in the matter of: the Resource Management Act 1991

and

in the matter of: a number of applications to take and use water from the Upper Waitaki catchment

Brief of evidence of Antonius Hugh Snelder

Dated: 16 September 2009

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BRIEF OF EVIDENCE OF ANTONIUS HUGH SNELDER

1 My full name is Antonius (Ton) Hugh Snelder.

2 I have a Bachelor of Engineering from the University of Canterbury and a PhD (Lincoln University) specialising in environmental management.

3 I am a principal scientist in Freshwater Ecology at the National Institute of Water and Atmospheric Research (NIWA). I have 23 years of experience in the field of water resource management including 14 years as a water resources scientist at NIWA. Prior to my current position I worked for regional councils and in consultancies as a water resources engineer. In my position at NIWA I have lead many projects that have assessed the effects of water takes and discharges on river environments. I have written a number of guidelines for the management of water quality and quantity and developed several tools for water management purposes. I have authored or co-authored several scientific publications in the field of river management, including two that specifically address setting nutrient concentration criteria in rivers.

4 I have been involved in the following investigations and assessments that are relevant to the current resource consent applications to take and use water from the Upper Waitaki Catchment for irrigation, which are the subject of the cumulative water quality assessment by Mackenzie Water Research Limited (MWRL):

- Snelder, T., Spigel, B, Sutherland, D. and Norton, N. (2005) Assessment of effects of increased nutrient concentrations in streams and lakes of the Upper Waitaki Catchment due to catchment land use changes. NIWA Client Report: CHC2005-003

- Norton, N., Spigel, B.; Sutherland, D.; Trolle, D.; Plew, D. (2009) Lake Benmore Water Quality: a modelling method to assist with assessments for nutrient loadings. NIWA Client Report CHC2009-091.

5 I have also reviewed the following relevant reports and statements of evidence of other experts giving evidence on behalf of MWRL and Meridian Energy Limited (Meridian) relevant to my area of expertise, including:

5.1 Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Catchment: Summary Report; August 2009, prepared for Mackenzie Water Research Limited

5.2 Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Basin: Rivers and Lakes Report of August 2009 prepared for Russell McVeagh on behalf of Mackenzie Water Research limited.

5.3 Coffey, 2009 Upper Waitaki Catchment – Follow up Stream Surveys to Assess the Effects of Irrigation on Nutrient Runoff to waterways Prepared by Brian T. Coffey and Associates Limited for GHD Limited (April 2009).

5.4 Larned *et al*. 2007 Ecological studies of Didymosphenia geminata in New Zealand, 2006-2007. NIWA Client Report: CHC2007-070. Prepared for MAF Biosecurity New Zealand

5.5 Wilks and Norton, In prep. Periphyton growth and nutrient limitation in the upper Waitaki catchment. Environment Canterbury Report U07/50.

5.6 Kilroy, 2008. Data and literature review on South Island rivers affected by the invasive, non-indigenous alga Didymosphenia geminata. NIWA Client Report: CHC2008-078. Prepared for Department of Conservation.

5.7 Relevant evidence of **Ms Sutherland, Dr Griffiths, Mr Greenaway and Mr Turner on behalf of Meridian;**

5.8 Relevant evidence of **Dr Coffey, Dr Ryder Dr Bright and Dr Robson on behalf of MWRL;**

5.9 The Section 42a Reports of **Dr Meredith** and **Dr Schallenberg** for ECan.

6 I confirm that I have read the Environment Court's Code of Conduct for expert witnesses and this evidence has been prepared in accordance with that code. I agree to comply with the code's terms. In that regard, I confirm that the statements made in this evidence are within my area of expertise (unless I state otherwise) and I also confirm that I have not omitted to consider material facts which might alter the opinions stated in this evidence.

SCOPE OF EVIDENCE

7 I have been asked by Meridian to prepare evidence in relation to the cumulative water quality assessment prepared by MWRL in respect of the current resource consent applications to take and use water from the Upper Waitaki Catchment for irrigation. My evidence includes a discussion of:

7.1 a general description of the rivers and streams in the Upper Waitaki Catchment;

7.2 the potential effects of increased nutrient concentrations in rivers and streams;

7.3 a conceptual model with which to understand the effect of increases in nutrient load on periphyton biomass;

7.4 an explanation of the nutrient concentration criteria derived for streams and rivers by MWRL;

7.5 an explanation of the work I consider would be necessary in order to define robust nutrient concentration criteria for streams;

7.6 monitoring and control requirements; and

7.7 an overall conclusion on the adequacy of the nutrient concentration criteria for all aquatic environments (lakes, canals, streams and rivers).

STATE OF THE RIVERS AND STREAMS IN THE UPPER WAITAKI CATCHMENT

8 In general, the sub-catchments of the Upper Waitaki Catchment are either undeveloped or in extensive dry land (low intensity) land use. This results in relatively high ecological quality of the rivers and streams of the Catchment at locations that are not currently affected by intensive agricultural land use (i.e. not irrigated) (Coffey 2009).

9 The streams in the Catchment, including the Omarama, Willowburn, Quailburn, and Wairepo Creek are characterised by hydrologically stable flow regimes with few floods and sustained baseflows, (Low FRE3, i.e. average number of flood events per year greater than 3 times the median flow, Cumulative Water Quality Effects Report, Appendix Z) probably as a result of receiving a large proportion of their flows as groundwater. These systems have low sediment transport rates and have stable substrates and deep u-shaped channels as a result.

10 The main rivers in the Catchment that are potentially affected by the current resource consent applications are the Ahuriri, Ohau, Tekapo and Twizel Rivers. The Tekapo and Ohau Rivers have historically been fed by lakes and are now regulated by the operation of the Waitaki Power Scheme.

11 Prior to construction of the Waitaki Power Scheme, Lake-fed rivers, such as Tekapo and the Upper Ohau Rivers would have had stable flows and low sediment supply, which would have led to bed-armouring. Bed-armouring is a process in which, if sediment supply is very low, the fine substrates are gradually removed and the bed surface becomes dominated by stable stones. The surface of armoured beds are rarely, if ever, moved even during very high flows. However, the beds of the Tekapo and upper and lower Ohau

Rivers have remained relatively armoured after the construction of the Waitaki Power Scheme.

12 The existing ecology of the rivers and streams in the Upper Waitaki Catchment is poorly described by any literature. Benthic algae in the rivers, streams and canals are comprised of diatoms, cyanobacteria and filamentous green algae (Daly 2004; Coffey 2009) but species diversity for this community is unknown.

13 The invasive, unwanted algae, *Didymosphenia geminata* (didymo) has been described in the evidence of **Ms Sutherland** and was first detected in the Upper Waitaki Catchment in 2006. It has been positively identified in the Ahuriri River, Tekapo River, Twizel River, Omarama Stream and Lower Ohau River (Biosecurity New Zealand, Didymo Samples Database, didymosamplesdb.org.nz). Didymo is now also present in the Tekapo and Ohau B - C Canals (Kilroy 2008).

14 There has been no data collected by MWRL or any other parties describing temporal variation of algal biomass and macroinvertebrates in any of the rivers and streams of the Upper Waitaki Catchment (Kilroy 2008).

EFFECTS OF INCREASED NUTRIENT CONCENTRATIONS IN RIVERS AND STREAMS

15 Periphyton, a collective term for benthic algae, cyanobacteria, bacteria, fungi and protozoa, is the basis of aquatic ecosystem in rivers. It is essential to ensure a healthy and diverse periphyton community in order to have a healthy stream ecosystem (MfE 2000). However, periphyton biomass can increase and become a nuisance that may degrade water and habitat quality and negatively impact on biodiversity, aesthetic and recreation values of streams and rivers (Biggs 2000; MfE 2000).

16 Increases in nutrient concentrations, particularly nitrogen (N) and phosphorus (P), can increase the growth rate of periphyton if one or both of N and P are presently limiting. Increased growth rates can lead to the development of nuisance growths. Typically there are also shifts in composition of the periphyton community to filamentous green algae, which provide poorer habitat and food for invertebrates. Stream nutrient enrichment from agriculture can start to become evident with as little as 20 percent of catchment conversion to intensive pasture (Biggs, 1995). Minor losses of nutrients from agricultural areas can represent large increases in the supply rates of nutrients to periphyton which normally receive nutrients at extremely low levels (MfE 2000).

17 The exact response of periphyton to increasing nutrients is difficult to predict, especially in streams and rivers with stable flow regimes

and substrates such as those of the Upper Waitaki Catchment. The first important question is whether nutrient supply is a factor limiting the growth rate of algae. Three separate studies provide strong evidence that the streams and rivers of the Upper Waitaki Catchment are sensitive to increased nutrient concentrations:

17.1 Firstly, bioassay studies in the streams and rivers of the Upper Waitaki Catchment have demonstrated that stream periphyton communities are nutrient limited (Wilks and Norton, In prep). Wilks and Norton, (In prep) showed that the growth of periphyton in 10 stream sites was limited by N, P or N and P. These studies demonstrate that the biomass of periphyton in the rivers and streams of the Upper Waitaki Catchment is probably sensitive to increases in both N and P.

17.2 Secondly, basic knowledge of didymo ecology and growth dynamics in New Zealand lakes is lacking. It has been shown that didymo biomass will increase with only small increases in nutrients (Larned et al 2007). In particular, bioassay studies showed significant increases in didymo biomass in response to nitrate enrichment in the Ahuriri River. It is very likely that small increases in N and P would cause proliferations of didymo in the streams, rivers and canals in the Upper Waitaki Catchment. This topic is also discussed in the evidence of **Ms Sutherland**.

17.3 Thirdly, the next piece of evidence that periphyton in the rivers and streams of the Upper Waitaki Catchment are sensitive to nutrients is provided by the study by Coffey (2009). This study indicates that there is generally an increase in observed periphyton biomass downstream of existing irrigated areas in the Upper Waitaki Catchment. On two sampling occasions in April 2008 and 2009 periphyton was sampled in eleven sub-catchments of the Upper Waitaki Catchment. Samples in each sub-catchment were taken above and below irrigated areas. In summary seven of the eleven sub-catchments the periphyton biomass was observed to increase, sometimes to nuisance levels, downstream of the irrigated areas. Of the remaining four sub-catchments where increased biomass was not observed, two sub-catchments had soft-bottomed streams that do not support periphyton communities. The remaining two sub-catchments were the Twizel and Ahuriri Rivers that had low periphyton biomass at both upstream and downstream sites.

18 As algae proliferate under increased nutrient conditions, there are typically a range of flow-on effects that impact on the values of streams and rivers. Increased biomass negatively effects water chemistry by altering dissolved oxygen and pH. Nuisance growths

also change the physical substrate in the stream altering habitat especially for invertebrates.

19 These ecosystem effects ultimately lead to effects on fisheries values. Periphyton proliferations also often result in a change in species composition to filamentous alga that have a more green and slimy appearance. This change impacts on aesthetic and recreational values. Recreational values and the potential effects of changes in water quality and periphyton communities are discussed in the evidence of **Mr Greenaway**. Periphyton community composition changes can also result in occurrences of toxic benthic cyanobacteria.

20 As set out in the evidence of **Mr Turner**, of particular concern to Meridian is the possibility of nuisance periphyton growths (including didymo) in the beds of the Tekapo and Lower Ohau Rivers. These regulated rivers are not subject to residual flows below the dams and any spill events are infrequent. The nuisance periphyton growths could place pressure on Meridian to release flushing flows in order to remove and reduce algal biomass. The establishment of periphyton or nutrient thresholds that would rely on flushes being released by Meridian is problematic and has implications that are discussed in the evidence of **Mr Turner**.

CONCEPTUAL MODEL OF THE EFFECT OF INCREASED NUTRIENTS ON PERIPHYTON BIOMASS

21 A conceptual model with which to understand the effect of increases in nutrient concentrations on periphyton biomass is provided by the New Zealand Periphyton Guideline (MFE 2000). This model shows biomass as a function of counteracting processes of accrual and loss of biomass. The rate of accrual (growth) is controlled by nutrients, light and temperature.

22 There are both physical and biological controls on loss rates. The physical control is primarily flood flows that dislodge and "flush" periphyton. The effectiveness of a flood flow for removing periphyton is dependent on the change in water velocity, the amount of suspended material in the water and degree to which substrate is moved (i.e. is unstable during floods). Biological control comprises grazing by invertebrates.

23 In rivers that flood frequently and that have unstable substrates, biological control is limited due to the constant disturbance of the invertebrate community and the maximum periphyton biomass depends largely on the growth rate and the period between flood events. Increased nutrients produce higher periphyton growth rates so that the maximum biomass that can occur between floods increases. In addition, increased growth rates mean that both the

number and duration of events that exceed any nominated biomass will increase.

24 In rivers with stable flows and substrates, the loss of periphyton biomass due to invertebrate grazing can be more important than in frequently flooding rivers. In stable rivers the effect of increasing nutrient concentrations can be less predictable. Small increases can lead to increased invertebrate grazing and have little effect on biomass. However, step changes in biomass can arise in these systems if biomass growth rates outstrip the ability of invertebrates to graze new growth, especially if biomass increases adversely affects invertebrate habitat.

NUTRIENT CONCENTRATION CRITERIA DERIVED BY MWRL

25 The MWRL assessment and the evidence of **Dr Coffey and Dr Ryder** concludes that nutrient concentrations in the rivers of the Upper Waitaki Catchment need to be restricted to certain limits in order to ensure that biomass remains within a sustainable range. Guidelines values for maximum periphyton biomass are provided by the New Zealand Periphyton Guideline (MFE 2000). The guideline specifies biomass in terms of ash-free-dry-mass (AFDM) and chlorophyll *a.* Two levels of protection are suggested (MfE 2000). For a high level of protection the guideline value is specified as a maximum annual biomass (chlorophyll *a*) of 50mg/m^2 and a mean monthly biomass of 15mg/m^2 (chlorophyll *a*). This guideline is suggested for protection of biodiversity. A lower level of protection for aesthetic values and trout habitat and angling is specified as a maximum annual biomass (chlorophyll *a*) of 120mg/m^2 and 200mg/m^2 for filamentous green algae and diatoms respectively.

26 The MWRL assessment has used a model developed by Biggs (2000) to calculate concentration criteria for N and P in order to meet guideline biomass. The model relates periphyton biomass in terms of chlorophyll *a* to the mean concentrations of N and P and the accrual period. The accrual period (days) is measured as FRE3. The model explained a large proportion (>70%) of variation in the maximum periphyton biomass. Another model presented in the same paper by Biggs (2000) explained the duration (months/year) of periphyton biomass greater than 60 mg/m^2 chlorophyll *a* as a function of mean concentrations of N and P and the accrual period. MWRL did not attempt to apply this second model.

27 MWRL has used the Biggs (2000) maximum biomass model to estimate the maximum biomass at various points (nodes) in the Upper Waitaki Catchment. They have used observed and modelled nutrient concentrations and estimates of FRE3 as input to the model. The estimated maximum biomasses at most nodes generally exceed even the most lenient periphyton biomass limits suggested by the MFE (2000) guidelines.

28 On this basis MWRL has proposed that the guidelines are too conservative and not applicable to the Upper Waitaki Catchment (Coffey 2009). MWRL suggest a relaxation of the guideline limits and propose that the maximum estimated biomass at each node be increased by 25% above current estimated levels on the basis that this would not be noticeable to a casual observer or result in significant adverse effects above current conditions (page 58, Cumulative Water Quality Effects Report). This appears to then be the basis on which they back-calculate the allowable nutrient concentrations on which to regulate future nutrient load limits.

29 I have a number of concerns with the MWRL approach to the calculation of the nutrient concentration thresholds for rivers:

29.1 Firstly, as Dr **Griffith's** evidence has pointed out, there are uncertainties with the water balance and calculation of flow rates. The modelled nutrient concentrations are derived by combining modelled nutrient loads and modelled flows. Uncertainties associated with the flow rates create uncertainty in the modelled nutrient concentrations and, therefore, uncertainty in whether additional nutrients can be assimilated or whether biomass thresholds could be met.

29.2 Secondly, the analysis by MWRL lacks spatial resolution. Basing the analysis on a series of nodes that are strategically located downstream of irrigated areas is, in principle, an acceptable method. However, Mr **Callander**'s evidence indicates that there is a lack of detailed information concerning the locations at which groundwater that is derived from irrigated areas will emerge in streams. These locations are likely to be the most impacted in terms of increased nutrient concentrations and should therefore be included as nodes in the analysis. The current network of nodes, therefore, only provides for a high-level summary of effects and may miss local areas where impacts could be more severe. I also note that the evidence of **Ms Sutherland** suggests that nodes that represent inflows into Lake Benmore should be located at the lake and not some distance upstream as is the case in MWRL's assessment.

29.3 My third concern is that the water chemistry data that was used to calculate the existing periphyton biomass is inadequate. MWRL's calculations for many nodes are based on three sampling occasions in December 2008 and January 2009. For locations such as the Stony Node and the Wairepo Creek Node there are more sampling occasions but these are irregularly distributed through time and cover a long time period often back to the 1990s. The Biggs (2000) model is based on the mean of monthly samples taken over an entire year because periphyton integrates nutrients over time so that the biomass at any point reflects this historic flux. The water chemistry data that MWRL have used cannot be regarded as being representative of the mean of monthly samples taken for an entire year and this may result in large errors in the calculation of maximum biomass. In addition, many of the N and P concentrations were below the detection limits of the analytical method used. It is unclear from any information that MWRL have provided how these below-detection concentrations were handled. This is of critical importance because the nutrient concentration used to calculate the maximum biomass is an average over all samples.

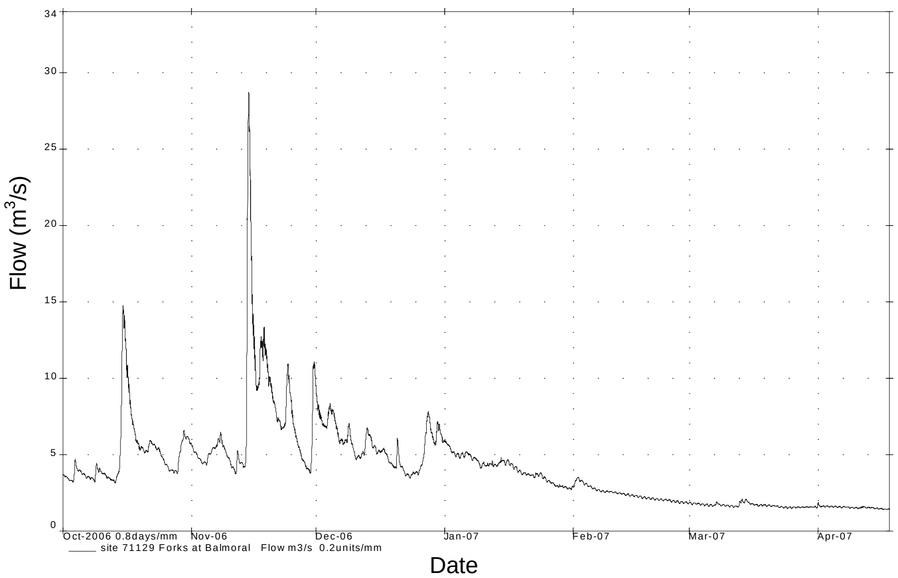
29.4 My forth concern is that MWRL's assessment lacks temporal resolution. The evidence of **Mr Callander** has pointed out that estimates of nutrient concentrations at nodes are based on averaged flows and nutrient fluxes. These averages are not informative about concentrations that may occur during critical periods for periphyton growth such as during summer low flows. Concentrations at these times could be much higher than the average and promote nuisance algal blooms.

29.5 My fifth concern relates to the use of the Biggs (2000) model. The Biggs (2000) model is calibrated for "hill-country" fed rivers. These rivers are characterized by frequent flood events and large sediment supply rates. As a result of these characteristics, bed substrates in hill-country fed rivers tend to be unstable and periphyton is easily dislodged and flushed. For example, 90% of the sites used in the calibration of the Biggs (2000) model had a FRE3 greater than 7. In contrast, the Cumulative Water Quality Effects Report (Appendix Z) lists only one river in the Upper Waitaki Catchment, the Twizel River, with a FRE3 of greater than 7 (7.2). Many of the other streams in the Upper Waitaki Catchment have estimated FRE3 of 3.8 or less. The Biggs (2000) model's success in explaining maximum periphyton biomass indicates that, in hill-country fed rivers, periphyton loss is strongly controlled by floods with limited importance of grazing by invertebrates. This is not likely to be the case in the rivers and streams of the Upper Waitaki Catchment which I have already described as hydrologically stable, with stable substrates and with armoured beds in the case of the rivers.

30 These concerns have two implications in terms of MWRL's assessment of effects of nutrient increases. Firstly, it is unlikely that MWRL's estimates of maximum periphyton biomasses at stream nodes under existing conditions are correct. Secondly, it is unlikely that the nutrient concentration criteria presented in the Rivers and Lakes Report will result in the biomass limits being met.

31 I have evaluated the first of the two implications discussed above by comparing the maximum biomasses estimated by MWRL with periphyton biomass actually measured in the Upper Waitaki Catchment. Periphyton biomass (chlorophyll *a*) was measured on one occasion in late summer (20th April) in 2007 at ten sites in the Upper Waitaki Catchment (Wilks and Norton, In prep). This sampling occasion is likely to represent the annual maximum biomass because it occurred after three months of stable and decreasing flows in the Upper Waitaki Catchment and warm late summer conditions (Figure 1).

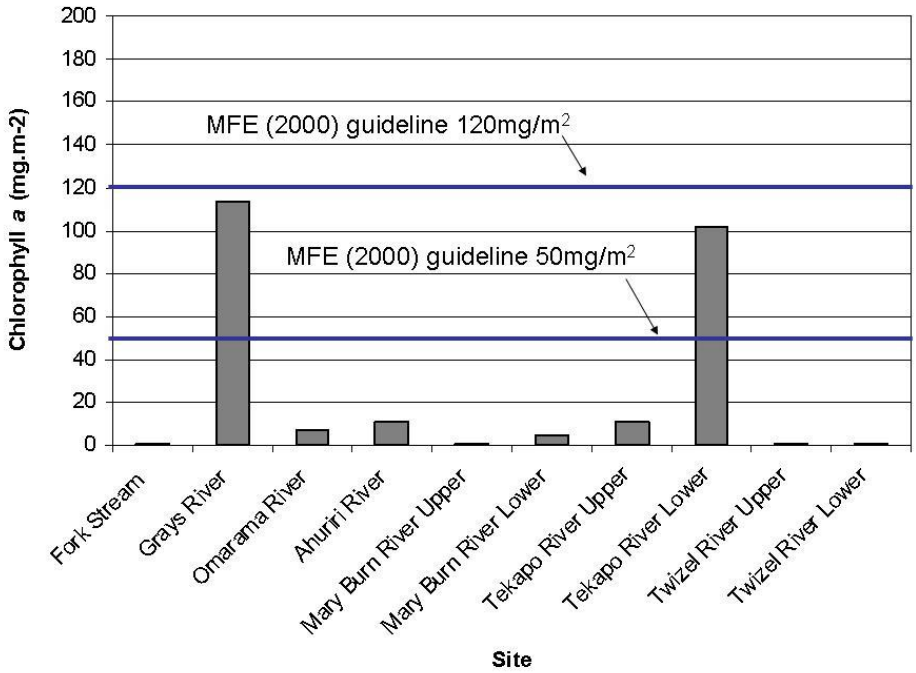
Figure 1 Hydrograph for the Fork Stream at Balmoral for the period October 2006 to April 2007. The Fork stream is an unregulated tributary of the Tekapo River and is representative of flow regimes in streams in the Basin. Periphyton biomass was measured in ten sites within the Upper Waitaki Catchment near the end of period shown on the hydrograph.



32 The MfE (2000) guideline of 120mg/m^2 was not exceeded at any of the ten sites and the more stringent limit of 50mg/m^2 was not exceeded at most sites (being Forks, Omarama, Ahuriri, Mary Burn upper, Mary Burn lower, Tekapo Upper, Twizel Upper and Twizel Lower) (Figure 2). These actual periphyton data, therefore, do not corroborate MWRL's assessment of the existing maximum annual biomass or the statement that the MFE (2000) periphyton guidelines are too stringent for the Upper Waitaki Catchment. I conclude that

there is no good evidence that the MFE (2000) guidelines are too stringent for the streams and rivers of the Basin. I also conclude that MWRL's analysis is likely to lead to very poor estimates of nutrient criteria for meeting any biomass limit.

Figure 2. Measured periphyton biomass (chlorophyll *a*) for steams in the Upper Waitaki Catchment (Figure 1) taken on 20th April 2007. (source: Wilks and Norton In prep).



33 The MWRL reports acknowledge areas of uncertainty such as estimates of FRE3, nutrient concentrations and groundwater flow paths. However, MWRL have made no attempt to assess the sensitivity of their estimates of existing maximum biomass or nutrient concentration criteria to the assumptions and uncertainties in their approach. A sensitivity analysis would be informative about the plausible range of values that have been calculated and the most important assumptions. A sensitivity analysis would also help inform the decision making process by providing an estimate of how incorrect the values that have been offered could be.

34 The Biggs (2000) model that was used in the assessment by MWRL was also used by two other recent and related studies. Some comment on the relative validity of these studies is necessary.

35 The Biggs (2000) model was applied in an earlier scoping study of the effects of intensification of land use in the Upper Waitaki Catchment by Snelder et al. (2005). The overall result of application

of the Biggs (2000) model was that yearly maximum biomass increased by a factor of up to two and well in excess of the MFE (2000) guidelines under Snelder et al.'s (2005) Scenario 2 land use intensification scenario, which is most consistent with MWRL's assessment. The important difference between this study and MWRL's assessment is that Snelder et al. (2005) did not extend the use of the model to setting nutrient concentration criteria for resource consents. Snelder et al. (2005) acknowledged that the lack of temporal data describing nutrient concentrations meant that their assessment "*should be interpreted as the lower boundary for yearly maximum algae biomass because it has assumed that the annual flux of nutrients is evenly distributed throughout the year*".

36 Snelder et al (2005) noted that their application of the Biggs (2000) model produced higher estimates of periphyton biomass compared to actual observations reported by ECan (ECan 2004). For example, Snelder et al (2005) estimated breeches of the MFE (2000) perihyton guideline of guideline of 120mg/m^2 under existing land use at 7 out of 9 of their nodes. As discussed above, MWRL's application of the Biggs (2000) model also produced an overestimation of periphyton biomass. Snelder et al (2005) suggested this lack of agreement between modelled and observed biomass may be because invertebrate grazing is currently able to control growth. This was corroborated by the ECan (2004) report, which noted that enrichment in the Mary Burn was "not currently showing any observable effect". As has been discussed above, the ECan report suggested that "it may take very little in the way of further nutrient inputs to upset the ecological balance".

37 Snelder et al. (2005) also commented that as well as increasing the annual maximum algae biomass, the duration of algae proliferations would increase under more intensive land use.

38 In summary, the Snelder et al. (2005) study was an initial scoping assessment and specifically acknowledged many assumptions and areas that would require further work to achieve greater certainty. The present MWRL assessment has largely repeated that study without greatly adding to the data and has extended the use of the Biggs (2000) model into setting nutrient concentration thresholds for resource consent applicants.

39 A second study has applied the Biggs (2000) study to assessing the effects of increased nutrient concentrations in seven streams draining the Hunters Hills area of the Southern Canterbury Plains as a result of land use intensification associated with the Hunter Downs Irrigation Scheme (Norton et al., 2007). This study was based on considerably more data that the MWRL assessment in the Upper Waitaki Catchment including monthly nutrient concentrations measured since 1989 and independent observations of periphyton biomass. Importantly, this study found that both observed and

modelled periphyton biomass exceeded the MfE Guideline values of 120mg/m^2 and 200mg/m^2 chlorophyll *a* respectively under the current land use. The reason for the exceedence of the MFE guideline was attributed, at least in part, to the natural occurrence of soft-sedimentary geological formations in the catchment which are associated with naturally higher nutrient loads. The overall conclusion of this assessment was that the MFE (2000) guidelines would not be able to be met, even under existing conditions. This differs from the MWRL assessment in that the certainty for the HDI assessment around the non-compliance with the guidelines is considerably greater due to better water quality data and actual observations of periphyton biomass.

WORK NECESSARY IN ORDER TO DEFINE NUTRIENT CONCENTRATION CRITERIA

40 The deficiencies listed above mean that MWRL's assessment of effects and calculation of nutrient concentration thresholds are, in my opinion, subject to considerable uncertainty. I consider that the streams and rivers of the Upper Waitaki Catchment are likely to be very sensitive to nutrient inputs because they are characterised by infrequent floods and stable bed sediments. This means that even small increases in N and P could cause proliferation of periphyton biomass. I also consider that the use of the Biggs (2000) model is unreliable because it does not include consideration of biological control of periphyton biomass and because the streams and rivers of the Upper Catchment differ so markedly from those for which Biggs (2000) calibrated his model.

41 The most major deficiency in the MWRL assessment is the lack of temporal data describing the annual hydrological regime, and the variation in nutrient concentrations and the periphyton biomass through the year. Periphyton dynamics are difficult to predict and it is therefore important to have some knowledge of the annual variation in hydrological regime, nutrient concentrations and periphyton biomass as part of consent-oriented assessments (MFE 2000, Page 45). I consider that, in order to have confidence in nutrient concentration criteria, it would be necessary to collect such data with which to calibrate the conceptual model I have discussed above.

42 In order to define nutrient concentration thresholds with confidence, the minimum information needed would be monthly data for 12 to 18 months describing periphyton biomass and community composition at a number of locations chosen to be representative of the streams and rivers of the basin. Monthly nutrient concentrations for the same sites would also be required. There would also need to be flow data for these sites so that the magnitude and frequency of floods that dislodge and flush periphyton could be established. A minimum of one year of monthly data is necessary because

periphyton responds to natural climatically driven factors and the Guidelines are based on annual maximum biomass. A full year is also needed in order to understand the seasonal variation. A further 6 months of data through a spring and summer growing season and low flow period would be preferable in order to have some understanding of the inter-annual variation.

43 Data of the type I describe above would define the actual periphyton biomass in the streams and rivers of the Basin. The data would enable a more robust model of the relationship between nutrients and periphyton biomass to be developed. Such a model could then be used to provide more robust criteria for the management of nutrients in streams and rivers of the Basin.

44 The periphyton biomass targets also need to be considered. I do not consider MWRL's suggestion that a 25% increase to the existing maximum biomass across every node is a robust or defensible approach given its arbitrary development. A more robust approach would be based on an assessment of the requirements of instream values (e.g., fisheries, angling, recreation, aesthetic values) such as is set out in the New Zealand Periphyton Guidelines (MFE 2000).

45 In addition, I do not consider that the annual maximum biomass alone is a sufficient basis on which to define nutrient management of the rivers and streams of the Catchment. Effects on some values (e.g., fishing, recreation, visual amenity) may be more sensitive to the total duration at which periphyton biomass exceeds a threshold (e.g., 100 mg/m^2 chlorophyll *a*) than a one-off maximum annual biomass. In other words, it may be less acceptable that a stream has a periphyton biomass of over 100 mg/m^2 chlorophyll *a* throughout the summer than a single annual maximum of 200mg/m^2.

46 Sustained periods of relatively high periphyton biomass are very likely under intensification of land use in the Upper Waitaki Catchment because of the relatively stable flows regimes (Figure 1). I consider that more work to assess the duration of biomass exceeding certain thresholds should be made. The paper by Biggs (2000) demonstrated that models providing the relationship between the duration that biomass exceed certain thresholds and concentrations of N and P can be derived. The requirements of the instream values should be considered and if necessary, nutrient limits should be defined to restrict the duration of periphyton blooms as well as the maximum biomass.

MONITORING AND CONTROL

47 Periphyton will be the most immediate indicator of the response of the streams and rivers in the upper Waitaki Catchment to land use intensification. Given this, and the complexity of the dynamics of

periphyton biomass, it should initially be subject to monthly not the annual sampling proposed.

48 MWRL has not established or proposed to establish a baseline of nutrient, flood flow and periphyton data on which future interpretation of monitoring could be based. A minimum baseline of at least a year to 18 months of monthly data similar to that suggested above to define nutrient concentration criteria would be necessary to be able to interpret future changes in conditions in the upper Waitaki Catchment.

49 I consider that the applicant has not provided sufficient information in terms of how mitigation actions would be triggered to control nutrient loads should monitoring indicate that biomass criteria were not being met. Of greatest concern is the likelihood that there will be lag times between implementation of irrigation and effects becoming apparent. It is likely that lags will apply to a greater or lesser extent as irrigation drainage is expected to discharge to the groundwater system and then re-emerge in streams and rivers. This is of critical importance as this lag will also apply to any retrospective actions taken to mitigate effects should they become apparent. The lag means that even if necessary controls are immediately applied, the effects will continue to worsen for sometime before the situation improves.

RESPONSE TO MWRL EVIDENCE

Dr Brian Thomas Coffey, 2 September 2009

50 In section 7 of his evidence, **Dr Coffey** states that application of the MfE (2000) periphyton guidelines implies that the streams and rivers of the Upper Waitaki Catchment would have no further capacity for nutrient assimilation. This is based on MWRL's assessment of existing maximum annual periphyton biomass using the Biggs (2000) model. In my evidence I have explained why the Biggs (2000) model has not provided realistic estimates of maximum annual periphyton biomass and have provided actual measured periphyton biomass to demonstrate that (Figure 2). The measured biomass (Figure 2) indicates that streams and rivers in the Basin probably have assimilative capacity, i.e. they could receive more nutrients without breaching the MfE (2000) guidelines.

51 At paragraph 7.20 **Dr Coffey** appears to be suggesting that MWRL should not be penalised for the appearance of didymo in the rivers and streams of the Upper Waitaki Catchment, notwithstanding the fact that increases in nitrogen and phosphorus will stimulate the growth of didymo. **Dr Coffey** suggests that nutrient concentration criteria should be set to that required to achieve a specified biomass (25% greater than the existing maximum calculated by MWRL) in the absence of didymo and that where didymo is present in

waterbodies that it would be best to default to monitored nutrient concentrations. This approach doesn't seem to acknowledge that there are already a large number of waterbodies in the Upper Waitaki Catchment invested with didymo (as identified in my evidence) and this approach could result in very large biomasses in didymo affected streams because didymo can achieve higher biomasses than other species at equivalent nutrient concentrations.

Dr Gregory Ian Ryder, 2 September 2009

52 At paragraph 3.4 in his evidence, **Dr Ryder** expresses his concern about the lack of quantitative sampling of periphyton biomass in the Upper Waitaki Catchment and the subsequent inability to verify MWRL's use of the Biggs (2000) model of maximum periphyton biomass. **Dr Ryder** suggests that this can be remedied by pre-irrigation monitoring. It is my opinion that the lack of verification of the Biggs (2000) model means the assimilative capacity of the streams and rivers in the Upper Waitaki Catchment has not been established. There is a genuine risk that the criteria suggested by MWRL have overestimated assimilative capacity by an amount larger than the possible reduction in nutrient concentration by mitigation.

Dr John Charles Bright and Dr Melissa Clare Robson, 2 September 2009

53 I disagree with the statement by **Dr Bright** and **Dr Robson** in paragraph 6.38 of their evidence that the nutrient concentrations reported by the MWRL reports have provided an assessment of the current state of the system at node points. The most important state parameter with respect to the streams and rivers is periphyton biomass. This has only been estimated at node points based on the Biggs (2000) model. For reasons traversed in my evidence above this is unreliable. Therefore, it is my opinion that the MWRL reports have not established with any certainty the existing state of streams and rivers in the Basin.

RESPONSE TO SECTION 42A REPORTS

Section 42A Officer's report - Dr Arian Selwyn Meredith.

54 I agree with the conclusions **Dr Meredith** has drawn from his evaluation of the cumulative water quality effects of nutrients from agricultural intensification in the Upper Waitaki Catchment – summary report and appendices. Of particular note is **Dr Meredith's** comments on the poor evaluation of existing nutrient concentrations in the streams and rivers of the Upper Waitaki Catchment and loads to Lake Benmore. He also concludes that the problems with MWRL's assessment are such that the likelihood that

the targets will be met is very uncertain. I agree with this assessment as detailed in my evidence.

55 I agree with **Dr Meredith's** comments that the MWRL reports have misused the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (commonly known here as the 'ANZECC guidelines'). The 'default trigger values' presented in the ANZECC Guidelines are a statistical (80^{th} percentile) summary of data from a subset of the NIWA National Rivers Water Quality Network of 77 (medium to large sized river) sites throughout New Zealand. The streams and rivers of the Upper Waitaki Catchment are not represented in this national data set. I agree with **Dr Meredith** that the ANZECC guidelines cannot be used to define targets for nutrient concentrations in the Upper Waitaki Catchment.

Section 42A Officer's report - Dr Marc Schallenberg

56 I agree with **Dr Schallenberg's** conclusions. In particular I agree that the use of the TLI to determine the nutrient load criteria for Lake Benmore is inappropriate. The TLI index is used to characterise and describe trophic status of lakes, not to determine loads limits.

RECOMMENDATIONS AND CONCLUSIONS

57 It is my opinion that the streams, rivers, canals and lakes of the Upper Waitaki Catchment are likely to be very sensitive to increases in nutrients. I consider that it is very likely that periphyton biomass will frequently exceed nuisance levels in streams, rivers and canals if nutrient concentrations are increased in these water bodies. **Ms Sutherland** has presented evidence that shows that Lake Benmore's trophic state will be altered by increased nutrient loads and that the Wairepo Arm is already vulnerable to increased nutrient loads, and reaches eutrophic and hypertrophic levels on occasions.

58 Given the scale of the activity being considered by MWRL and the potential effects of this on the aquatic environments of the Upper Waitaki Catchment (including the streams, rivers, canals and lakes) it is important that nutrient criteria are carefully set. It is my opinion that the studies by MWRL do not establish with sufficient certainty the likely effects of intensification of land use or define nutrient concentrations (streams and rivers) or loads (Lake Benmore).

59 In order to have sufficient certainty it would firstly be necessary to have a greater degree of certainty in all "upstream" aspects of MWRL's assessment. There is considerable uncertainty concerning the estimates of existing nutrient concentrations and loads. Some of these uncertainties result from inadequate sampling intensity and uncertainty surrounding how measurements below detection limits were handled, which I have addressed in my evidence as has **Ms Sutherland** and **Dr Meredith**. Uncertainties concerning estimates

of existing nutrient concentrations and loads also result from the manner in which flows and concentrations have been combined as addressed by the evidence of **Dr Griffith**. There are also large uncertainties associated with the projected future nutrient losses on farms and movement of nutrients through the groundwater and surface water systems. The evidence of **Mr Potts** and **Mr Callander** indicate that there is uncertainty associated with MWRL's assessment of these upstream sources of nutrients and the processes that transport them from irrigated areas to the stream, river and lake receiving environments.

60 The dynamics of plant responses to nutrients in streams, rivers, canals and lakes is complex and influenced by natural variations such as seasonal variation and random climatic events as well as anthropogenic disturbances. Before the effect of increased nutrient loads from land use intensification on plant growth in the water bodies of the Upper Waitaki Catchment can be assessed, it is necessary to understand these existing dynamics. The dynamics of plants in the water bodies of the Upper Waitaki Catchment are not well understood and MWRL have produced no data describing either the annual variation in periphyton in rivers streams and canals of the Upper Waitaki Catchment or algae in Lake Benmore.

61 It is my opinion that the minimum data requirements for robust assessment of the effects of increased nutrients and definition of nutrient limits for the streams and rivers of the Upper Waitaki Catchment are at least one year of monthly sampling carried out at stream and river nodes and at critical locations in the lakes of the Catchment. Sampling should include nutrient concentrations and plant biomass and community composition measurements. I suggest that these data be used to calibrate models of maximum periphyton biomass and the duration of biomass above specified levels in streams and rivers of the Catchment. **Ms Sutherland** has specified in her evidence that a minimum baseline of at least 18 months of water quality, physio-chemical parameters and biological data also needs to be established for the lakes, canals and Wairepo Arm. **Ms Sutherland** has specified how such data needs to be collected.

62 Notwithstanding the all "upstream" aspects of MWRL's assessment, it is my opinion that MWRL's methodological approaches to assessment of nutrient criteria in both the streams and rivers of the Upper Waitaki Catchment and in Lake Benmore are inadequate and misleading.

63 Firstly, the rivers that were used to calibrate the Biggs (2000) model, which MWRL used to estimate annual maximum periphyton biomass and nutrient concentration criteria, are demonstrably different to those of the Upper Waitaki Catchment. Even if nutrient concentrations were reliable, application of this model would be very unlikely to produce reliable biomass estimates.

64 Secondly, as **Ms Sutherland** and **Dr Schallenberg** have discussed, MWRL have applied the TLI index inappropriately to determine their nutrient loads to the lake. The TLI index was created to define ranges of measurable water quality parameters that in combination characterise the trophic status of lakes. It was never the intention of the developers of the TLI that it be used to forward calculate nutrient loadings.

65 Finally, given the scale of the activity being considered by MWRL and the potential effects, I consider that the criteria that MWRL have defined for managing trophic status of the aquatic environments are inadequately defined. As I have discussed above, I have no confidence in MWRL's assessment that the MFE (2000) periphyton guidelines are too strict for the Upper Waitaki Catchment.

66 Notwithstanding how the maximum periphyton biomass was established, I do not consider that adding 25% to current levels is a robust method for establishing a sustainable periphyton biomass. I suggest that both the effect of maximum periphyton biomass and the duration of biomass above specified levels on all the values are considered in setting nutrient criteria for the streams and rivers of the Basin.

67 In a similar vein, **Ms Sutherland** has pointed out that the use of annual TLI as a not to be exceeded threshold to determine loads for Lake Benmore is inappropriate. I suggest that nutrient load limits for the rivers and lakes be based on a sound analysis of the biological responses to increased loads, and the flow on effects of these such as effect on frequency and duration of nuisance growths, impacts on aquatic food webs, and changes in other physio-chemical variables that affect all the values of these waterbodies.

Dated: 16 September 2009

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Antonius Hugh Snelder

References

Biggs, B. J. F. (1995). The contribution of disturbance, catchment geology and landuse to the habitat template of periphyton in stream ecosystems. Freshwater Biology, 33:419-438.

Biggs, B. J. F. (2000). Eutrophication of streams and rivers: Dissolved nutrient-chlorophyll relationships. Journal of the North American Benthological Society., 19:17-31.

ECan. 2004. Summary Report 2003/04: Investigation of Land Use Effects on Water Quality - Mackenzie Upper Waitaki Catchment (EMQ028400-3). Report prepared by Adrian Meredith and Zella Smith.

Kilroy, 2008. Data and literature review on South Island rivers affected by the invasive, non-indigenous alga Didymosphenia geminata. NIWA Client Report: CHC2008-078. Prepared for Department of Conservation.

Larned et al. 2007 Ecological studies of Didymosphenia geminata in New Zealand, 2006-2007. NIWA Client Report: CHC2007-070. Prepared for MAF Biosecurity New Zealand

Norton, N., Floeder, S., Drake, D., 2007. Hunter Downs Irrigation Scheme: Assessment of potential effects of increased nutrients on aquatic ecology values in rivers and Wainono Lagoon. NIWA Client Report: CHC2007-057. Prepared for Meridian Energy limited.

Norton, N., Spigel, B.; Sutherland, D.; Trolle, D.; Plew, D. 2009. Lake Benmore Water Quality: a modelling method to assist with assessments for nutrient loadings. NIWA Client Report CHC2009-091.

Snelder, T., Spigel, B, Sutherland, D. and Norton, N. 2005. Assessment of effects of increased nutrient concentrations in streams and lakes of the Upper Waitaki Upper Waitaki Catchment due to catchment land use changes. NIWA Client Report: CHC2005-003

Wilks and Norton, In prep. Periphyton growth and nutrient limitation in the upper Waitaki catchment. Environment Canterbury Report U07/50.