorus concentration for the surface waters of two sites is shown from the beginning of 2004, about three years before alum dosing began.

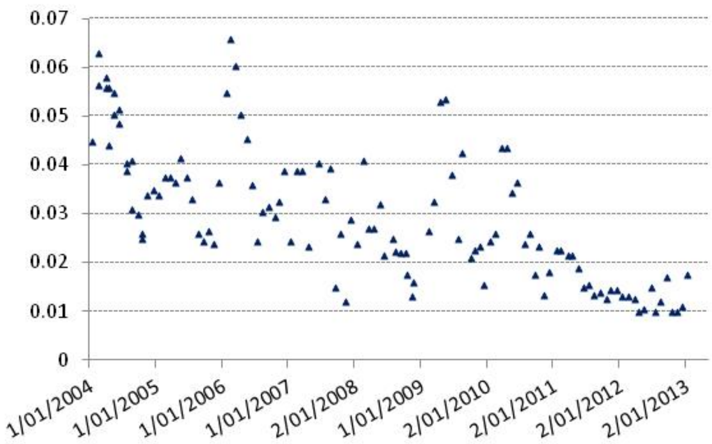

Figure 1 The monthly average total phosphorus concentration (g/m^3) of the surface water from two sites in Lake Rotorua.

In Figure 2 the total phosphorus concentration for the surface water from these two sites are plotted with the raw data, and with the monthly average, a two monthly average and a 3 monthly average.

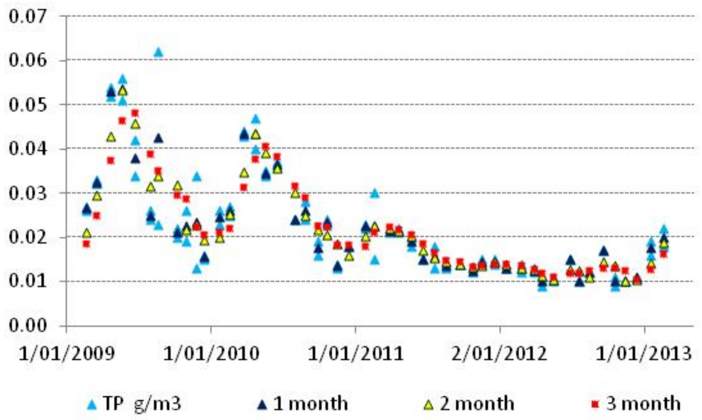

Figure 2 The total phosphorus (g/m^3) data from two sites in Lake Rotorua with the one monthly, two monthly and three monthly averages.

Figure 2 indicates that the response in reduction of the phosphorus load in Lake Rotorua was within an annual period of the Puarenga Stream dosing plant starting. It is suggested that a sensitive trigger to use for adjusting the alum dose could be built on the one, two and three monthly average total phosphorus (TP) concentration of the surface waters of Lake Rotorua.

For every 0.001 g/m^3 increase in total phosphorus in Lake Rotorua, the load of total phosphorus in the lake increases by 800 kg (lake volume = 801690000 m^3). To remove 800 kg of phosphorus, about 4000 kg of Al^{3+} (95238 kg 47% liquid alum or 10.8 L/hr for a year) would be required based on an Al^{3+}:P reaction ratio of 5:1.

The proposed management strategy is that the alum dose is increased by 10 L/hr when the TP concentration in Lake Rotorua surface waters becomes greater than (>) 0.020 g/m^3. When the two monthly average TP becomes > 0.020 g/m^3, the alum dose is increased by a further 10 L/hr and when the three monthly average TP becomes > 0.020 g/m^3, the alum dose is increased by a further 10 L/hr. If all 3 events happened in one month the dose would be increased by 30 L/hr. If the monthly average TP increases, when the 3 monthly average TP > 0.020 g/m^3, the dose rate is increased by a further 10 L/hr.

When the TP of the surface water of Lake Rotorua falls below 0.017 g/m^3, the alum dose should be reduced according to the same plan as above (see Appendix I).

The combined dosing rate for both sites at February 2013 is 100 L/hr (49 t/yr aluminium). Each 10 L/hr increase in the alum dose increases the annual dose by 4.9 t/yr aluminium. Four, monthly increases of 10 L/hr each, would increase the annual dose rate to 69 t/yr aluminium. This is similar to the actual dose rate for 2010 and 2012 when the TP concentration of Lake Rotorua was reduced to a low level.

Figure 3 shows recent TP data, up to February 2013, from the monthly monitoring of Lake Rotorua surface waters with monthly average statistics.

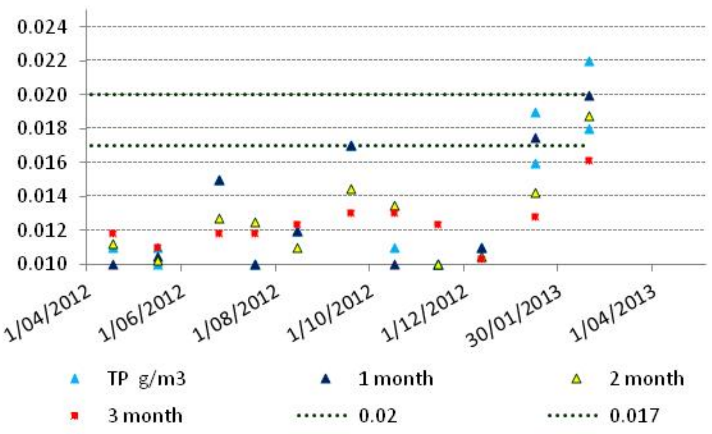

Figure 3 The total phosphorus (TP) concentration in Lake Rotorua from 2 sites, with the one, two and three monthly average TP concentrations and the control band between 0.017 and 0.020 g/m3 TP, from monthly sampling between April 2012 and February 2013.

The monthly average TP becomes the lead statistic. According to the proposed dose management strategy, the alum dose rate would remain at 100 L/hr when the results for January and February 2013 were considered.

3 Discussion

The phosphorus concentration of Lake Rotorua will fluctuate with changes in the annual climate and changes in external/internal nutrient loading. Thus, adjustment of the alum dose may be required continually. Frequent small adjustments may provide better management than allowing the lake concentration to fluctuate wildly.

The annual average total phosphorus concentration of 0.020 g/m^3 is the phosphorus component of the objective TLI of 4.2 for Lake Rotorua (Rutherford *et al* 1989). The TLI is an index of four components (total phosphorus and nitrogen, chlorophyll *a* and Secchi depth) and a TLI of 4.2 may or may not be met while maintaining the total phosphorus concentration at 0.020 g/m^3. While the total phosphorus concentration has varied between 0.010 and 0.020 g/m^3 the TLI has been below 4.2. If the TLI is found to exceed 4.2 while the total phosphorus concentration is 0.020 g/m^3, a lower total phosphorus concentration may provide a better objective for managing alum dosing.

The Bay of Plenty Regional Council has the ability to control the adverse effects of blue-green algal blooms which affect Rotorua, Rotoiti and the Kaituna River by a balance of methods including alum dosing of the Utuhina Stream and Puarenga Stream. The deed funding for alum dosing will cease in the future and unless the Regional Council and their Lakes Strategy partners renew their commitment the remediation method could cease at that time. In the meantime, a science task exists to fine tune the alum dosing strategy so that an accurate cost can be made for alum dosing which can be balanced against other nutrient reduction methods. A dosing strategy is proposed in this report based on maintaining the total phosphorus concentration of Lake Rotorua waters at or below 0.020 g/m^3.

A steady state combined dose rate of 100L/hr liquid alum to the Puarenga and Utuhina Streams has been in place in 2013. This is lower than the alum dose rate for the years 2010 to 2012. Figure 3 shows that the TP concentration in Lake Rotorua has been raised from below the 0.017 – 0.020 g/m^3 TP control zone, into the control zone. Table 2 outlines the expected range of the combined alum dose to the Puarenga and Utuhina Streams. The highest dose rate in Table 2 is equivalent to the dose rate in 2011.

The data for March 2013 is not yet available and the issue of timely availability of data has been raised. It is proposed that separate surface water samples are taken during the regional monitoring monthly sampling of Lake Rotorua and these are sent to Hills Laboratories with the results returned to the staff member controlling alum dosing. These would be added to the control chart and the alum dose adjusted according this proposal if necessary.

Table 2 The annual dose rate of liquid alum and its aluminium portion for a range of hourly dose rates that is expected to be used to maintain the TP concentration of Lake Rotorua between 0.017 and 0.020 g/m^3.

Dose rate liquid alum L/hr	liquid alum t/yr	aluminium t/yr
60	699	29
70	816	34
80	932	39
90	1049	44
100	1165	49
110	1282	54
120	1398	59
130	1515	64
140	1631	69
200	2330	98

4 Conclusion

The report proposes a method of maintaining the TP concentration of Lake Rotorua between 0.017 and 0.020 g/m^3 by managing alum dosing through use of a control chart and monthly lake monitoring. The method entails raising or lowering the alum dose rate by 10 L/hr depending on the one, two and three monthly average TP concentrations in Lake Rotorua. At this rate of increase, the highest annual alum dose rate used (2011) would be reached in 10 steps from the current (Feb 2013) rate (see Tables 1 and 2). The annual dose rate for 2010 and 2012 would be reached in 4 steps.

For the past two years sediment phosphorus releases of any significance have not been recorded in Lake Rotorua, yet at times, conditions with respect to stratification and de-oxygenation have favoured releases. It seems reasonable therefore that the lake phosphorus could be managed with a maximum dose rate of 140 L/hr (equivalent to 2010 and 2012) which means that lake phosphorus will be manageable with four control change steps above the current dose rate. That indicates a reasonable measure of control without micro-managing the dose rate.

With the proposed iterative process a steady state alum dose rate should be reached where the TP of Lake Rotorua is maintained within the control zone. At that stage lower dose increments could be considered. There are a number of unknowns regarding phosphorus locking and the rapid reduction in the phosphorus concentration in Lake Rotorua but patient and controlled adjustment of the alum dose will help unlock these facts.

Appendix II shows how the consent limits can be assessed against the stream flow rate.

5 References

Rutherford J C, Pridmore R D, White, E. 1989. Management of Phosphorus and Nitrogen Inputs to Lake Rotorua, New Zealand. J. Water Resources Planning and Management. 115(4) p. 431.

APPENDIX I

Control chart	Alum dose rate	Cumulative alum dose rate
Monthly average TP > 0.020 g/m^3	plus 10 L/hr	plus 10 L/hr
Two monthly average TP > 0.020 g/m^3	plus 10 L/hr	plus 20 L/hr
Three monthly average TP > 0.020 g/m^3	plus 10 L/hr	plus 30 L/hr
TP trending upwards or static and the 3 statistics above TP > 0.020 g/m^3	plus 10 L/hr	plus 40 L/hr
Monthly average TP < 0.017 g/m^3	reduce by 10 L/hr	reduce by 10 L/hr
Two monthly average TP < 0.017 g/m^3	reduce by 10 L/hr	reduce by 20 L/hr
Three monthly average TP < 0.017 g/m^3	reduce by 10 L/hr	reduce by 30 L/hr
TP trending upwards and the 3 statistics above TP < 0.017 g/m^3	reduce by 10 L/hr	reduce by 40 L/hr

APPENDIX II

The minimum flow below which the concentration of aluminium in the Utuhina and Puarenga Streams will exceed 1 g/m^3 at specified combined alum dose rates with the dose divided 40:60 Utuhina:Puarenga. Note that the aluminium will not be present in the streams in the form Al^{3+}.

Combined Alum dose rate L alum/hr	combined Al^{3+} dose rate kg/hr	combined Al^{3+} dose rate g/s	Min stream flow L/s to comply with 1 ppm Al3+ in Utuhina Stream (40% total dose)	Min stream flow L/s to comply with 1 ppm Al3+ in Puarenga Stream (60% total dose)
180	10.1	2.8	1117	1676
170	9.5	2.6	1055	1583
160	8.9	2.5	993	1490
150	8.4	2.3	931	1397
140	7.8	2.2	869	1303
130	7.3	2.0	807	1210
120	6.7	1.9	745	1117
110	6.1	1.7	683	1024
100	5.6	1.6	621	931