Responses from Professor David Hamilton and Chris McBride to memorandum "Two issues highlighted with the lake (J McIntosh 20/5/14)"

Two issues highlighted with the lake model (J McIntosh 20/5/14)

I consider that there is an inappropriate correlation in calibrating the de-oxygenation rate in the lake model and secondly that the effects of the direct treated sewage discharge had not dissipated from the lake in the calibration period to 2007. How this affects the model ouputs I do not know.

I have taken the values in the table below from plots in the Lake Manager's handbook and the UoW document on the lake model.

	Lake Rotorua VHOD	Lake Rotorua TN mg/m3	ROTAN load t/y	Total annual N load on Lake Rotorua t/y
1978	0.4	320	400	558
1979	0.6	325		
1980	0.55	340		694
1983	0.75	510		
1984	0.65	400		825
1985	0.8	450	550	825
1986	0.83	530		
		Bill Vant		Rutherford et al

Bill Vant correlated Rotorua's VHOD against the annual lake concentrations. These were two quantities based on in-lake measurements. The UoW model description has a correlation of Bill Vant's VHOD data plotted against the historic ROTAN catchment load. VHOD should have been plotted against data such as presented in Rutherford et al 1989 because VHOD is a result of the total load on a lake including the internal load.

Response

We needed a method to hindcast and forecast VHOD. We could not relate VHOD to total (i.e. ext+internal) load in the past or future because we have no measurements, and we can't model VHOD directly. This is the reason that 4-year N-load was used; the assumption is that internal load will be in equilibrium with the previous 4-year external load, and therefore a relationship between external load and VHOD is a valid proxy for a relationship between VHOD and external+internal load. It is an assumption that has a statistical basis and in the absence of any other empirical fit was required for progress to be made.

In addition, ROTAN was not envisaged as a method of assessing historic scenarios and the shortcomings of the historic data input is noted in the ROTAN model documents.

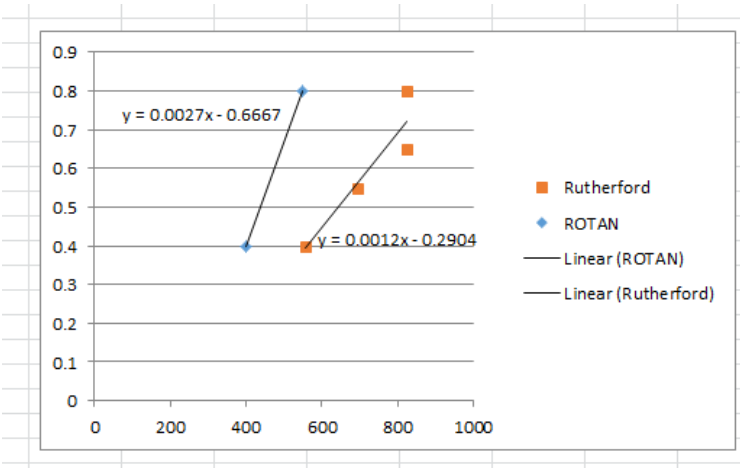
Response

There is no alternative quantitative method that we are aware of. The historical time periods are far less relevant for the latest modelling, where we've abandoned the 20s, 60s and future periods to focus on alum and land use scenarios using 2001-2012 data. The only historical period used is the 70s/80s data in the table above, to model VHOD and internal release, as discussed.

If you substitute the Rutherford data in the VHOD plot in the model document the line would be transposed to the right The intersection with the x axis would be much higher.

Response

This assertion is incorrect. On the contrary the slope would increase (from 0.0012 to 0.0027 mg m^{-2} d^{-1} (t N y^{-1})$^{-1}$ and the intercept (zero VHOD) of the linear regression would be similar (change from 242 to 247 t N y^{-1}). The figure immediately below demonstrates the relevant statistical relationships based on the table provided above.



VHOD	ROTAN	Rutherford
0.4	400	558
0.6		
0.55		694
0.75		
0.65		825
0.8	550	825
0.83		
Intercept ROTAN		246.9259
Intercept Rutherford		242

Response

The figure above supports our methodology because it shows that the VHOD is largely insensitive to the method chosen (external or internal + external loads) at very low values of VHOD. Thus, based on the limited historical data available to us, which shows a quantitative proportional increase in internal and external loads as VHOD increases, there is no evidence to reject using external load as a proxy for total load.

The intersection represents the VHOD apprx= 0.

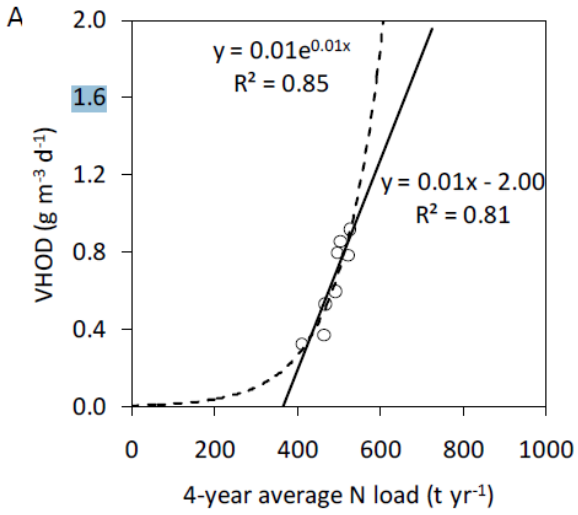
Response

We obtained a very good linear fit of VHOD to 4-year modelled N load. But it would not be wise to extrapolate too far beyond the bounds of the data used to develop the regression model. VHOD cannot theoretically be zero in deep waters and neither can external load, but a value of zero for both could provide a reasonable (theoretical) starting point for an alternate statistical (exponential) fit to deal with very low N loads. The dashed line was used in the figure below to account for the theoretical nature of the relationship and indicate tht the fit extended beyond the bounds of any data available to us.

This by the original definition would be our catchment target.

Response

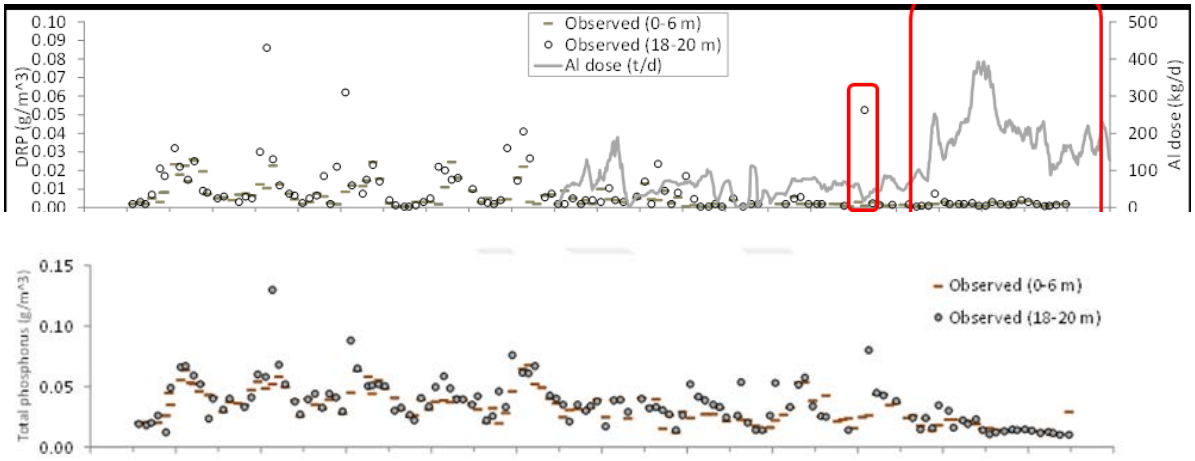
This is wrong. A VHOD of zero cannot exist for deep waters and will never be obtained, let alone be used to prescribe a TLI target.



I consider that the lake nutrient concentrations show that there was a change in the lake that started in 2006. This coincidentally was when alum dosing began. When I assessed the effectiveness of alum in reducing phosphorus in the lake there was a large reduction in phosphorus between 2006 and 2010 which I did not attribute to alum dosing. This indicates that some other process was acting on the lake nutrient concentrations.

Response

We are curious; what “other process” (besides alum dosing) suddenly started up in 2006? What is this process for which it was possible to “attribute to alum dosing”. By contrast we have demonstrated that loads of N and P from most individual streams have continued to increase since 2006 and that total N and P loads from the catchment have increased. We have used quantitative mass balance and numerical simulation approaches to provide quantitative evidence of the effect of alum on P. It has become increasingly clear that changes in in-lake P concentrations are a direct consequence of alum dosing and now co-vary according to the rate of alum dosing (see figure below). The relationship is now so strong that BoPRC use alum dosing in a process control mode, regulating TP concentrations (at 20 mg $^{-3}$) by altering the rate of alum dosing.



The only significant action that had been taken was removal the direct discharge of treated sewage effluent in 1991.

Response

But this was an action taken in 1991 not 2006. Why would the effect of wastewater removal suddenly be expected to become evident in 2006?

Since then the lake nitrogen concentration has also reduced to the level predicted by Rutherford and his colleagues that would be the result of removing the treated sewage discharge.

Response

This is a flawed interpretation of Rutherford's work because he did not know at the time that other catchment N loads (i.e. besides wastewater) would keep increasing. The work that should be referred to is Rutherford's most recent ROTAN work which had the benefit of hindsight to model the increasing catchment N loads in streams influenced by pastoral land use. Nitrogen loads have not decreased – they have continued to increase. It has become increasingly evident that there is a sequential process induced by alum, which has led to reductions in in-lake N; increased P limitation of phytoplankton (shown indirectly by more prolonged periods of elevated dissolved inorganic N (NO_3-N + NH_4-N), less deposition of labile organic matter to bottom sediments and reduced VHOD and sediment nutrient release (refer to reduced frequency of high NH_4-N concentrations in figure below).

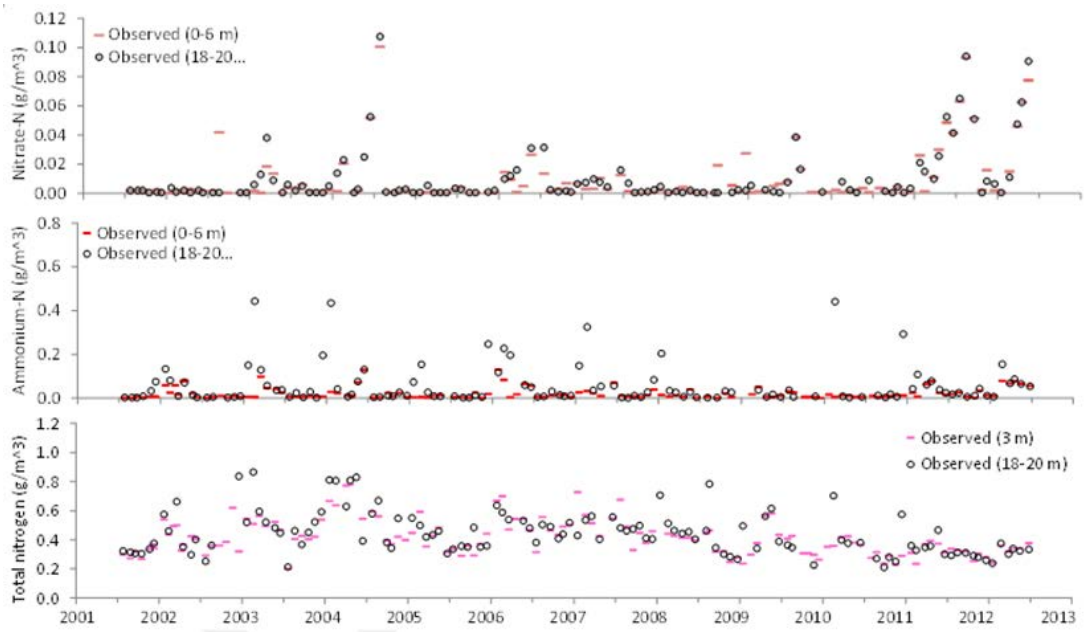


Figure 22: In-lake measurements for nitrate, ammonium, total nitrogen, dissolved reactive phosphorus (DRP), and total phosphorus at the surface (0 - 6m) and bottom (18 – 20m), and total chlorophyll a at the surface (0-6 m) from 2001 to 2013.