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Discussions

Interactive comment on "Comment on "Using groundwater age and hydrochemistry to understand sources and dynamics of nutrient contamination through the catchment into Lake Rotorua, New Zealand" by Morgenstern et al. (2015)" *by* J. M. Abell et al.

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The Comment by Abell et al. provides useful and timely analysis of Morgenstern et al. (2015)'s conclusion that P cannot be usefully managed in Lake Rotorua due high natural inputs via groundwater. Here, I provide some additional suggestions for clarifying the scientific discussion. I support all conclusions reached by Abell et al., but offer that their case would be stronger and simpler if they provide clearer background on

the substantial legislative, policy and management undertaken thus far. My perspective is rooted in the application of catchment nutrient budgets, and their components related to land-use and management in a policy context. I have been working to understand how the scientific framework developed to protect nearby Lake Taupo can be applied to catchments with more intensive land use (Baisden and Hamilton 2014, http://j.mp/B-14-RPV5), such as Lake Rotorua, despite analysis suggesting that the legislative, policy and economic framework for Lake Taupo will remain unique (Yerex, 2013 http://bit.ly/Yerex).

There are two main reasons for this suggestion. The first relates partly to HESS Discussions as a platform: these discussions occur with openness and transparency that was previously lacking in peer review. We may first accept that free expression of viewpoints is good and important, yet it is also helpful if the discussion forum as well as the published content is careful to reference perspectives, including existing legislation and policy in a way that informs both scientists and non-scientist stakeholders. The applied science and policy process for Lake Rotorua is well developed, and those involved can be considered to be invested in the progress so far toward outcomes. Perspectives also have a disciplinary context, and any solution to Lake Rotorua's nutrient budgets is necessarily multi-disciplinary, requiring care to make discussion accessible across disciplines and the full readership. I also note that perspectives are most likely to constitute bias if left unstated (so I have summarised my perspective above). Second, clarifying existing policy and policy development helps to avoid excessive argument directed at "straw-person" policies. The authors can provide greater clarity by referencing and explaining policy developments to date.

To make these broad goals more specific, if the goal is providing policy-relevant science and analysis, I therefore recommend being clear about how science is incorporated in the current policy. This then provides a platform for evaluating whether there are useful scientific reasons to alter policy. The authors may conclude that Morgenstern et al (2015)'s is invalid, but could potentially identify other issues worthy of examination to enable better and clearer science-based policy. Additional factors that can be useful to consider include historical legacies (especially those that cause hysteresis) and a comparison of the ecosystem under consideration to a wider national and international context. Benefits will be maximised if all relevant factors can be incorporated in a simple and efficient framework, enabling unidirectional progress without unnecessary complexity. The following items seems highly relevant to include:

1. The well-developed local government policy for Lake Rotorua includes a cap on terrestrial nitrogen and phosphorus losses to water (Rule 11, operative since 1 December 2008 http://j.mp/BOPRC), as well as a non-binding 2009 Action Plan that directs considerable investment in lake restoration (http://bit.ly/RotoruaAction). Shouldn't this be stated and referenced in the first paragraph or two? It is implied but not explained at L5 p10382.

2. The 2009 Action Plan and related policies set a target for Lake Rotorua's water quality using a trophic level index (TLI) specifically developed for New Zealand. The TLI combines four measures. The first two are total P and total N concentrations. The second two are chlorophyll-a concentration and Secchi depth, two measures that may be considered largely a result of P and N levels combined with other lake conditions. These are the same four measures set as objectives in Lake Taupo (http://j.mp/RPV5-Final), with legislation defining the object that each return to 2001 levels by 2080 with a focus on nitrogen as the most critical effort. In Rotorua and other lakes, the TLI provides a combined goal. The TLI-based approach would presumably identify a single nutrient to be managed if this were in fact the most efficient action?

3. The TLI scores indicate improvement in Lake Rotorua's water quality (Sholes 2011 http://j.mp/2011-R-TLI; more recent data on lawa.org.nz). Are recent improvements largely as a result of P management? In this HESS Discussion, Val Smith makes provides both a local and global description of how the potential for this improvement, and actual progress, can be assessed. More elaboration on how the stabilisation and improvement in Lake Rotorua's TLI have been achieved may be relevant to the com-

mentary and issue at hand, including apparent success in achieving the 2009 Action Plan's goal to switch the lake from N to P limitation. This seems like a key point in the Action Plan, which is highly relevant. Can data be shown to evaluate this, presumably showing the disappearance of DRP spikes?

4. Abell et al.'s point (4) is a fairly clear explanation that excess P can enable noxious N-fixers, and that cynobacterial blooms are a legitimate concern in Lake Rotorua. It may be useful to also consider incorporating the simple wording the 2009 Action Plan for the lake. The following bullet point describes the rationale for the P targets in section 2.3.1, "stop cyanobacteria blooms (with their toxins and effects on recreation) dominating by making phosphorus the key limiting lake nutrient instead of nitrogen."

5. The 2009 Action Plan also makes it clear that policy is based on N and P budgets for the lake, rather than a partial budget for groundwater inputs alone. Important components of the P budget for the lake recognise three major input components resulting from land use: groundwater-dominated DRP influx, particulate/sediment inputs, and re-release of sediment inputs from lakefloor sediments. The budget is not however summarised in table or flow diagram that I'm aware of. Assembling the numbers in one or more tables would be extremely helpful in allowing the reader to assess the author's main point. The interim Environment Court decision for Lake Taupo's legislation contained considerable detail that highlights the importance of budgets, their components, and management (http://j.mp/RPV5-interim).

6. Within the use of N and P budgets to drive policy frameworks, a key outcome of this discussion may be the importance of explicitly defining "manageable" components of the budget. Confusion associated with Morgenstern et al. (2015) appears to result from implicitly associating natural and anthropogenic components of the budget with unmanageable and manageable components of the budget, respectively. The separation of natural and anthropogenic changes in budgets and the lake's state retain relevance in a narrative sense, but can be difficult to link to future targets and policy. Further, Abell et al. correctly point out that it may be the sink terms that matter most, and focus

should not unnecessarily be placed on sources alone. However, manageable sinks may apply to specific sources, and natural sources may in some circumstances be more cost-effectively managed than anthropogenic sources (at least in the short-term). Recent work (including the authors of this Comment) has concluded that alum-dosing is unusually effective in removing groundwater derived DRP, compared to particulate P derived from erosion (Peryer-Fursdon et al. 2015; http://dx.doi.org/10.1007/s12665-014-3508-y). This is an important point and suggests that the natural DRP in old groundwater highlighted by Morgenstern et al. may partly represent a manageable load (albeit with a cost, and implications of adding alum).

7. Rotorua is unique in certain respects that will influence its management strategies. Would it be beneficial, as a contribution to literature to briefly elaborate? This includes the dominance of ground-water derived baseflow in stream water inputs – a fact that emphasises the importance of the groundwater science described in Morgenstern et al (2015). This could be summarised in a more global context – does Rotorua represent the groundwater-dominated extreme end member for global lakes? Also among the most important are the relatively low contribution of sediment P compared to typical New Zealand values (Parfitt et al 2008; http://dx.doi.org/10.1080/03014220809510545), although this manageable input still appears to represent about half the inputs to the lake and is also mainly responsible for P release from sediments. If the uniquely large contribution of groundwater-derived DRP enables cost-effective P management using alum-dosing, this is a point worth emphasising in an international journal.

8. Last, and perhaps most challenging is placing the opportunities for reduced N and P inputs on a timeline of progress for Lake Rotorua's TLI. The implied question, address in the Comment's point (3) is whether P management provides an opportunity for more immediate gains than N management. This is a difficult topic for scientists because it may involve calculations that are political and economic. If it is possible to address this using scenarios, that might be desirable. In doing so, I would caution that the

use of MRTs implied on P10381 L5 may be incorrect, or lead to misconceptions about the time-response of N delivery. Instead the distribution of transit times (as shown in Morgenstern et al.'s Figure 10) should be referred to, and contains a large (and possibly uncertain) component with a faster response that the "MRT".

To sum up, I note key opportunities for improvement by clarifying the role of the TLI in Lake Rotorua's management and making budgets more systematic to define manageable components, and this may include the potential for groundwater-derived DRP to be managed more easily than historic sediment-derived P.

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