BEFORE THE CANTERBURY REGIONAL COUNCIL

UNDER	the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Hurunui and Waiau River Regional Plan before Environment Canterbury

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STATEMENT OF EVIDENCE OF DR VAUGHAN FRANCIS KEESING ON BEHALF OF THE HURUNUI WATER PROJECT LIMITED

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Qualifications and Experience

1. My full name is Vaughan Francis Keesing. I am a Senior Ecologist and principal with the consulting firm of Boffa Miskell Ltd, Christchurch. I hold the qualification of Doctor of Philosophy (PhD) in Ecology.

2. My base skills lie in community ecology, and in measuring and understanding interactions between species and their environment. I have specialist skills in the areas of limnology, entomology, zoology and botany and have worked extensively in freshwater and terrestrial habitats. My PhD thesis and subsequent research focuses on community and habitat inter-relations and invasion-disturbance ecology.

3. I have been practising as an ecologist for the last 14 years, and have worked in a variety of locations including the West Coast, Canterbury, Central North Island, Lower North Island, the Far North, Auckland Region and the Bay of Plenty.

4. During that time I have undertaken a wide range of ecological surveys of natural and semi-natural sites, incorporating both botanical and wildlife values. I have provided assessments of values and significance of sites for many Councils and private clients; and ecological effects of a range of activities on those sites.

5. I have undertaken research studies and assessments of at least 7 hydro generations systems and of over 20 subdivisions that included aquatic issues, of 42 Northland streams (four years of SES long term monitoring for Council), I have surveyed over 300 streams and rivers in that time (including low flow assessment of the Conway system) as well as assessed numerous roading, mining, quarrying, water take and other developments involving water use and discharges. I am thus very familiar with measuring aquatic ecosystems, of interpreting the data in regard to value, uniqueness and sensitivity, the changes water use, diversion, loss and discharge in regard to aquatic community response and aquatic systems in general. I have also helped design and assess stormwater devices, fish passage devices, new stream sections and wetlands in relation to improving water quality and as habitat for aquatic species.

6. I have read the current Code of Conduct for Expert Witnesses as contained in the Environment Court Consolidated Practice Note (2011), and I agree to comply with it as if this Inquiry were before the Environment Court. My qualifications as an expert are set out above. 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. I set out below my data collection, information sources, analysis and assumptions that have influenced the opinions I present.

Executive Summary

7. HWP, in progressing their irrigation water storage programme, have raised in their submissions several issues related to the Proposed Hurunui and Waiau River Regional Plan (PHWRRP) and aspects of aquatic ecology that may be affected or require testing of and have submitted changes based in part on expert technical findings arising from preparation of its resource consent applications.

8. In regard to aquatic ecology there are three primary issues associated with the Hurunui Water Project (HWP) that may be affected by thePHWRRP. These are:

- The minimum flow regime at various allocation levels (A, B & C);
- Accessing and using the C Block (33 cumec) allocation from the Hurunui River;
- Increasing nutrient (and decreasing dilution) in waterways as a result of access to irrigation water and often resultant land intensification.

9. Allocation and minimum flow regimes are based on expert opinion and a limited set of IFIM 2D modellings undertaken by NIWA. The modelling of habitat availability based on flow variation returns a wide and complex set of results which are dependent on the value (or taxa) of interest and on the level of Wetted Useable Habitat (WUA) determined as desirable for that value (from optimum downwards).

10. The effects on WUA of flows between 10 and 20 cumecs are open to debate and are dependent on the value assessed, as well as the

acceptable or desired habitat retention level. It is not clear with the science available that 15 cumecs in December and January is substantively better than 12 or even 10 cumecs.

11. The C Block allocation issue relates to the potential to remove or deflate small freshes (and normal “middle-range” flow variability) in the main stem of the Hurunui River.

12. The deflation of flows between the minimum flow regime (29-33 cumecs for the C Block) and 160 cumecs relates primarily (but not solely) to the potential change of algae/periphyton flushing flows and is dependent on when the C Block is utilised and to what extent.

13. Field work undertaken on the Hurunui River between the Mandamas and SH7 bridge suggests that flows under 120 cumecs do not materially cause flushing of late summer algae growths. Field work shows that a flow of 230 cumecs causes significant flushing of later summer growths. I have no field data for the effect of flows between 120 and 230 cumecs.

14. Modelling suggests flows greater than 120 cumecs causes flushing and flows of that magnitude create sub-optimal habitat for a range of algae. This is somewhat above the PHWRRP’s view of 1.5-2.5 times the median flow.

15. Therefore with the 17-33 cumec C block and considering two cases: the typical (consented) winter take of 17 cumecs and the worst case possible scenario (i.e. late summer-autumn high algae condition and with a potential full take of 33 cumecs) a fresh must be present of either 137 or 153 cumecs (instead of 120 cumecs) for at least a partial flush.

16. PDP hydrology modelling shows that in summer months the C block use (at 33 cumecs) results in the number of distinct events of potential flushing size to be reduced by 30%, and the mean number of days of 120 cumec flow falls from 7 to 4. There is also an increase in the mean number of days which this 120 cumec flow is absent against the “natural” regime (a 25% change).

17. Flows over 160 cumecs, (where even with the C Block take, good flushing is likely to occur) are reduced from a mean number of events of 1.5 to 1.1. The average number of days per year at this higher flow reduces from 4 days to 2 days. The duration of time beyond 6 weeks without this larger flow is not however exacerbated, but the number of days where this flow is absent is extended by 8 days (a 13% increase).

18. These changes do reduce the frequency and extent of potential partial flushing flows. However, the modelling suggests that the changes predicted do not substantively change the effectiveness of the flushes in summer (those being reliant on one or two large flows) that would have occurred over 160 cumecs.

19. The largest effect of the C Block use is to the “middle-range” flow variations which may have some function in minor flushing, as well as fish biological functions (cueing movement) - the effect of C block allocation being to remove half of the variation in flow.

20. The nutrient issue relates primarily to additional nutrient run-off from irrigation and land use intensification resulting in a potential increase in algae nuisance and potential nitrate toxicity effects.

21. Mr Callander of PDP will present nutrient related evidence (land use intensification results etc) but I examine nutrients from the point of view of their relationship with periphyton and algae and how a limit might be set, or problems monitored (as opposed to a fixed nitrogen load); and in regard to toxicity to in-stream life.

22. Nitrogen and phosphate are related to potential algae blooms but the relationship of a catchment wide loading limit to algae particular spatial issues is not simple and linear and the science behind the loading limits is based on numerous assumptions and estimation.

23. ThePHWRRP’s proposed load limits (Schedule 1) are set at or about the river’s current load levels (accepting a proposed allowance for a 20% increase until 2017), but the river remains in general good health at this level. High levels of N & P at SH1 do, however, appear to correlate with decreasing in-stream health.

24. While I appreciate and agree with the perceived need to better manage nutrient pollution, the load limits of the schedule should be a catchment guideline not a cap.

25. I also note that the proposed loading limit on the Mandamus reach appears to be less about protecting the Mandamus reach as opposed to assisting the lower SH1 reach. I am of this opinion because despite the current nutrient levels in the Mandamus reach, the ecology remains in good health.

Scope Of Evidence

26. The purpose of my evidence is three fold:

27. First it looks, in brief, at the Hurunui main stem and what is known of its aquatic ecology and the evidence behind the current ECAN proposed minimum flow regime*;* and

28. I discuss what changes could occur to the aquatic ecology process of algae accrual and flushing with the potential utilisation of the C Block water; and

29. I describe the nutrient-periphyton relationship and expectations of algae accrual based on potential in-stream-nutrient change, (including Nitrate toxicity).

30. This has involved :

    i. utilising a wide array of published and pseudo-published (such as Council reports and privately commissioned reports) literature relating directly to the Hurunui environs, as well as to periphyton biology and records including ECAN and NIWA published material supporting the proposed flow regime, and

    ii. my own main stem periphyton data that my colleague Dr Ruth Goldsmith has collected under my instruction and on the use of the NIWA (developed by Dr Duncan, and which ECAN (Mr Parish) has allowed me to use) produced 2 D habitat model for the modelling of algae flushing flows (especially Didymo flushing).

iii. collaboration with PDP in modelling and predictions of nutrient regimes in-river related to the potential water use of irrigation storage water (land intensification).

31. These are coupled with my general field experience working on the Hurunui and Waitohi River between since November 2008.

The General ecological values and condition of the Hurunui River in its upper-middle plains Reach

32. The Hurunui River, in the plains reach has become a more widely studied river in the last 5 years. It has always had an array of water quality and braided river bird research as well as salmonid research (e.g. ECAN SOE, (Meredith 2003[1]), O'Donnell & Moore 1983[2], O'Donnell 2000[3], Hughey 1985[4]). Native fishes, benthic invertebrates and periphyton have been less well researched and recorded, although more recent research related to flow requirements has been undertaken (eg Glova 1986[5], Jellyman 2009, Duncan & Shanker 2004[6], Duncan 2007[7]) and water quality has been reasonably recorded at least in the last 10 years (e.g. Ausseil 2010[8], Hayward

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[1] Meredith, A.S., Cottam, D., Anthony, M. Lavender, R. 2003. Ecosystem health of Canterbury Rivers: Development and implementation of biotic and habitat assessment methods 1999/2000. Report No. R03/3 ISBN 1-86937-477-0. Environment Canterbury.

[2] O'Donnell, C.F.J.; Moore, S.M. 1983. The wildlife and conservation of braided river systems in Canterbury. Fauna Survey Unit Report No. 33. NZ Wildlife Service, Wellington.

[3] O'Donnell, C.F.J. 2000. The significance of river and open water habitats for indigenous birds in Canterbury, New Zealand. Environment Canterbury Unpublished Report U00/37. Environment Canterbury, Christchurch.

[4] Hughey, K.F.D. 1985. Hydrological factors influencing the ecology of riverbed breeding birds on the plains reaches of Canterbury's braided rivers. Unpublished thesis PhD thesis, Lincoln College, University of Canterbury, Christchurch.

[5] Glova, G. 1986: Distribution of small fish in the Lower Hurunui River. Freshwater catch 29: 20-21 13 figs; 10 tables.

[6] Duncan, M; Shanker, U. 2004. Hurunui River habitat 2D modelling. ECAN report U04/19, April 2004..

[7] Duncan, M.J. (2007). Hurunui River habitat 2-D modelling: habitat for periphyton. NIWA Client Report: CHC2007-039 for Environment Canterbury, Christchurch.

[8] Ausseil, O. 2010 Hurunui River – Influence of the middle reach tributaries on water quality of the lower Hurunui River (2005-2008). ECAN report No. R08/55. March 2010.

2001, 2009[9], Norton & Kelly 2010[10]) as well as some IFIM modelling (NIWA, Duncan & Shanker 2004).

33. Dr Mosley (2002[11]) compiled a significant amount of information on the Hurunui waterway in general and historically Dr. O'Donnell has done so in regard to riverine Birds (O'Donnell and Moore (1983), O'Donnell 2000). Armstrong (2006[12]) reported the findings of a wide array of Hurunui River related publications under the title of intrinsic values, and in that review noted the paucity of aquatic invertebrate data, especially data characterising the river as a whole, noting some data collected with water quality and SOE data (e.g. Meredith et al 2003, Scarsbrook 2000[13], Stark 1976[14]). The native fishery is covered to a degree (Docherty et al. (1978) Docherty (1979)[15], Davies 1983[16], Bonnet and Docherty 1985[17], Glova 1986[18], Grant et al. 1999[19], Jellyman & Harding 2011[20]), NIWA freshwater water fish data base. As well as in the 2009 Water Conservation Order evidence of Dr

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[9] Hayward, S.A. 2001. Hurunui River. Results of water quality monitoring: January 1989 to December 1999. Environment Canterbury.

Hayward, S.; Meredith, A.; Stevenson, M. (2009). Review of proposed NRRP water quality objectives and standards for rivers and lakes in the Canterbury region. Environment Canterbury technical report R09/16. Heather, B.; Robertson, H. 2000: Field guide to the birds of New Zealand. Viking, Auckland, New Zealand.

[10] Norton, N. Kelly, D. 2010. Current nutrient loads and options for nutrient load limits for a case study catchment: Hurunui catchment. ECAN report R10/66

[11] Mosley, M. P. 2002. Hurunui River: in stream values and flow regime. Environment Canterbury, Christchurch. *Environment Canterbury Technical Report No*. *R 02/01*. 172 p.

[12] Armstrong, D.M. 2006. *Intrinsic Natural Values of the Hurunui River.* Department of Conservation, October 2006, Canterbury Conservancy.

[13] Scarsbrook, M. R.; Boothroyd, I.K.G.; Quinn, J.M. 2000: New Zealand's National River Water Quality Network: long-term trends in macroinvertebrate communities. *New Zealand Journal of Marine and Freshwater Research 34*: 289-302.

[14] Stark, J. D.; Fordyce, R.E.; Winterbourne, M.J. 1976: An ecological survey of the hot springs area, Hurunui River, Canterbury, New Zealand. *Mauri Ora 4*: 35-52

[15] Docherty, C. R.; Lane, W.L.; Johns, W.S. 1978: Hydroelectric development and its impact on the fishery of the Hurunui River. Christchurch, New Zealand. Fisheries Management Division. 17. [4]. Docherty, C. 1979: Submission on the fish and fishery requirements of the Hurunui River to the North Canterbury Catchment Board. Ministry of Agriculture and Fisheries, Christchurch. 48 p.

[16] Davis, S. 1983: Hurunui small hydro. Freshwater catch 19.

[17] Bonnett, M. L.; Docherty C. R. 1985: An assessment of trout stocks in the upper Hurunui River. Fisheries Research Division: 34.

[18] Glova, G. 1986: Distribution of small fish in the Lower Hurunui River. Freshwater catch 29: 20-21 13 figs; 10 tables.

[19] Grant, A.; King, W.; van Dijk, A. 1999: Hurunui "Mainland Island" project 1998/99. Department of Conservation, Christchurch.

[20] Jellyman, P. Harding, J. 2011. Aquatic ecosystem survey of the Hurunui Catchment. University of Canterbury, School of Biological Sciences report for the Hurunui Water Project, November 11.

Alibone, Dr Young, Dr Jellyman, Dr Burrell, all of whom have summarised the fish and aquatic invertebrate data associated with the Hurunui Catchment.

34. Without delving in to those reports and research and acknowledging the array of gaps in our knowledge of the Hurunui (Armstong 2006) it is suffice to say that the plains portion of the Hurunui River is generally accepted as being significant habitat for a range of riverine birds, including migratory and threatened species. It is acknowledged as a passage portion of the river (rather than habitat) that facilitates a significant salmonid fishery in the Hill country reaches, although salmon returns are diminishing. The trout fishery is most valued in the upper north branch below Lake Sumner.

35. There is insufficient knowledge in regard to the invertebrate communities across the whole river but annual sampling by ECAN at SH7 bridge since 1999 and at the Mandamus and SH1 by NIWA since 1989 provide good general condition and trend data. From that data and the acknowledgement of the higher trophic levels supported (i.e. salmon, trout, and riverine birds) one can assume that the aquatic invertebrates are present in sufficient abundance and diversity and in sufficient habitats as to support the upper trophic level taxa and abundances present and valued. Dr Burrell (2009) in his evidence for the Hurunui Water Conservation Order (HWCO) produced summary graphs of the ECAN and NIWA data that generally suggest good quality benthic faunal communities trending upwards in terms of taxa richness abundance and QMCI[21]. The QMCI indices suggesting that fauna near the Mandamus represent generally excellent water quality (habitat) which declines downstream to generally fair to poor quality by SH1.

36. Jellyman and Harding (2011) undertook further surveys and compilation of other data for the HWP programme and produced analysis and maps showing invertebrate community quality, water quality, habitat quality and fish assemblages throughout the Hurunui (but not between the Pahau confluence and the Surveyors stream section of the main stem). Their Maps are reproduced in my Appendix

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[21] Quantitative Macroinvertebrate Community Indices

1 and generally show good to excellent water quality along the main stem of the Hurunui River, a high invertebrate diversity above the Mandamus and in many larger tributaries, but a poor diversity in the lower Main stem of the Hurunui (and their faunal data does not correlate with the water quality assessment), and excellent “stream health” generally in the main stem of the Hurunui River.

37. Knowledge of the native fishery in the upper plains section (NZMS topo M33 and N33) of the Hurunui Main stem is poor with the NIWA managed Freshwater fish data base only reporting 14 records, and 4 taxa (trout, 1 record of a torrent fish, Canterbury river galaxid and common bully). Armstrong’s (2006) review reports 29 species of fish identified in the Hurunui catchment over all. Twenty five of the identified fish species being native and six of these threatened (i.e. giant kökopu, lamprey, longfin eel, shortjaw kökopu,upland longjaw galaxias and Stokell’s smelt).

38. A more recent survey (Jellyman & Harding 2011) recorded 12 taxa from 42 sites with an average diversity between 2 and 3 taxa per sample site. Only four of the 12 taxa however, were commonly distributed (trout, river galaxid, koaro, eel). Their analysis suggests that only the Pahau River had high fish diversity (Appendix 1, noting again that they did not assess the Mandamus to Pahau confluence reach); but that density of fish was high in both the Pahau and Waitohi tributaries and is likely high in the plains reach of the Hurunui River.

39. Water quality has trended down and, more recently, is trending up (Hayward 2001, 2009, Ausseil 2010, Norton & Kelly 2010), but can generally be said to have periodic issues related to nutrient contamination and resultant algae blooms or nuisance algae growths at various locations and that there is also a general spatial trend in declining water quality from the Mandamus down to the SH 1.

40. Whatever the current array of native and exotic biodiversity values, the Hurunui River is one of the major water / riverine habitats on the plains with species and habitats of increasing importance with decreasing condition and representation in the wider Region.

The proposed minimum flow regime.

41. Mosley (2002) set out to (as one of a number of objectives) identify the life supporting capacity of water and associated aquatic and riparian ecosystems.

42. Mosley reported:

    i. That the highest (flushing) flows were in winter and spring (snow melt) with a mean annual flow of 543 cumecs with a range of 3 -10 (average of 6) floods per year over 120 cumecs.

    ii. That the biomass of aquatic vegetation (mostly periphyton) is adjusted to the frequency of freshes that can shift it and that that shifting flow is around 120 cumecs.

    iii. In this report Dr Mosley suggests (but had no substantive evidence in support) that 40 cumecs (about the median flow) is likely optimum for food production and that that feature may drop off rapidly below 20 cumecs.

43. Mosley used a “rule of thumb” estimate of 25% of the median (i.e. 10 cumecs) at Mandamus as the minimum flow required for fish habitat (although he noted that this estimate required verification through a formal IFIM modelling process) and that flows over 20 cumecs are required to secure fish passage of salmonids.

44. Mosley noted a range of other “minimum” flows based on recreational requirements.

45. At that point there was a restriction regime based on a flow minima of 20 cumecs at the Mandamus in September to December, 15 cumecs January and March to August and 12 cumecs in February.

46. These minima flows are not based on modelling or other in-stream data collection and analysis systems but on observational data and a conglomerate of various factors (and expert opinion).

47. NIWA undertook, in 2004, 2 D IFIM and habitat modelling (Duncan & Shanker 2004) to model flow requirements. They did this in a 1.2 km reach of the Hurunui River 1 km downstream of the State Highway 7 Bridge. This reach was chosen for study as being representative of the braided reaches of the river.

48. In section 9 of their report they identified the most favourable flow, or flow range, for each species/life-stage that they investigated (several fish taxa, two bird taxa and benthic invertebrates). Those results are repeated below in Table 1.

Table 1. Duncan & Shanker's (2004) "optimum" flows derived from flow versus WUA[22] curves with the authors interpretation

	Flow for max WUA (m3/s)	Most efficient flow	Optimum flow
Salmon <55mm	50	5	<10
Salmon 52-102mm	<5	5	<10
Brown trout yearling	< 5	5	<10
Brown trout adult	10	10-15	10-15
Torrent fish	80	10-20	10-30
LF eel.300mm	<5	5	5-80*
LF eel <300	80	5-70	5-80*
Deleatidium	80	5-25	10-30
Wrybill Plover	40	5-10	40
Black fronted tern	50-80	5-25	15->40

49. I have omitted the recreational preferences (angling etc).

50. Duncan & Shanker (2004) went on to show the monthly minimum flow regime together with a regime proposed by Mosley (2002) and monthly flow statistics from the water-level recorder on the Hurunui River at Mandamus (Table 2).

Table 2 Comparison of two potential minimum flow regimes and the mean 7-day low flows

Month	Duncan & Shanker (2004) minimum flow (m3/s)	Mosley proposed minimum flow	Mean 7-day low flow
January	10	15	30.1
February	10	12	23.5
March	10	15	22.3
April	10	15	28.4

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[22] Wetted Useable Area

May	10	15	26.6
June	10	15	37.5
July	10	15	34.3
August	11	15	41.5
September	13	20	44.4
October	17	20	58.4
November	16	20	44.4
December	11.5	20	33.6

51. From this research the current proposed flows were developed (but you may note are not directly consistent with the output of Duncan et al (2004) or Mosely (2002) (Table 2)).

52. The proposed Minimum flow regime in General for the A Block (the base minimum) and the B block without storage and the A block and C block with 20 million cubic meters of storage is as Table 3

Table 3. ECAN plan proposed minimum flow regime.

Season	For A Block (m3/s)	For B block (m3/s)	When storage is > 20,000,000 A Block	When storage is > 20,000,000 C Block
January	15	27	15	37
February	12	27	15	37
March	12	27	15	37
April	12	27	15	37
May	12	19	12	29
June	12	19	12	29
July	12	19	12 (10)	29
August	13	20	12 (10)	29
September	15	27m	15	37
October	15	27m	15	37
November	15	27m	15	37
December	15	27m	15	37

53. In the absence of storage, the currently proposed regime for the base minimum flow, i.e. that of the A block and so the lowest flow point of the river is higher than the previous flow regime, similar to the Mosley and lower than the mean 7-day low statistics per month. The regime also generally meets the salmond requirements as described in the modelling of NIWA, but only parts of the Deleatidium, torrent fish and black fronted tern optimum requirements (See M Duncan's and Burrell's 2009 WCO evidence).

54. The cut-off for the C block, when the storage capacity is reached, satisfies all of the requirements with a slight surplus after the A and B allocations are removed (i.e. the result is slightly more than the A block minima).

55. In my opinion and given the difficulties in setting minimum flows that achieve and account for all water resource aspects and accepting that a “natural” flow regime cannot be an option; the minimum flows support the current aquatic life and in general those seasonal variations in abundances as well as all processes currently in action.

56. However, there is a range of minimum flows that might have been accepted and are acceptable and this analysis does not consider the water nutrient concentration issue (as discussed by Norton in his evidence (September 2012).

57. The analysis of Duncan & Shanker (2004, and Duncan 2007) shows that 10-20 cumecs would produce a similar result as that of the 12-15 cumecs proposed. There is no evidence substantively stronger for any one particular flow than another, as various different values are generally supported by different flows. Figure 16 (page 29 of Duncan & Shanker 2004) shows the WUA as a percentage of total area by flow and this supports a flow of 5-15 cumecs. What I can say is that in the absence of clear scientific evidence for a flow preference, the change from 12 to 15 cumec minima in December and January for the A block may be simply a precautionary approach as a flow of 12 cumec can be found to be generally just as effective for the sustainment of aquatic values as 15.

Periphyton Accrual and Flushing potential

58. While there is an acceptance in the PHWRRP of a C- block allocation and a minimum flow set on the main stem for such an allocation, there remains a potential issue in regard to accrual of periphyton in the absence of large (flood) flows and whether a C block allocation could significantly affect those flows which may still flush periphyton. Snelder (ECAN evidence September 2012) and Norton (ECAN evidence September 2012) discuss some aspects of flushing and periphyton accrual and I shall address that evidence later in my evidence..

59. This “effect” however, is unlikely for one basic reason. The flows through the summer period are naturally low, while the flushing flow

requirement (based on current data) is relatively high and the ability of the proposed takes to change or depress a potential flush flow is low. I discuss this in more detail below in my evidence.

60. Mosley predicted a requirement of at least 120 cumecs to achieve flushing, the evidence below will test this, but in essence the C block take means that a flow of over 160 cumecs (in summer-autumn) would be needed to cause a flush if 120 cumecs did result in flushing. This is a small increase in flood flow and the historic records show that a depression of 33 cumecs on potential flushing flows, while changing the frequency and duration to a degree, is unlikely to change moderate flushing flows and will have no effect on the seasonally typical one off large flood occurrences.

61. In the next section I describe periphyton and cyanobactieria biology, the factors of accrual (accumulation), the algae condition in the late summer – autumn in the upper plains Hurunui this season (2012), the adverse effects of that accrual and what flows in the Hurunui are likely to cause flushing.

62. This evidence will place in perspective the potential summer take of a C block.

Periphyton biology

63. Benthic algae, cyanobacteria and associated micro-organisms (periphyton) occur on the bed of most streams and rivers, and do not often cause environmental problems. Those taxa are an important base of the food web in most river habitats, but especially those with open unshaded braided rivers. Periphyton influences nutrient cycling, provides food and habitat for invertebrates, and may comprise a substantial proportion of aquatic biodiversity.

64. As with all organisms, periphyton require multiple nutrients for growth, maintenance of their metabolism and for reproduction. These nutrients include nitrogen (N), phosphorus (P), potassium, carbon, calcium, silicon and iron.

65. Biggs (2000a[23]) notes that the rate of biomass accrual is controlled by the supply of resources (nutrients and light) and temperature. Phosphorus, nitrogen, carbon (from dissolved carbon dioxide in the water) and light provide the energy and basic building blocks necessary for photosynthesis and cell growth to proceed. Shortages in any of these materials, or shortages in light energy, can limit the rate at which cells divide. When these become adequate to fully meet algae community demands (that is, when there is both nutrient saturation and light saturation), then temperature becomes the next most important controller of how fast the cells divide and the algae biomass develops.

66. Most research and management efforts concerned with periphyton accrual focus on N and P because the availability of these nutrients is often the limiting factor for periphyton growth. In the Hurunui River Ausseil 2010 considered it most likely that Phosphate (and not nitrogen) is the primary limiting nutrient for periphyton (algae) growth.

67. One of the most common responses to increases in N and P in streams/rivers from intensive land use is accelerated periphyton growth and accumulations of thick, slimy mats. In cases where nutrient-enhanced periphyton growth exceeds the rate of removal by invertebrate herbivores, floods and desiccation (during extreme low flows), periphyton biomass can increase to “nuisance” levels. Nuisance refers to ecologically, economically and/or recreational/aesthetically deleterious effects of accumulations of periphyton and is defined by MfE standards (Biggs, 2000a).

68. Nutrient enrichment can also cause changes in periphyton composition, and may favour toxic algal species over benign species. There are a range of potentially deleterious effects of periphyton proliferations and changes in composition. Some of the most common effects are:

    i. Benthic habitat degradation and loss of aquatic diversity (particularly for invertebrates), declines in populations, and impairment of reproduction.

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[23] Biggs, B. 2000a. New Zealand guide to periphyton: detecting, monitoring and managing enrichment of streams. New Zealand Ministry of the Environment publication, Wellington.

ii. Production of toxins or irritants and subsequent deleterious effects on contact recreation, livestock, potable water supplies.

iii. Increasing day/night fluctuations in stream water dissolved oxygen and pH, reduction of dissolved oxygen due to periphyton decomposition, and subsequent deleterious effects on aquatic animals and nutrient cycling.

iv. Impairment of angling.

v. Reduction of visual aesthetic values and creation of odour problems.

vi. Clogged irrigation and industrial water supply intakes.

69. However, as Biggs (2000a) notes in practice, linking periphyton biomass to stream nutrient concentrations is very difficult.

70. This is because of:

vii. the dynamic nature of biomass accrual and loss processes,

viii. the concentrations of dissolved nutrients measured in solution mainly reflecting nutrients that are left over after the periphyton have removed what they need and not the supply concentration,

ix. the difficulty of isolating seepage and groundwater upwelling zones to quantify the local supply of nutrients to periphyton on the stream bed.

71. Periphyton biomass accrual is not open ended and there is evidence for communities to become saturated and growth (accrual) to be asymptotically related to nutrient. That is, even with continuing abundance of nutrients, biomass of algae community types “levels off”. Biggs 2000a produces an array of examples and evidence of saturation levels.

72. Biomass accumulation is also a self regulating process as the lower cells in a mat of accumulation become increasingly less able to get light and receive less water flow and so less nutrient, thereby reducing their growth and / or even leading to their demise. Sloughing is

typically the result and accrual can become a stable process of growth and sloughing.

73. Thus, while growth rates of cells on the surface of the mat may be nutrient saturated at quite low nutrient concentrations in flowing waters, high nutrient supplies are required to develop thick mats.

74. Of greatest importance in regard to the PHWRRP is what is the nitrogen and phosphate relationship with "nuisance" algae events and especially with Didymo which is present in the Hurunui River but not (as yet) in the Waiau River (see discussion on Didymo later).

75. Briggs 2000a illustrates strong linear relationships of Chorophyll a[24] with Conductivity (a proxy for nutrient / mineral concentrations) and good correlation with DIN[25]. Noting that higher nutrient supplies allow thicker layers of periphyton to develop before the basal cells die and the mat sloughs. It is from these relationships that he develops the equations (regression model) used by Norton & Kelly (2010) to calculate a range of possible limits for the PHWRRP (Schedule 1).

76. The relationship with Phosphate (as soluble reactive phosphate) is asymptotic; the chlorophyll a response is rapid up to 20 µgl-1 and then levels off post 25-25 µgl-1.

Periphyton in the upper plains Hurunui River

77. Historic periphyton data from ECAN monitoring of the Hurunui (Meredith et al 2003) was estimated from the riverbank and should be considered as indicative, categorical data, and may not be representative of the whole river width.

78. ECAN found that filamentous algae cover at the upstream (SH7) site was below the 30% guideline level on all monitoring occasions. Both downstream sites occasionally breached the 30% threshold (three times at Footbridge, once at SH1).

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[24] Chorophyll a is a simple measureable quantum that is a proxy or strongly correlated indices of algae biomass.

[25] Dissolved Inorganic Nitrogen

79. There is anecdotal evidence of nuisance periphyton growth in the Hurunui River, which has led to complaints in the past (Mosley, 2002).

80. This year (initially 26th-27th of April 2012, the 13th July) Dr Goldsmith of Ryder Associates Consulting undertook for me, at three locations below the Mandamus confluence, a detailed periphyton survey. At that initial measure the flow in the river was 14 cumecs and had been low and stable since early March (nearly two months (60 days where accrual time is considered 52 days (Norton & Kelly 2010)). The survey was undertaken with the purpose of determining the main algae taxa involved, to establish the late summer – autumn accrual, and to set up a flow – flush monitoring programme.

81. The data show that in the upper plains Hurunui (that set of reaches above the Hurunui Bridge and to the Mandamus confluence) were dominated by Didymo. I append the Ryder report as Appendix 2.

82. The survey found that both mat and filamentous growth forms of periphyton were present at all three periphyton monitoring sites in the Hurunui River. Mat and filamentous cover guidelines for aesthetics/recreation and trout habitat and angling (filamentous only) were not exceeded at any sites

83. As was found for periphyton cover diatom mats were more abundant than filamentous growths in biomass samples at all sites. Didymo was present in all samples, and was especially dominant in samples collected near the river's edge at the Intake Road site

84. The dominance of Didymo at the Intake Road site was reflected in the higher Kilroy Biomass Index there than at the other two sites.

Table 5 taxa sampled in scrape samples and indicating by indices taxa dominance.

Site	**Intake Road**			**Bishells Road**			**SH 7 Bridge**		
Biomass sample	**2**	**5**	**9**	**2**	**5**	**9**	**2**	**5**	**9**
Filamentous Green Algae									
Mougeotia		1	1		2		2	2	2
Filamentous Red Algae									
Audouinella								2	
Filamentous Diatoms									
Melosira							3	2	2
Diatoms									
Cocconeis			2						
Cymbella			1	2					
Didymosphenia	8	8	3	7	3	2	3	3	5
Epithemia						1			
Gomphoneis	2	1	4		4	3		2	2
Gomphonema			2	1		2	2		1
Nitzschia		1	2		2	2			1
Rhopalodia	2	2							
Rhoicosphenia							2		
Synedra	2	2	1	2	2	1	2	2	

85. The Kilroy Biomass Index ranges from 0-500 and therefore the values of the index are ‘moderate’ at the Intake Road site and ‘low’ at the Bishells Road and State Highway 7 Bridge sites.

86. Chlorophyll a concentrations were below the Ministry for the Environment trout habitat and angling guideline for diatoms/cyanobacteria (and filamentous algae).

87. Ash free dry mass concentration guidelines were exceeded at the Intake Road and State Highway sites. However, the Ministry for the Environment guidelines were developed prior to the introduction of Didymo to New Zealand and therefore are not applicable to Didymo dominated communities such as are present in the upper plains Hurunui.

88. It is my opinion that it is reasonable to assume, based on the level of accrual at the 60 day period (as measured in the field), that the 120 cumec flow in early (4th) March 2012 had some, but not a complete flushing effect.

Proposed plan nutrient loading limits– and Periphyton

89. As support for the PHWRRP Norton and Kelly (2010) modelled (using Biggs 2000a chlorophyll a – nutrient equations) nutrient concentrations that link to periphyton levels, and loadings linked to

nutrient concentrations and then estimated nutrient loading that would allow a periphyton level objective to be meet (having set that periphyton objective).

90. They themselves state that there are “numerous “assumptions required in this modelling, that the current algae data is generally less reliable that desirable, and that there is uncertainty in the results but that those results are likely to be accurate in terms of the direction and magnitude of predicted periphyton growth responses to increased nutrients.

91. I agree with them that the science is not fully developed in this area and that there are numerous uncertainties (as well as difficulties in scale). But I consider that their method likely gives a good indicative output of the relationship between load of nutrients in a catchment and periphyton levels, but not a definitive one for all locations on the Hurunui River catchment.

92. Schedule 1 of the PHWRRP suggests a load limit for the catchment above the Mandamus (not inclusive of the Mandamus) of 40 tonnes per year (DIN) and at SH1 693 tonnes/yr. In the Norton and Kelly (2010) report (the plan is based) they show that the “current” DIN levels at SH1 are between 654 and 732 tonnes/year (section 4.2, page 33 and Table 6a) and at the Mandamus 34.8-44.5 tonnes/yr, and at SH7 91.6-92 tonnes/yr). These figures would suggest that the PHWRRP load limits are likely to be breached in some years given that they are averages. The same current condition and load limit for DRP also exists where by the current measures are already at or beyond the proposed load limits in some years.

93. The conclusion of the Norton & Kelly report (2010) does note that the current loadings of nutrients exceeded the nutrient standard load limit that is associated with the currently recommended NRRP nutrient concentration standards (Hayward et al. 2009) at four of the seven sites for DIN (Hurunui at SH1, Waitohi upstream of Hurunui confluence, Lower Pahau at Dalzells Bridge and St Leonards Drain); and at four of the seven sites for DRP (Waitohi upstream of Hurunui confluence, Lower Pahau at Dalzells Bridge, St Leonards Drain and Dry Stream).

94. The PHWRRP loads do not appear to be directly related to the conclusions of the Norton & Kelly 2010 report. The Norton and Kelly report (2010) provides a wide range of options (Table 6a of that report):

- Numeric objectives for periphyton biomass;
- Nutrient concentration standards linked to achieving each objective; and
- Nutrient standard load limits linked to each nutrient concentration standard.

95. The evidence is that the loading is already high below the mandamus and especially so near SH1. The PHWRRP's proposed loading limits allow a 20% increase in SH1 measure levels (i.e. 138 tonnes/year) until 2017, but otherwise are generally already breached. Indeed Mr Norton's evidence to this hearing is that there is little allowable load available when considering DRP and that development (depending on type and scale) involving using the C block and land fertilisation) is unlikely to be possible.

96. However, measures of the river in general still show good quality aquatic habitat, flora and fauna, with signs of decreasing health nearing SH1. Ecan evidence also suggests that algae issues are not frequent throughout the river but occur in the upper (low nutrient input areas) as well as the middle river (medium nutrient) and the lower river. Dr. Snelder's[26] analysis (Tables 5-6, paragraph 43-45) suggests that there is a 1.8 - 3.1 % periphyton exceedance probability (Mandamus, SH1 Hurunui River) naturally and that rises by 0.2% at Mandamus with full C Block allocation and 2.2% at SH1. These changes in probability of issue algae are small (acknowledged by Dr Snelder (para 45)), and I suggest that the relative differences, ie a 11 to 71% change from the natural probabilities are not useful statistics in judging the magnitude of change.

97. The possible result of the C allocation is the extension of time over which an exceedance may occur, i.e. 11-12 days increasing to 18-19

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[26] September 2012 Evidence of A.H.Snelder for ECAN

days (Snelder paragraph 45) is biologically speaking unclear, as the additional 7 days will exacerbate in-stream ecological issues but may not do so substantially greater than is already the case at 12 days.

98. Furthermore, Didymo is spreading from the upper system downwards and can be measured in nuisance abundance in any reach it occupies, and I suggest that it will continue to spread through the Hurunui regardless of the current nutrient loading or flows. .

99. It is not that I consider nutrient management is not necessary, quite the opposite, but it is not at all clear how nutrient levels are currently affecting or causing periphyton issues throughout the catchment. Nor is it clear that wider in-stream health is deteriorating (several evaluations suggest the main stem remains in a healthy condition) and I am therefore not convinced that the limitation of load of nitrogen (especially) as tonnes per year (with a 20% buffer until 2017) is sufficiently spatially explicit or appropriate as a limit. Furthermore, in protecting lower reaches of the main stem (i.e. SH 1), the upper reach loads appear restrictive and are not set in terms of the protection of in-stream health at that reach (i.e. the loading appears set to protect the SH1 situation, not the Mandamus reach situation).

Didymospenia geminata

100. As I have shown in Table 5 above (and as illustrated in Jellyman & Harding 2012[27]) Didymo has become a growing issue in the Hurunui River system. Currently it can be found from the Lake Sumner outlet downwards to at least SH7 Bridge, although it remains largely absent in the South Branch. Jellyman and Harding (2012) consider the south Branch absence to be because of the frequency of FER3 flows and associated quantity of sediment, as well as constant bed movement. Of interest is that the Didymo in the North branch occurs in seasonal large biomass and cover (>350 g AFDM m^{-2}) and is (as overseas literature shows) especially abundant in oligotrophic (low

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[27] Jellyman, P.; Harding, J. 2012. The impact of Didymo on freashwater communities. University of Canterbury, school of biological sciences, report for Hurnui Water Project , September 2012.

nutrient) conditions. The Hurunui River is now one of the heaviest inundated South Island rivers (Jellyman & Harding 2012).

101. Of particular interest here, and relevance to the HWRP, is that recently Kilroy and Bothwell (2012)[28] (noted also in Jellyman and Harding 2012) found that Didymo may be inhibited by high DRP concentrations (i.e. concentrations >2-4mgm^{-3}). Their research concluded that where DRP > 4 mgm^{-3}, Didymo was only present at low coverage and that coverage > 50% was correlated with DRP concentrations <2 mgm^{-3}. While this research is new and explorative and there are more complex issues than simply Didymo stalk production is negatively correlated with DRP, there is a suggestion that high DRP limits Didymo and this suggestion was put forward by Jellyman & Harding as the explanation for the current absence of Didymo in the Waitohi river system.

102. It appears possible that high DRP, while promoting (facilitating) native algae blooms may inhibit Didymo biomass.

103. In setting the load limits for DRP (at least) the question may need to be asked, should higher loading be accepted where it inhibits Didymo even in the understanding that the result will be an increased probability of other algae blooms annually? Is Didymo dominance and lower DRP better than higher DRP less Didymo and increased potential seasonal native algae blooms ?

Nitrogen toxicity.

104. The PHWRRP supports a Nitrate toxicity level of 1.7 mg/L which is the ANZEEC guide (trigger) level for 95% protection level. This level is primarily set in regard to toxicity to Salmonids. I note the current toxicity thresholds are being reviewed as outlined in the evidence of Peter Callander. The latest thresholds are based on testing of some native species.

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[28] Kilroy, C, Bothwell, M. 2012. *Didymoshenia geminate* growth rates and bloom formation in relation to ambient dissolved phosphorus concentration. Freshwater Biology vol 57: 641-653.

105. There is little research in New Zealand on toxicity levels to native aquatic species. Hickey & Vickers (1994[29]) tested nine aquatic invertebrates against concentrations of Ammonia with LC_{50}'s of between 0.18 and 0.8 mg/L. Richardson (1997[30]) researched effects of acute Ammonia toxicity to eight native fish species in which she discovered an LC_{50} range of 0.75-235 mg/L ammonia, while for salmonids the USEPA (1985) trigger (at a particular temperature and pH was 0.35 mg/L)). ECAN commissioned a review by NIWA (Hickey & Martin (2009[31])) in which they found that the international acute toxicity data had only four species found in Canterbury's water bodies (rainbow trout, lake trout & Chinook salmon), including one indigenous species, the native snail, (*Potamopyrgus antipodarum*). However, there were also five representative species, including amphipods, caddisflies and a snail.

106. That review did not find sufficient data for assessment of native fishes (or invertebrates), nevertheless it did conclude that overall, the acute nitrate data showed macroinvertebrates were the more sensitive organisms, while the chronic data showed fish to be more sensitive to long-term exposures. A table of guideline values was produced based on the level of toxicity and value of habitat affected from overseas literature (and is where the PHWRRP attains its recommend 1.7 mg/L) (see table 6 below).

Table 6

Guideline type	**Application to:**	**Guideline value (mg NO3-N/L)a**
Acute	Very localised point source	20 mg NO3-N/L
Chronic– high conservation value systems (99% protection)	Pristine environments with high biodiversity and conservation values.	1.0 mg NO3-N/L
Chronic – slightly to moderately disturbed systems(95% protection)	Environments which are subjected to a range of disturbances from human activity.	1.7 mg NO3-N/L
Chronic – highly disturbed systems (80 to 90% protection)	Specific environments which: (i) either have measurable degradation; or (ii) which receive seasonally high elevated background concentrations for significant periods of the year (1-3 months)	2.4 – 3.6 mg NO3-N/L
Chronic – site-specific(species-specific protection)	Collection of specific data for representative species and life-stages with calculation of site-specific guideline values.	No data

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[29] Hickey,C.W.; Vickers, M.L. Toxicity of ammonia to 9 native NZ freshwater invertebrate species. Archives of environmental and toxicity 26: 292-298

[30] Richardson, J. 1997. Acute ammonia toxicity of 8 NZ indigenous freshwater species. NZ journal of marine and freshwater Research. Vol 31:2 pgs 185-90.

[31] Hickey, C.W.; Martin, M.L. 2009. A review of Nitrate toxicity to freshwater aquatic species. ECAN reportR09/57. June 2009.

a Multiply by conversion factor of 4.43x to convert to NO_3

107. An American review (Carmago et al 2005[32]) presented toxicity results for a range of fish, aquatic invertebrates and amphibians. The invertebrates tested included a *Hydropsyche* sp. a genius present in New Zealand and *Potamopyrgus antipodarum*, also present in NZ. The range of LC_{50} concentrations for the *Hydropsyche* included: 4.5 to 183.5mg/L. The LC_{50}'s for the snail were 195-2009 mg/L. The freshwater crayfish (*Astacus astacus*), had only minor up take of water borne nitrates (14 mg/L) and no death.

108. While these results are not for NZ taxa, the similarities may suggest that New Zealand invertebrate taxa may be of an equivalent magnitude of sensitivity. This paper recommends a level of 2 mg NO3-N/L is appropriate to protect sensitive freshwater species (similar to, but different from the guideline for 95% protection habitats). The ECAN review shows that Acute toxicity results are found generally above 10 mg/L and often nearer 100 mg/L, while Chronic effects are found between 1.5 and 2.5 mg/L.

109. In the absence of New Zealand taxa testing these numbers must be viewed only as best current estimates, and precautionary.

Hurunui River Periphyton Flushing Flow requirements.

110. In mitigating summer algae issues and of increasing importance where nutrient levels are to increase in the Hurunui system, flow disturbance and enhanced sloughing by floods becomes of greater interest and benefit.

111. The question then falls as to what is required to flush periphyton in the main stem of the Hurunui River below the Mandamus confluence?

112. The quantity of water that may cause a flush depends on the substrates present, the age taxa present and the extent (biomass), the

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[32] Camargo, J.A.; Alonso, A.; Salamanca, A. (2005). Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates. *Chemosphere 58*: 1255-1267.

health and "floppiness" of that algae, the quantity of suspended solids in the water and then the volume and velocity of the flow.

113. There are three ways algae may be affected by high flows: the first is, sharing off of the top "bits" of long filamentous algae beds (the "floppy bits" are "ripped" off); the second is that the substrates on which the algae are attached are rolled and tumbled and this scraps and rips off large areas of the algae; the last is that large amounts of suspended sediments "rip" through the algae (like shotgun pellets) and tear up the algae.

114. The question arises then as to what velocity and volume of water for what duration is required to do any or all of these processes to an extent that changes the biomass and distribution of algae present.

115. There is a general "rule of thumb" in aquatic ecology circles that a flow that is three times (and sometimes noted as 4-6 times) the base (or median) flow will have such an effect (sometimes termed the FRE3). However, that rule of thumb (loosely established based on Clausen & Biggs 1997)[33] is actually about the frequency of flows that have a notable impact on biological variables (periphyton, macroinvertebrates etc). Clausen & Biggs (1997) stated that it is the frequency of flows that are of a magnitude of three times the median that have the greatest "impact" on biological variables. This is not therefore advocating that the FRE3 is of the correct magnitude to flush algae in all cases.

116. A minimum flow requirement for flushing must be a flow that has sufficient force to either move the substrate or "rip" off algae. The PHWRRP suggests that a flow of 1.5-2 times the median flow is important for flushing periphyton (page 7) (i.e. 60-80 cumecs at the Mandamus).

117. There is a surprising lack of specific data and analysis on this flushing factor, but as any hydrologist will tell you it is possible to calculate the flows in any river that will cause bed movement and

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[33] Clausen, B. Biggs. B. 1997. Relationship between benthic biota and hydrological indices in New Zealand streams. Freshwater Biology vol 38: 327-342

shear forces can be calculated too. In the following section I relate three recent flushing flow measures reported from the Hutt River, Opua River and the Manawatu River as examples of flushing flows that have been measured.

River examples of flushing flows

118. Ryder and Associates (2010)[34], in researching the Hutt River examined requirements via IFIM modelling and a range of in-field observations for "surface" and "deep" flushing. They found that in relation to "deep" flushing causing sediment mobility a flow of 25-30 cumecs was required on a base flow (that being a median of 14 cumec and a 7-day MALF of 3.7 cumec). In this report Ryder et al describe a flush that causes 50% surface and 25% deep flushing of periphyton as indicative of a flow that causes considerable periphyton flushing.

119. Across the length of the river they report the following in regard to flushing periphyton (Table 6). They used the inflection points from their modelled outputs of flushing versus flows.

Table 6

Place	Substrate size	Median flow	Flow (cumecs) to attain 50% surface flush	Flow (cumecs) to attain 25% deep flush	Difference from the medina
Birchville (2 areas)	155-230mm	12.4	30-75	65-290	X 2.5 - 6
Akatarawa confluence	136.7mm	~15	40	50	X2.7 – 3.3
Taita gorge	152.1mm	14.2	125	325	X 8.8 - 23
Melling Bridge	52.4mm	>20	50	85	X2.5 – 4.3

120. It can be seen from the table above (Table 6) that substrate size plays a large role in determining the flush effect as at the Melling

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[34] Ryder & associates. 2010. Hutt River: Assessment of algal growth and other potential aquatic impacts from reducing flow in the Hutt River at Kaitoke. A report prepared for GWRC.

bridge site above with the largest median flow required the least flow for "deep" flushing. Typically between 2.3 and 6 times the median flow was required to get a mix of surface and deep flushing over a substantial portion of the waterway.

121. The Opua River flushing flows were examined by NIWA (Dr Arscott[35]) in 2008, using observation, experimental design and field work. In that report they present magnitudes of difference between the pre-flush mean flow (at around 5 cumecs (2.7-9.3) and the flushing flow (18-42 cumecs).

122. Those magnitude ratios ranged from 2.5 to 10 and averaged 5.88 times the pre-flush mean. They also found that flushing flows generated by the dam release reduced in effect the further downstream the pulse travelled.

123. On the Ashley River (a river about half the flow of the Hurunui River) Scrimgeour and Winterborn (1989)[36] noted that reductions in benthic periphyton density occurred when flow exceeded about 30 m^3s^{-1}, the minimum discharge at which they recorded small cobbles are moved. Whereas floods of over 400 cumecs completely altered the benthos.

124. In the West Kowai and Tongariro Rivers Jowett and Biggs (1997)[37] measured chlorophyll a and AFDM (ash free dry mass) and found that a 3.8 times median flow decreased the AFDM by 14% (i.e. a small decrease) while the Chlorophyll a measure increased; whereas a 5.5 times median flow (in the Tongariro River) clearly scoured periphyton and a 4.4 times median flow removed over 75% of periphyton (measured by AFDM). The effect on periphyton was due to velocity changes of floods, shear stress appeared to remove less of healthy algae communities that earlier literature reports. The changes in AFDM appear to be related to removal of dead, or decaying algae whereas Chlorophyll a represented healthy algae presence. They

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[35] Ascott,D.B.; Kelly,D.J.; Tuck, E. 2007. Flushng flows for the control of nuisance periphyton growths in the Opuha-Opihi river systems (20042009). A NIWA report (CHC 2007-034) for the Opuha Dam company.

[36] Scimgeour, G.J.; Winterbourne, M.J. 1989. Effects of floods on epilithon and benthic. macroinvertebrate populations in an unstable New Zealand river. Hydrobiologia 171: 33-44

[37] Jowett, I.; Biggs, B. 1997. Flood and velocity effects on periphyton and silt accumulation in two New Zealand rivers. NZ journal of marine and Freshwater Research, 31: 3, 287-300.

attributed effective flushing to velocity but also the quantum of sediments incorporated in the flood, noting a second flood, not substantially different in size (with much reduced sediment), did proportionally less flushing.

125. The over view is that flushing flows occur in different systems at widely different flows (small to large) and are dependent mostly on water velocity and suspended sediment (the shot gun pellets) but that generally at least a 3 times median flow may result in effective flushing.

Hurunui Flushing

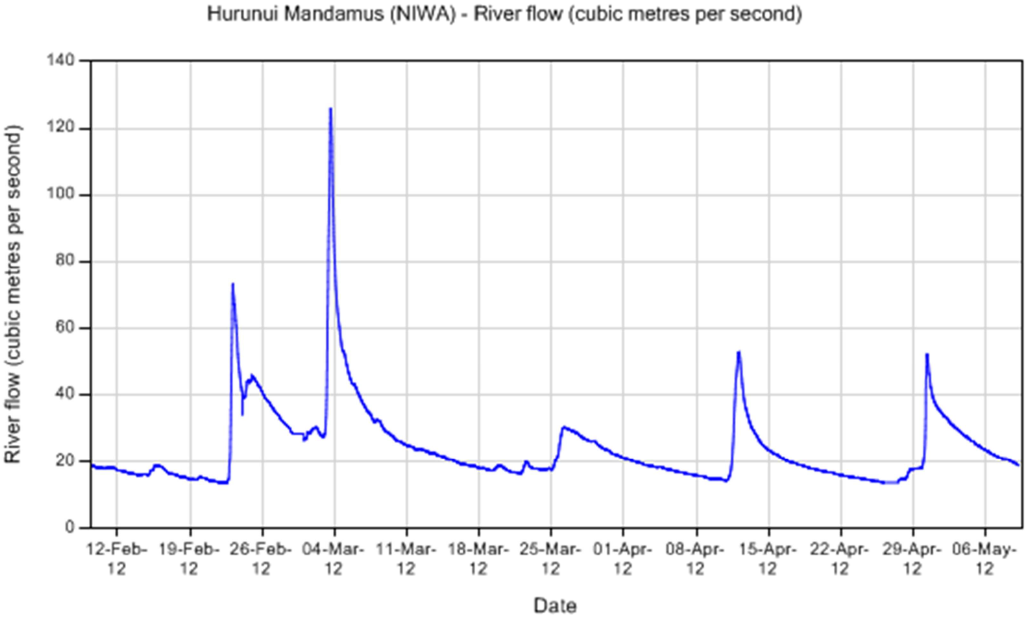
126. For the middle reach of the Hurunui, that is between the Mandamus confluence and SH 1 bridge, where the median flow is around 40 cumecs, the rule of thumb (and I suggest Dr Mosley's estimate rationale) makes a flushing flow to be around 120 cumecs.

127. The substrate in that section of the river is generally 20% medium cobble (150mm) to larger cobble 20% (250)mm with a range of smaller substrates (70-150 mm) and only 10% small cobble / gravel – i.e. predominantly larger sized substrate requiring greater velocity to shift than a bed of smaller substrate. The bed could be treated as having a substrate size of 150mm, further suggesting at least 3X the median flow magnitude is required.

128. The algae monitoring plots I had installed over 2012 April suggest that freshes of less than 60 cumecs do not result in a flush (Figure 1). The accrual (biomass) measured in late April further suggest that the one 120 cumec flush (early March (4th)) is likely to have had some impact, but not of good clearance. The biomass measured at the three sampling areas suggest an accrual time at measurement of over two months.

129. It can be seen by the ECAN river flow hydrograph (Figure 1) that since the 4th of March no flows have been recorded over about 70 cumecs and the river has sat generally around 20 cumecs since the 4th of March with two small 40 cumec freshes which appear to have had no notable periphyton flushing effect.

Figure 1. ECAN web site river flow monitoring output for the Mandamus flow recorder over the 2012 summer.



130. Duncan (2007) undertook to develop a 2D model periphyton for the reach just below the Hurunui SH7 bridge, some 21 km downstream of the Mandamus (and the flow recorder) and some 5 cumecs less than that recorders records (due to the Amuri water take). In that report he shows WUA for periphyton (long and short filamentous and diatoms) with flow. His conclusions were as follows:

i. long filamentous algae at **12** m^3/s is confined to the edges of the main stem and to shallow side braids and seeps. As flows increase to **30** m^3/s the edges of the main stem become too swift for long filamentous algae and suitable habitat is confined to minor braids and seeps.

ii. Short filamentous algae occupy edge habitat and shallow riffles at a flow of **12** m^3/s, but at higher flows physical conditions in riffles become too deep and swift, thus physical habitat for short filamentous algae is limited to the edges on the main stem and shallow side braids.

iii. At flows of **12** m^3/s, diatom WUA occurs in deeper and faster parts of the main stem of the river. At 30 m^3/s there is more of this type of habitat, but conditions in the fastest and deepest parts of the river start to become too harsh to provide suitable physical habitat for diatoms.

131. Their research suggests that generally over 12-30 cumecs in the middle-upper reach restricts filamentous algae habitat, but does not suggest flushing flows.

132. HWP commissioned NIWA (Dr Duncan) to run his 2D model for long filamentous, short filamentous, Diatome and Didymo flush requirements in the upper middle reaches of the Hurunui main stem at higher flows. A Didymo habitat curve, supplied by Mr Jowett, was used along with NIWA LGF and SGF and Diatome habitat curves. He tested flows from 40 to 300 cumecs.

133. The model, rather than predicting flushing flows, predicts useable (suitable) wetted habitat. To do this with least biases he restricted the model to the area occupied by the median flow. I have assumed that where WUA diminishes as flow increases (noting the above "optimal" WUA results) is the position where flushing may become effective. For example (and with reference to the table below) LGF begins to have diminishing WUA at 60 cumecs and has half the WUA at 160. Whereas short green filamentous algae appear to start to diminish in WUA (flush) at around 60-80 (perhaps 70) cumecs and flushes readily after that. Diatoms may not be substantively flushed at any flow under 300 cumecs.

Table 7 Weighted useable area for algal species in the median flow bed of the Hurunui River (NIWA 2012)

Flow (m^3s^{-1})	**40**	**50**	**60**	**80**	**120**	**160**	**200**	**240**	**300**
Species	WUA (m^2m^{-1})	WUA (m^2m^{-1})	WUA (m^2m^{-1})	WUA (m^2m^{-1})	WUA (m^2m^{-1})	WUA (m^2m^{-1})	WUA (m^2m^{-1})	WUA (m^2m^{-1})	WUA (m^2m^{-1})
Long filamentous algae	16.28	16.71	14.37	12.03	8.34	5.72	3.84	2.90	0.53
Short filamentous algae	16.66	19.02	20.44	15.54	11.27	9.05	7.06	4.20	2.59
Diatoms	32.35	30.84	30.52	30.45	28.62	27.40	26.27	25.34	27.49

Didymo (Jowett)	45.03	43.48	42.14	39.72	33.91	29.12	25.49	21.83	20.05
Didymo (Chisholm)	61.78	59.97	56.91	51.88	41.83	34.24	28.73	23.35	17.76
Wetted area	96.9	96.9	96.9	96.9	96.9	96.9	96.9	96.9	96.7
Mean depth (m)	0.50	0.56	0.62	0.72	0.89	1.02	1.14	1.24	1.37
Mean velocity (ms^{-1})	0.67	0.78	0.87	1.02	1.24	1.40	1.53	1.65	1.78

134. Two curves are utilised for Didymo (Jowetts and Chrisholms) I prefer the Jowett curves as they are more recent and made with knowledge of Chrisholm's. The results suggest that diminishment in WUA begins after 40 cumecs, and starts to be more substantive after 80 cumecs and then is progressive and large after 120 cumecs.

135. The WUA is a diminishing curve with flow in regard to Didymo (indeed all the algae) and there is no "flush" event (i.e. large drop) noticeable in the curves and that is to be expected using the IFIM 2D model meaning this process does not produce a clear and definitive flush flow from the modelling. Curves of the results are shown in Annexure 1).

136. My interpretation of the data modelling is that flows greater than 80 cumec begin to potentially flush (on a base summer flow) LGF and SGF while flows of 120 and more may begin to flush Didymo; but it requires flows of larger magnitude (over 200) to cause "full" bed moving flushes.

Periods of Flushing flows in Summer- Autumn and the C Block Allocation.

137. From the above discussion I recommend that while flushing may begin to occur at 80-90 cumecs that substantive effective flushing does not occur until over 120 cumecs and that significant flushing is at flows over 200 cumecs (but in the analysis below I use 160 cumec).

138. PDP have calculated flows based on the proposed water use of the HWP in the Hurunui River, below the Mandamus. I present in the following three tables, those estimates of the effect to the frequency and periodicity of flows of around 60, 120 and 160 cumecs. It is these flows that I consider may be most affected by the C block

takes and note that flows of 120 and 160 (as noted above in my evidence) are those flows with potential flushing functions that will be depressed by the C block at full summer allocation.

139. The following statistics are for a typical period of 1 December to 31 April, being that period of time seasonally that is most likely to have algae issues and at which time flushing flows can be influential to wider biological quality in the Hurunui River.

Table 8: For flows greater than 60 m^3/s

Statistic	Natural flow	Existing Irrigation Development	Modelled Full Irrigation Development
Mean days per annum	31	29	15
Mean number of distinct events per annum	5.8	5.3	3.8
Mean number per annum absent more than 6 weeks	0.9	1.0	1.2
Mean number per annum absent more than 21 days	1.9	1.9	1.9
Mean number of days absent	19	21	30

140. These statistics show that quantity of flows of around 60 cumecs are nearly halved (45% less) by the C Block allocation, and the number of average days at this flow are halved in summer. There is an extension of time without a flow of around 60 cumecs by a magnitude of 25%, but no change to a shorter duration statistic (21 days). There is however, an increase (63%) in the number of days over summer that such a flow does not occur. There is no flushing effect of this reduced flow regime nor is there a decrease in the sustainability of the system, but there is a longer period of low and reduced variability flow.

141. Modelling of the larger flows (i.e. 120 cumecs) show the mean number of days at that flow falls from 7 to 4. The number of distinct events of flushing size declines by 30%, but otherwise the periods between flushes (i.e. the time between events) changes little, as does the number of days such events are absent. There is an increase on the mean number of days which this flow is absent against the "natural" regime (a 25% change).

Table 9: For flows around 120 m^3/s

Statistic	Natural flow	Existing Irrigation Development	Modelled Full Irrigation Development
Mean days per annum	7	7	4
Mean number of distinct events per annum	2.3	2.2	1.6
Mean number per annum absent more than 6 weeks	1.2	1.3	1.2
Mean number per annum absent more than 21 days	1.8	1.8	1.7
Mean number of days absent	45	47	57

142. Flushing size flows are therefore diminished in frequency and the periods between such flows extended by the takes, but the period between flows is still beyond expected accrual times (roughly 40-50 days). This would mean greater accrual periods and therefore generally an ability for greater abundances of algae to populate the river; however, the extension of time and reduction in frequency is not so great as to cause extreme ecological concern.

143. In the following table PDP looked at changes to flows which, even with the takes, are likely to cause flushing (i.e. > 160 cumecs).

Table 10: For flows greater than 160 m3/s

Statistic	Natural flow	Existing Irrigation Development	Modelled Full Irrigation Development
Mean days per annum	4	3	2
Mean number of distinct events per annum	1.5	1.4	1.1
Mean number per annum absent more than 6 weeks	1.2	1.2	1.2
Mean number per annum absent more than 21 days	1.6	1.6	1.5
Mean number of days absent	61	63	70

144. Here we see that flushing flows are reduced from an average of 1.5 events to 1.1, a small reduction. The duration of time beyond 6 weeks without this larger flow is not exacerbated, but the number of days where this flow is absent is extended by 8 days (a 13% increase).

145. PDP have also prepared a hydrograph showing (from flow data since 1981) the expected flow regime with and without the proposal (this is appended as Appendix 3). That hydrograph shows that in the modelled situation, there would have been three potential flushing flows of which none were sufficiently sized (i.e. dropped below 120

cumecs) that the periphyton flushing flow would have been notably diminished.

Conclusion of flushing in the Hurunui River below the Mandamus

146. For the middle reach of the Hurunui, (between the Mandamus confluence and SH 1 bridge) where the median flow is around 40 cumecs, the rule of thumb (and we suggest Dr Mosley's estimate rationale) makes an effective flushing flow to be upward of 120 cumecs. Dr Duncan confirmed (Duncan 2007, and WCO evidence 2009) that in his opinion a flow of 120 cumecs was sufficient, and that at 120 cumecs there would not need to be a prolonged duration of such a flow; smaller flows may require 2 days (his estimate only).

147. The periphyton accrual measured in late (26th) April 2011 suggest that the one 120 cumec flush experienced in early March did some flushing but the flows under 80 cumecs did little given the quantities of periphyton measured. Recently, the effects of 228 cumecs were measured and the results show that a very effective flush was achieved by that flow.

148. It is, on the above evidence, my assessment that the C Block allocation while significantly affecting flows under 60 cumecs, will not significantly exacerbate flushing function because significant flushing flows (flows > 200) will not be affected. Minor flushing flows are reduced, but these, being minor and their function dependent on where in the accrual cycle the periphyton communities, are not of significant aquatic ecological concern.

149. I note that in the application for resource consents HWP has proposed conditions that will cause them to shut the intakes on the Hurunui River for summer flushes, dependent on periphyton monitoring, so that these minor flush events will in fact be allowed to pass unaffected (not reduced) in support of the river heath.

Conclusion.

150. Generally the main stem of the Hurunui and its upper catchment tributaries are in reasonable health with good densities of aquatic species (there are reaches with poor water quality and differing in-stream biology values), but there is some evidence of a general but not consistent decline downstream from the Mandamus to SH1. The connection to nutrient loading is in my opinion not clear and expressly correlated with nutrient loading.

151. While there are seasonally related sporadic periphyton issues they are not consistent and spatially dominant and have a relatively low exceedance probability (now or with the C block allocation). Nutrient levels at SH 1 one are higher than elsewhere and appear to correlate with a lower in-stream health, but I am not aware that there is a correlated linear periphyton issue, Didymo for example is an upper reach issue (currently) and will become a lower river issue in time and possibly regardless of the nutrient background. Furthermore a number of different measures suggest varying health patterns persist in the lower reaches and the ecological issue related to nutrient in the Hurunui is not clear.

152. The science supporting 15 cumec as opposed to 12 cumecs as a minimum flow in December and January is not definitive in regard to either flow.

153. The nutrient loading caps of schedule one are at the current river loading levels (implying no “headroom” for additional nutrients) and are too low if one accepts that the river is generally in good health. The low cap in the upper-middle reach (Mandamus) appears to target protection of the lower reach, rather than be strictly relevant to issues of the upper-middle reach, (although I acknowledge that given the connected nature of waterways this is problematic and there may be no way around that fact).

154. It is my conclusion that the C Block allocation while significantly reducing lower flow variability will not affect effective flushing flows. Partial flushing flows (in the absence of mitigation actions) however, are reduced by around one third. Events that make

a significant difference are not affected. There are consent conditions on water take uses of the magnitude of HWP that can mitigate this effect.

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Boffa Miskell

4th October 2012.