BEFORE THE HEARING PANEL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of application by Tararua District Council to Horizons Regional Council for application **APP-2005011178.01** for resource consents associated with the operation of the Eketahuna Wastewater Treatment Plant, including a discharge into the Makakahi River, a discharge to air (principally odour), and a discharge to land via pond seepage, Bridge Street, Eketahuna.

STATEMENT OF EVIDENCE OF ADAM DOUGLAS CANNING (FRESHWATER ECOLOGY) FOR THE WELLINGTON FISH AND GAME COUNCIL

20 March 2017

Introduction

1. My name is Adam Douglas Canning. I am a Doctoral Researcher in Freshwater Ecology in the Institute of Agriculture and Environment – Ecology at Massey University. I have a Bachelor of Science with Honours – First class (Biological Sciences and Environmental Science) also from Massey University.

2. I am a member of the Ecological Society of America, the International Association for Ecology (INTECOL), and the New Zealand Freshwater Sciences Society, the International Society for Ecological Modelling, the Australasian Society for Fish Biology, and the Society for Ecological Restoration. I have presented research at conferences held across New Zealand, Australia and the USA.

3. My research is focussed on understanding community and ecosystem thresholds to ensure ecosystem health (life supporting capacity) of freshwater and estuarine systems in New Zealand. I am very familiar with literature relating to ecological community stability, ecological thresholds, and the nutrient and environmental determinants of New Zealand freshwater ecosystem health.

4. I have read the Environment Court's Code of Conduct for Expert Witnesses and I agree to comply with it. My qualifications as an expert are set out above. Other than those matters identified within my evidence as being from other experts, I confirm that the issues addressed in this brief of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of evidence

1. In this evidence I:
    a. Discuss the ecological health of a river and explain how periphyton blooms can affect ecosystem health.
    b. Review and critique the resource consent lodgement for the Eketahuna Wastewater Treatment Plant, primarily the Assessment of Environmental Effects report: *Eketahuna WWTP discharge to the Makakahi River: Summary of Current effects on freshwater quality and ecology*. Published 30th of March 2015 by Aquanet Consulting Ltd.
    c. Provide recommendations to ensure One Plan ecological health targets are achieved.

Lotic biological communities

2. Within the flowing water ecosystems there is Periphyton, Detritus, Terrestrial Plant and Animal matter, Aquatic Invertebrates, and Fish. Periphyton (the coating of slightly furry green or brown algae on rocks) and detritus (both in-stream and terrestrial derived plant matter, e.g., leaves) form the basis of the stream food web. Some periphyton is required as food for many aquatic invertebrates; however, too much algal growth can dramatically change the ecology and habitat conditions of a river. Aquatic invertebrates consume the periphyton and plant matter either directly (along with other organic sources) or indirectly by predating the smaller grazing invertebrates. Native and sport fish eat these invertebrates and some terrestrial inputs. All of the biological components of a river food web require the correct habitat, water quantity and water quality in order to maintain healthy populations and functioning ecosystems.

3. Macroinvertebrates are important contributors to a river food web's functioning and stability (important aspects that comprise ecosystem health). However, not all macroinvertebrates are equal contributors, contrast those presented in figure 10. Some invertebrates are more energetically rewarding with lower foraging costs for fish. Maintaining the diversity of these energetically rewarding invertebrates is important for the stability of fish diet. Large grazers are also important for down-cutting periphyton. Rivers with good water quality are dominated by mayflies, stoneflies and caddisflies, whereas rivers with poor water quality are dominated by worms, snails and midges and do not

support the same abundance, biomass or diversity of fish that the former communities do. Fish that feed on poor invertebrate communities become stressed, susceptible to disease and develop poor condition as a result of undesirable dietary changes (Dean & Richardson, 1999; Franklin, 2013).

4. Periphyton growth can change invertebrate community composition in two ways:
   a. Increased periphyton changes the relative ratios of primary producers. Therefore, more periphyton leads to relatively more invertebrates that graze on periphyton relative to those that feed on vegetation/particulate organic matter (POM). The increase in periphyton grazers increases the habitat competition with those grazing on vegetation/POM.
   b. When periphyton biomass builds to high levels the lower layers start to rot. This can dramatically reduce the oxygen levels and change the pH of the water leading to significant adverse effects on many invertebrates and fish. Whilst oxygen concentration may be very high during the day time from high rates of photosynthesis, at night the lack of light prevents oxygen from being released into the water and oxygen levels can plummet to lethal levels with increased bacterial activity (Dean & Richardson, 1999; Franklin, 2013). A good example of this is the Manawatu River, particularly a sampling site at Hopelands Road where continuous monitoring of dissolved oxygen revealed levels swinging between 40% and 140% over 24hrs in late summer (Joanne Clapcott & Young, 2009). Visually, an example of such diurnal fluctuations can be seen in figure 1, whereby dissolved oxygen peaks at approximately 20mg/L during the day and goes below 2-3mg/L at night. By way of comparison, moderate reductions in fish and invertebrate production occur when dissolved oxygen is <5mg/L and 50% of common bullies will not survive an hour below 3mg/L (Dean & Richardson, 1999; Franklin, 2013). The most tolerant invertebrates are typically small bodied with low metabolic demand and consequently undesirable for fish (Landman, Van Den Heuvel, & Ling, 2005). Thus many fish and invertebrate species are unable to survive, regardless of high oxygen concentrations that are recorded from daytime measurements, leading to differences in community composition.

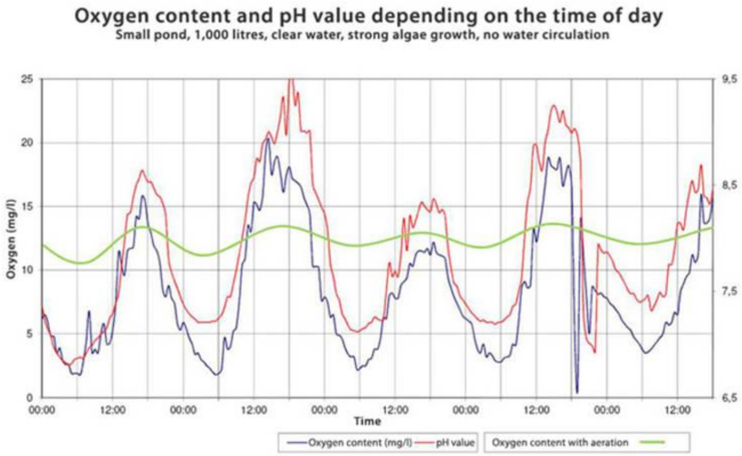


Figure 1. Example of continuous monitoring of oxygen and pH. Sourced from: https://www.oase-livingwater.com/en_GB/water-garden/online-guide/biological-fundamentals/oxygen-content.html

5. Various indices of community structure have been developed as biological measures of life-supporting capacity and ecosystem processes, such as the MCI (Macroinvertebrate Community Index). Freshwater communities are largely a product of their environment, that is, for species to persist then environmental conditions must be within their tolerance zones. As freshwater organisms are always present in the water they are sensitive to environmental disturbances that may otherwise go un-noticed if we relied simply on traditional physicochemical spot samples. Physicochemical samples are hypervariable and only indicate on the moment we conduct the spot test. Figure 1 exemplifies the diurnal fluctuations and natural variability associated with oxygen and pH levels. Therefore, spot physicochemical test results are largely dependent on the time and day samples are taken. Even using periphyton biomass as a metric of ecosystem health, as mandated in the National Policy Statement on Freshwater Management, is often a poor direct measure of ecosystem health as it is highly influenced by the level of stone movement which is driven by variable flows. Macroinvertebrate communities are slow to develop, maintain relatively consistent compositions and can provide excellent insight into ecosystem health just from one off annual surveys. Therefore, the composition of macroinvertebrate communities can be used as excellent indicators of overall ecosystem health.

6. The Macroinvertebrate Community Index (MCI) and its quantitative variant (QMCI) are popular and simple indices of macroinvertebrate community health (Stark, 1993). Each

species is assigned a value between 1 and 10 depending on their sensitivity/tolerance to enrichment. Depending on the species present within a stream/river an overall score of sensitivity is derived. High scores indicate a community with many sensitive species, which only persist when environmental conditions are optimum; whereas low scores indicate a community with low sensitivity which occur when environmental conditions are poor. The QMCI is similar to the MCI, however it accounts for both species and abundance in its calculation of community sensitivity. It should be noted that the MCI is primarily an indicator of enrichment and does not indicate all aspects of a community's ecological health. Ecosystem health represents the state in which an ecosystem has the "ability to maintain its structure (organization) and function (vigor) over time in the face of external stress" (stability) (Costanza and Mageau 1999).

Review of *Eketahuna WWTP discharge to the Makakahi River: Summary of Current effects on freshwater quality and ecology*. Published 30th of March 2015 by Aquanet Consulting Ltd.

7. Effects on water quality:
    a. To assess the current impact of the wastewater treatment plant (WWTP) on freshwater ecology three sites were examined. One upstream and one downstream of the WWTP on the Makakahi River and one at the lower reach of the Ngatahaka Creek tributary. The Ngatahaka Creek enters the Makakahi River in between the upstream and downstream sites. This likely has its own impact on the freshwater ecology at the downstream site; however, corrections can be applied to contaminant loads to assess the impact.

    b. In Table 4 in their report, Aquanet Consulting Ltd has provided theoretical downstream concentrations for key contaminants corrected for the influx from Ngatahaka Creek. Their report gives no indication of the load calculation methodology used. Nutrient concentrations typically differ with flow, and unless continuous flow and contaminant sampling occurs then methods need to adjust for flows. Nutrient sampling at the sites was conducted monthly. There are a range of load calculation methodologies developed for monthly contaminant sampling, each have their own strengths and weaknesses and margin of error. It is unclear what method(s) were used and the range of error the method yielded. Furthermore, in Table 4 the theoretical downstream SIN (soluble inorganic nitrogen) concentration is predicted to be negative at the 20th percentile. It is not possible for sub-zero concentrations to occur, raising concern over the accuracy and reliability of the other values presented.

c. It is also unclear what TKN and NH3-N loading values were used. The original application estimates that the TKN load coming into the WWTP from Eketahuna township is approximately 3.0kg/day and the NH3-N is 3.5kg/day. Whilst in the letter *Eketahuna Further Information Request Response* (27/02/2017) the WWTP effluent has a TKN load of 7kg/day and a NH3-N load of 4kg/day. These are large discrepancies that suggest more TKN and NH3-N leaves the WWTP than enters it. In the information request response the applicant states that the effluent SIN concentration will remain unchanged following upgrades. For the other contaminants (whose influent loadings also seem grossly underestimated), it is unclear whether the applicant has estimated effluent improvements based on the seemingly incorrect influent loads or from the current measured effluent loads. Thus any environmental impact assessment should be treated cautiously until this is clarified and errors amended.

d. Figure 6 (a) of their report shows the Ngatahaka Creek frequently, and downstream Makakahi River occasionally, has SIN concentrations in exceedance of the One Plan target. Assuming their load calculations are correct, the WWTP appears to contribute only a relatively small SIN load to Makakahi River. Whereas Figure 7 (a) shows the Makakahi River and Ngatahaka Creek rarely exceed the One Plan target for DRP.

e. Nutrients often limit periphyton growth by capping the amount of growth that can occur. Once nutrients are no longer sufficiently available, periphyton biomass stabilises. The nutrients that are almost always limiting are either Dissolved Inorganic Nitrogen (DIN) or Dissolved Reactive Phosphorus (DRP). If either nutrient becomes limiting, then growth is also limited. To use an analogy of building a house, having a limiting nutrient is like having no more bricks or mortar to continue building. However, unlike a house periphyton does not stop growing once the plan has been built, instead periphyton will continue growing until at least one resource becomes limiting (often Nitrogen or Phosphorus) or a flood scours the periphyton away (a bomb goes off and the house is destroyed then rebuilt until resources are limiting again). When the limiting nutrient is increased then periphyton biomass will continue to increase. High nutrient concentrations can allow periphyton to grow excessively, which is not only aesthetically unpleasing, but can drive large oscillations in dissolved oxygen that suffocate other wildlife and cause competitive exclusion to occur. This is known as the Paradox of Enrichment. Therefore, it is necessary to manage instream nutrient concentrations for both nitrogen (DIN) and phosphorus (DRP) to prevent excessive periphyton growth from occurring.

f. The authors have provided analysis of nutrient ratios to suggest conditions at which the sites periphyton growth might be limited by nitrogen or phosphorus. I do not support the use of nutrient ratios to indicate nutrient limitation for periphyton and consider it fraught with risk. Flow, temperature, pH and nutrient fluxes can easily switch a DRP limited stream to a DIN limited stream, and vice versa (Briand, 1983; Wilcock et al., 2007); different algae species thrive in and are composed of different N:P ratios (B. J. Biggs, 1990; B. J. F. Biggs & Price, 1987; Milner, 1953); and finally, two recent reviews of an extensive array of studies (237 and 382 studies, respectively) have found Redfield ratios (the molar N:P ratio) are inaccurate for determining nutrient limitation (Francoeur, 2001; Keck & Lepori, 2012). Both SIN and DRP need to be managed at all times for periphyton growth to be limited.

g. As explained in paragraph 4, excessive periphyton can alter the ecological communities via large oscillations in dissolved oxygen. Figure 18 in their report depicts dissolved oxygen saturation and can give misleading conclusions that dissolved oxygen is unaffected. The data was collected from spot samples during the day time which cannot indicate on hypoxic events occurring at night. The authors highlight this caveat on page 38 and I reinforce their point. I suggest that any future monitoring plans include continuous dissolved oxygen monitoring throughout summer months.

8. Effects on freshwater ecology:
    a. As explained above, too much periphyton is the primary driver of poor macroinvertebrate and fish communities. Just how much periphyton is too much? Matheson, Quinn, and Hickey (2012) and Matheson, Quinn, and Unwin (2016) used

Quantile Regressions to investigate relationships between MCI, QMCI and Periphyton biomass (measured in terms of chlorophyll a density in mg/m2). They found that to achieve an MCI of 100 or QMCI of 5 with ≥85% compliance then Chlorophyll a density needs to be ≤120 mg/m2, or for an MCI of 120 or QMCI 6 then Chlorophyll a needs to be <50mg/m2.

b. Periphyton is controlled principally by:

    i. Ensuring natural hydrological variability is maintained so that freshes and floods can regularly scour periphyton growth from gravels.

    ii. Keeping nutrient inputs sufficiently low (for example, SIN concentrations at approximately 0.1-0.4mg/L).

    iii. Ensuring sufficient riparian vegetation to shade rivers and lowering temperatures, thereby preventing growth.

c. Whilst the One Plan Chlorophyll a limit is at 120mg/m2, in order to meet the One Plan MCI target of 120 then Chlorophyll a should be kept below 50mg/m2. The Aquanet report only assessed ten Chlorophyll a sampling occasions over a 15 month period. Periphyton is highly variable (as observed in Figure 19 of the Aquanet report). To get more certainty around typical periphyton densities then I recommended monitoring at least monthly (ideally fortnightly over summer months) for a continuous period of at least seven years.

d. The macroinvertebrate communities were also only assessed over two years, which is not enough to confidently assess the impacts of the discharge. From the macroinvertebrate data that is available, there appears to be little change in MCI, yet considerable change in %EPT individuals and QMCI, between upstream and downstream sites. Furthermore, the EPT% individuals and QMCI downstream are also lower than the tributary which the applicant claims contributes the majority of the nutrient loads between the upstream and downstream sites. The degradation of the downstream community (lower EPT and QMCI and higher periphyton) may be caused by loads from the WWTP or could be the effect of differences in shading between sampling sites. I suggest the monitoring plan consider an alternative test location for the downstream site to ensure shade between sites is similar and ideally remove the influence of Ngatahaka tributary.

e. Figure 27 of the Aquanet report shows an NMDS depicting the overall differences between macroinvertebrate communities between sites at each sampling event. However, they have not tested whether the observed differences in community composition are likely to be artefactual or real. They could test the differences using two-way PERMANOVA (Permutational Multivariate Analysis of Variance) or ANOSIM (Analysis of Similarities) and control for year.

f. In order to achieve the One Plan's target MCI nutrient concentrations will need to be lowered. What level should the nutrient concentrations be lowered to in order for an MCI of 120 to be achieved? I recommend using a multiple lines of evidence approach.

   i. Matheson and others (2016) used quantile regression on data from several regions, including Manawatu, and concludes that to achieve a chlorophyll a concentration of 50 mg/m2 then SIN needs to be below 0.1mg/L.

   ii. Clapcott and others (2013) used data collected between 2007 and 2011 from over 1000 reaches around the country to predict (using random forests) MCI at all locations around the country (r=0.83). The predicted MCI values were then regressed (ln(y)=x) against modelled nutrient data from Unwin and Larned (2013). For an MCI of 120, SIN concentration should be approximately 0.02mg/L (r^2=0.54, p<0.00001) and DRP concentration approximately 0.004mg/L (r^2=0.39, p<0.0001).

   iii. Assuming a scouring event does not occur for 30 days, then according to B. Biggs (2000) to achieve a maximum monthly chlorophyll a concentration of 50 mg/m2 then SIN needs to be below 0.1mg/L and DRP needs to be 0.0039mg/L.

   iv. A private collection held by Prof. Russell Death of macroinvertebrates from 962 sites throughout the lower North Island collected between 1994-2007 measured (Death, Death, Stubbington, Joy, & van den Belt, 2015) were regressed with (Unwin & Larned, 2013). For an MCI of 120, SIN concentration should be approximately 0.11mg/L ($r^2=0.35$, $p<0.00001$) and DRP concentration approximately 0.008mg/L ($r^2=0.18$, $p<0.0001$).

- <u>Therefore, to achieve the One Plan MCI target of 120, average SIN should be between 0.02-0.1mg/L and DRP between 0.0039-0.008mg/L.</u>

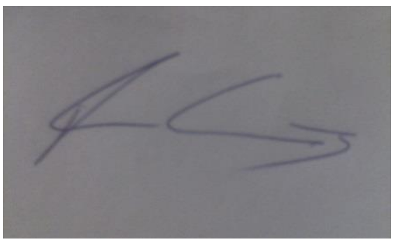
g. Ultimately, if the One Plan MCI target is to be achieved then the whole catchment loads will need to be reduced. Therefore, in addition to correcting any errors in the current load and theoretical concentration calculations, I suggest that it be determined the proportion of nutrient loads likely to arise from the WWTP for the stream in the hypothetical situation that its SIN was ~0.1mg/L and DRP ~0.005mg/L. This exercise will be important because it will check that any loads won't preclude the target state (for MCI) from being achieved and it will allow decision makers to have a fairer assessment of the proportion of loads coming from the WWTP at the target state.

9. I am confused about the position of the proposed discharge location. The request for further information response suggests three sites for discharge. Each location will have its own costs and benefits. The existing site pipes effluent directly into the Makakahi River – I have presumed that it is this discharge site that they have estimated effluent load to river at. They suggest an overland pathway through a small gully with bunded areas/wetlands (option one). The second option is to discharge to a much larger wetland area. The ability of both options to improve the quality of effluent discharge needs to be examined. However, I anticipate that option will assimilate more nutrients than option one. Given the One Plan MCI target of 120, following a more thorough examination of nutrient assimilation capability, the site that will yield the least impact on water quality should be chosen.

Adam Douglas Canning

Aquatic Ecologist

19^{th} of July 2016



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