Before the Commissioners appointed by Canterbury Regional Council

IN THE MATTER OF The Resource Management Act 1991

AND

IN THE MATTER OF Applications by the Central Plains Water Trust and Central Plains Water Ltd. to Take and Use Water for Irrigation in the Central Plains area.

Section 42A Officer's Report

Date of Hearing: 25 February 2008

Report of MAURICE JOHN DUNCAN

INTRODUCTION

1. My name is Maurice John Duncan. I hold the qualification of Master of Agricultural Science in Agricultural Engineering from Lincoln University. I am a member of the New Zealand Institute of Agricultural Science, The New Zealand Hydrological Society, The New Zealand Freshwater Sciences Society and the New Zealand Soil Science Society. I have been employed by the National Institute of Water and Atmospheric Research and its predecessor organisations for 39 years. I am currently employed as a Senior Scientist in the field of surface water hydrology. My recent experience is with hydrodynamic modelling, the effects of hydrological flow regimes on instream values and the effects of land-use change on hydrology. Before the Rakaia River Water Conservation Order hearing I co-authored a paper on the relationship between flow in the Rakaia River and the instream habitat for juvenile salmonids and native fish. (Glova and Duncan 1985). I also presented data on the Rakaia River water resources at the Rakaia River Water Conservation Order hearing. I also have 15 years experience of on-farm irrigation scheduling.

2. I acknowledge that I have read the code of conduct for expert witnesses contained in the Environment Court's Practice Note dated 31 March 2005. I have complied with it when preparing my written statement of evidence and I agree to comply with it when I give this oral evidence.

3. This report is prepared under the provisions of Section 42A of the Resource Management Act 1991 (RMA). This section allows a Council officer to provide a report to the decision-maker on a resource consent application made to the Council, and allows the decision-maker to consider the report at the hearing. Section 41(4) of the RMA allows the decision-maker to request and receive from any person who makes a report under Section 42A "*any information or advice that is relevant and reasonably necessary to determine the application*". This report will provide information and advice related to:

- A brief description of the hydrology of the Waimakariri and Rakaia Rivers,
- An assessment of potential cumulative effects of abstractions on the hydrology of the rivers,
- Assessment of the effects of bywash flows on the receiving rivers,
- An assessment of potential cumulative effects of abstractions on the bedload transport in the rivers.

4. I also provide a brief 'executive summary' of the key conclusions reached by the Central Plains Water Scheme (CPW) on the topics listed above. I will comment on their method of assessment of effects, and whether it is appropriate to quantify the effect using those methods. I will comment on whether the inputs and assumptions used appear to be appropriate, and if not, the reasons for and significance of my conclusions.

5. I will discuss whether I agree with their overall conclusions, and, if not, my reasons. I will state whether I agree with the conclusions of CPW that the effects will be minor, and, if not, what mitigations might be appropriate.

Key CPW conclusions regarding hydrology of the Waimakariri and Rakaia Rivers

6. This section presents my understanding of the key conclusions reached by CPW in regard to aspects of the effects on the hydrology of the Waimakariri River, as detailed in Golder Associates (Dec 2007). That report assumes a maximum take of 25 m^3s^{-1} from the Waimakariri River:

(a) Flows in the 65-115 m^3s^{-1} range will be the most affected, as water will be abstracted down to a flow of 64.24 m^3s^{-1} (B permit minimum flow of 63 m^3s^{-1} plus 1.24 m^3s^{-1} of B permit water allocated to Ngai Tahu Properties Limited). This may cause some flat lining of the river at this level.

(b) The maximum take rate of 25 m^3s^{-1} will occur 24% of the time.

(c) The median flow will be reduced from 75 m^3s^{-1} before CPW to 63 m^3s^{-1} after CPW (a 16% reduction) and summer (November to April) median flow will be reduced from 66 m^3s^{-1} before CPW to 44 m^3s^{-1} after CPW (a 33% reduction).

(d) River flow will be at the minimum flow of 41 m^3s^{-1} for longer increasing from 15% of the time before CPW to 33% after CPW and in summer increasing from 26 % of the time before CPW to 48% after CPW.

(e) CPW will reduce FRE3 (3 times the median flow) and MIN3 (3 times the minimum flow) events by less than 10 % comparing before and after CPW. When comparing no abstraction with CPW there is a 14 % reduction in the number of FRE3 events and a less than10% reduction in MIN3.

(f) Time between FRE3 and MIN3 events will increase by 14% and 12% respectively during summer when comparing before and after CPW. When comparing no abstraction to after CPW time between FRE3 and MIN3 events increases by 21% (9 days) and 31% (4 days) respectively.

7. This section presents my understanding of the key conclusions reached by CPW in regard to aspects of the effects on the hydrology of the Rakaia River, as completed by Golder Kingett Mitchell (March 2007):

(a) The maximum take of 20 m^3s^{-1} for CPW alone will occur for 8% of the time and for 18% of the summer.

(b) The maximum take of 40 m^3s^{-1} for CPW plus ACWT will occur for ~26% of the time and for ~28% of the summer.

(c) CPW take will not cause flat-lining of the river, due to varying monthly minimum flows and flow sharing rules.

(d) CPW will not increase time at the 7-day MALF.

(e) Cumulative effect of water abstraction reduces natural flows to CPW + ACWT + existing takes.

(i.) Median river flow reduction 159 – 132 m^3s^{-1} (17% reduction).

(ii.) Summer median reduction 187 – 155 m^3s^{-1} (17% reduction).

(f) Flow range affected the greatest by CPW is 218-348 m^3s^{-1} (5-6% reduction).

(g) The cumulative effect of existing takes plus CPW on summer FRE3 is a 21% reduction in the number of floods.

(h) Median rate of take in summer (Nov-Apr) is only 1.6 m^3s^{-1}. Low due to minimum flows and flow-sharing.

Hydrology

8. The proposed takes of up to 40 m^3s^{-1} from each of the Rakaia and Waimakariri Rivers may have potentially significant effects on their hydrological regimes and so it is worthwhile investigating the effects of the abstractions. The proposed scheme will also increase the flow in many lowland streams many of which flow into Lake Ellesmere and these will be commented on by Ms Hayward and others.

My assumptions:

9. That the unmodified flow of the Waimakariri River is the mean daily unmodified flow record prepared by Mr Richard de Joux of Environmental Consultancy Services Ltd. for North Canterbury Fish and Game Council as detailed in Appendix 1. I have reviewed the methods that Mr de Joux has used to derive the flow series. He appears to have made a comprehensive assessment of the likely takes and the series is arguably as good as could be derived given the lack of hard data on some of the historic and current take. I understand the applicant has also used this same series as the basis for their recent assessments of the hydrological effects of the scheme.

10. That flow in the Rakaia River is that recorded at either the Gorge or Fighting Hill recorders.

11. I have found it difficult to determine the exact extraction regime proposed by CPW especially with regard to the consents to take water from the Waimakariri River. On one hand the application is for a 40 m^3s^{-1} take and yet the Golder Associates (December 2007) report details a maximum 25 m^3s^{-1} take. Then there is the issue of whether or not their published analyses assume use of A permit water.

12. In an attempt to overcome these issues I have used demand series supplied by URS that are known as 20:25:240 and 20:40:220 where the first number refers to the Rakaia maximum take, the second to the Waimakariri maximum take and the third number refers to the reservoir capacity in terms of millions of cubic meters. I assume that the demand series provides the takes that would occur given that Rakaia water would be taken first, and the irrigation demand as determined by climate and crop mix and distribution constraints.

13. Because of the uncertainty of the assumptions used to derive the two scenarios I have been unable to confirm or duplicate the exact values of the analysis presented by the applicant, but I believe my analysis will be close enough to determine the general nature of the effect of the proposed scheme.

14. I have assumed the definition of summer as in Golder Associates (December 2007) to be from 1 November to 30 April and an analysis period of 1967 to 2001 to make my analysis comparable with theirs. However, it is my experience that it is common for irrigation to commence during October and less commonly in September.

15. Appendix 2 outlines the methods I have used to create 4 datasets using the flow record from the Waimakariri River at Old Highway Bridge (site number 66401) as recorded by Environment Canterbury.

(a) *Unmodified flow – includes estimates of long –term stock water takes, and abstractions for others users from river added back to record until June 2006, as defined by de Joux in Appendix 1.*

(b) *Residual flow (CURRENT) - A Permit only (Take during summer1 Nov- 30 Apr) (decreasing allocation from 63 m^3s^{-1}) including a 4 m^3s^{-1} unrestricted take.*

(c) *Residual flow – CPW 20:25:240 scenario - the current take (b above) plus the modeled 25 m^3s^{-1} demand.*

(d) *Residual flow – CPW 20:40:220 scenario - the current take (b above) plus the modeled 40 m^3s^{-1} demand.*

16. For the Rakaia River I understand from Mr Fietje that 33.84 m^3s^{-1} of the 70 m^3s^{-1} able to be allocated from the Rakaia River according to the conditions of the “National Water Conservation (Rakaia River) Order 1988” (WCO) have already been allocated. Thus only 36.16 m^3s^{-1} is currently available for allocation.

17. Accordingly in my simulations for the Rakaia River when considering only CPW I have assumed that 20 m^3s^{-1} was available above the current allocation that is in bands that have a higher priority than the CPW water. When considering both CPW and ACWT I assume that 36.16 m^3s^{-1} was available in a band with lower priority than other allocations.

18. I assumed that the takes were fully exercised all the time as there are no restrictions on the takes.

Review of the hydrology of the Waimakariri River

19. I would like to draw your attention Table 1 that shows changes to flow statistics from the unmodified flows if the various take scenarios had been in operation from 1976 to 2001 according to my simulations.

(a) There are no significant changes to the minimum, mean annual low flow (MALF) or the 7-day MALF due to CPW when compared to the current situation but both are reduced significantly in relation to the unmodified record.

(b) The most notable changes are to the mean and median flows. The median flow will be reduced from 84 m^3s^{-1} before CPW to 72 m^3s^{-1} after CPW for both the 25 m^3s^{-1} and 40 m^3s^{-1} maximum take scenarios (a 14% reduction), while the summer median flow will be reduced to from 69 m^3s^{-1} before CPW to 48 m^3s^{-1} and 43 m^3s^{-1} after CPW for the for 25 m^3s^{-1} and 40 m^3s^{-1} maximum take scenarios respectively (30% and 38% reductions respectively).

(c) The mean annual flow reduces from 116 m^3s^{-1} before CPW to 107 m^3s^{-1} after CPW for both scenarios (an 8 % reduction) and the summer median flows reduce from 101 m^3s^{-1} ^{before} CPW to 90 m^3s^{-1} and 88 m^3s^{-1} after CPW for the 25 m^3s^{-1} and 40 m^3s^{-1} maximum take scenarios respectively (11% and 13% reductions) due to CPW compared to the current situation.

	Unmodified (m^3s^{-1})	Before CPW (A Permit) (m^3s^{-1})	After CPW 20:25:240 (m^3s^{-1})	After CPW 20:40:220 (m^3s^{-1})
Minimum flow	26	22	22	22
MALF	43.1	35.9	35.8	35.8
7-day MALF	47.3	38.6	37.6	37.4
Median	96(90)	84(69)	72(48)	72(43)
Mean	127(119)	116(101)	107(89.6)	107(88.0)
MAF	982	970	960	960
Maximum flood	1939	1917	1917	1917

Table 1. Flow statistics for various scenarios. The table is based in mean daily values and summer data is (bracketed) (data period 1967-2001). MALF = mean annual low flow; MAF = mean annual flood.

20. Figure 1 shows cumulative frequency plots of the modelled rates of abstraction for 1967 to 2001 as supplied by URS. Both scenarios take similar volumes of water and the mean annual take is ~9.1 m^3s^{-1} for both scenarios. The mean summer take rates are 11.1 m^3s^{-1} and 12.7 m^3s^{-1} for the 25 m^3s^{-1} and 40 m^3s^{-1} maximum takes rates respectively. Because the flow distribution is so skewed the use of median take rates is somewhat misleading in my view. The maximum take rates for the 25 m^3s^{-1} maximum take occur for 21% and 25% of the time for the whole year and summer respectively. The maximum take rates are occur for the 40 m^3s^{-1} maximum take occur for 8% and 9% of the time for the whole year and summer respectively. Clearly the trade off between the two take scenarios is between taking larger flows for a shorter time or smaller flows for a longer time.

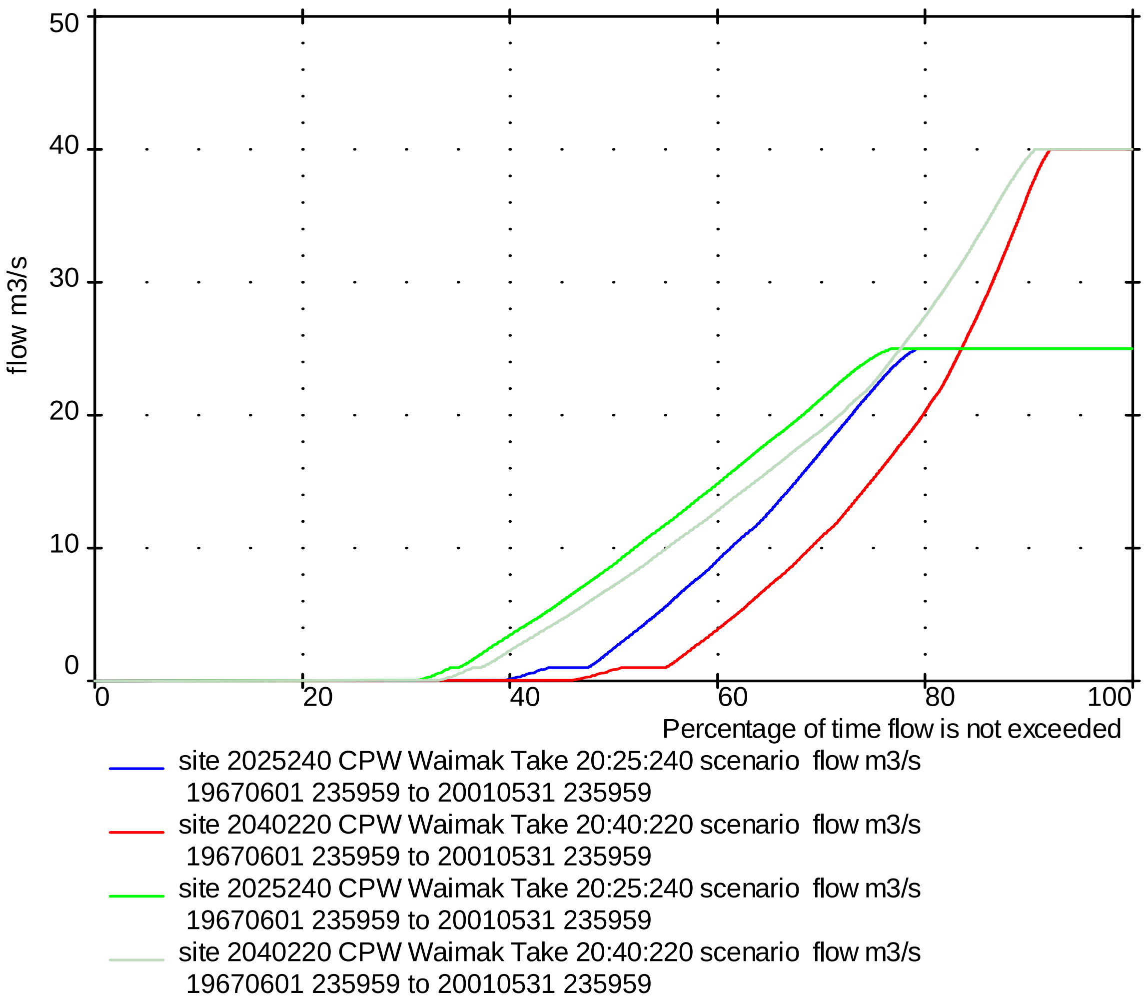

Figure 1. Cumulative frequency plots of the CPW take from the Waimakariri River during summer (November to April) and throughout the year for both the 25 m^3s^{-1} and 40 m^3s^{-1} maximum take scenarios. Data from URS.

21. Figures 2 and 3 are cumulative frequency plots that allow a comparison of flows in the Waimakariri River before abstraction, with the A Permit takes (before CPW) and after CPW for the two scenarios being considered for the whole year and for the summer respectively.

22. According to my simulations:

(a) The duration at flows less than the unmodified median flow (96 m^3s^{-1}) for the whole period of record has increased from 50% of the time to 58% of the time for before CPW to 64% of the time for the both CPW scenarios.

(b) The duration at flows less than the unmodified median flow (90 m^3s^{-1}) for the summer has increased from 50% of the time to 64% of the time for before CPW to ~71% of the time for the both CPW scenarios.

(c) For the whole year river flow will be at the minimum flow of 41 m^3s^{-1} for longer: increasing from 10% of the time before CPW to 17% for the 20:25:240 scenario (70% increase) and increasing from 10% of the time for before CPW to 19% of the time after CPW for the 20:40:220 scenario (90% increase).

(d) In summer, the river flow will be at the minimum flow of 41 m^3s^{-1} for longer increasing from 18% of the time before CPW to 34% and 38% of the time for the 20:25:240 and 20:40:220 scenarios respectively (89% and 111% increases respectively).

(e) Note that in my calculations to obtain the results above I have used the time at 41 m^3s^{-1} and 42 m^3s^{-1} as my simulations did not exactly duplicate those of the applicant and may have been due to some small difference in the times used in the calculation. Nevertheless it is clear that the substantial time spend at 41 - 42 m^3s^{-1} indicates a significant increase in the flat-lining.

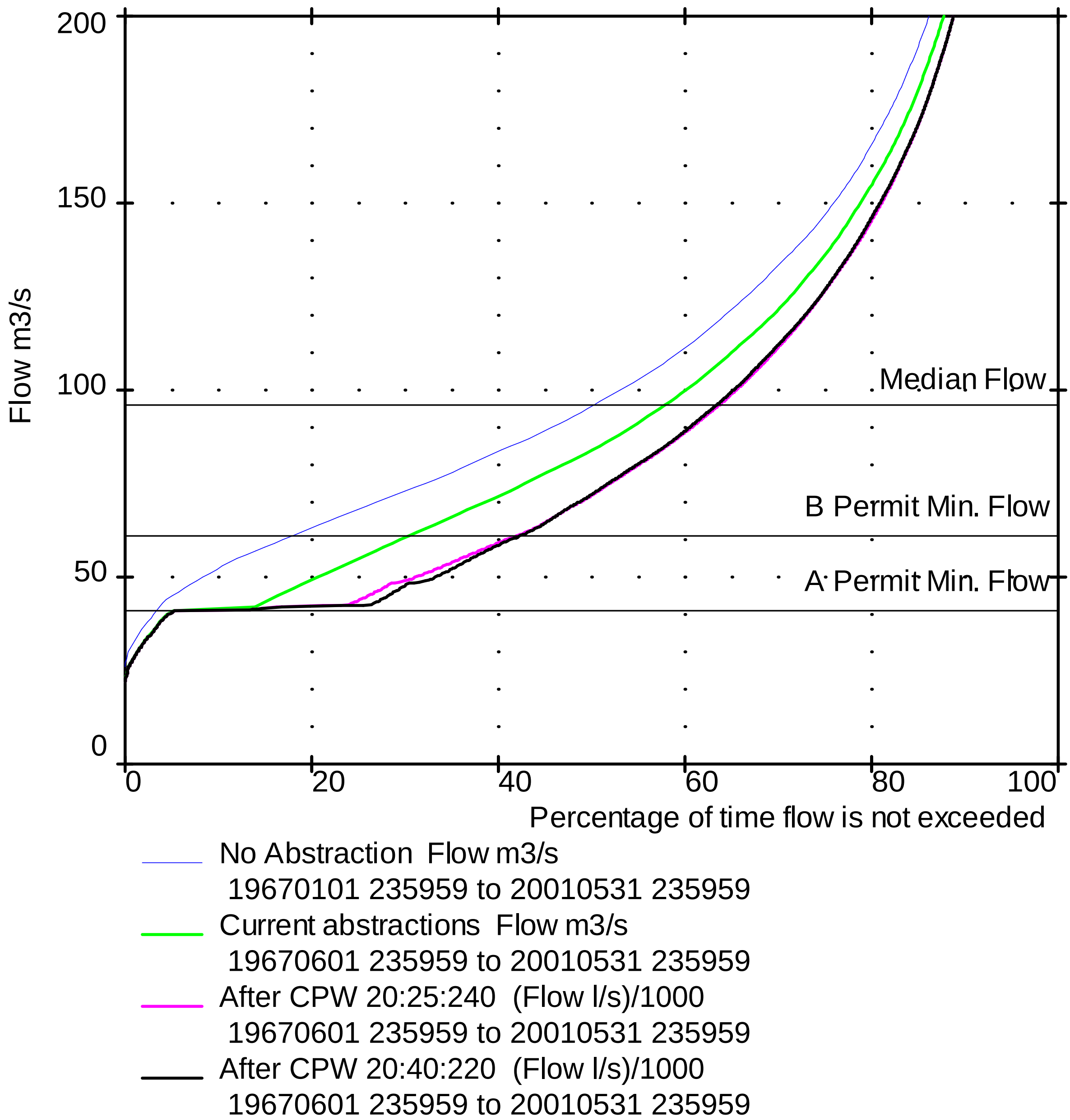

Figure 2. Waimakariri River flow duration curves for the whole year.

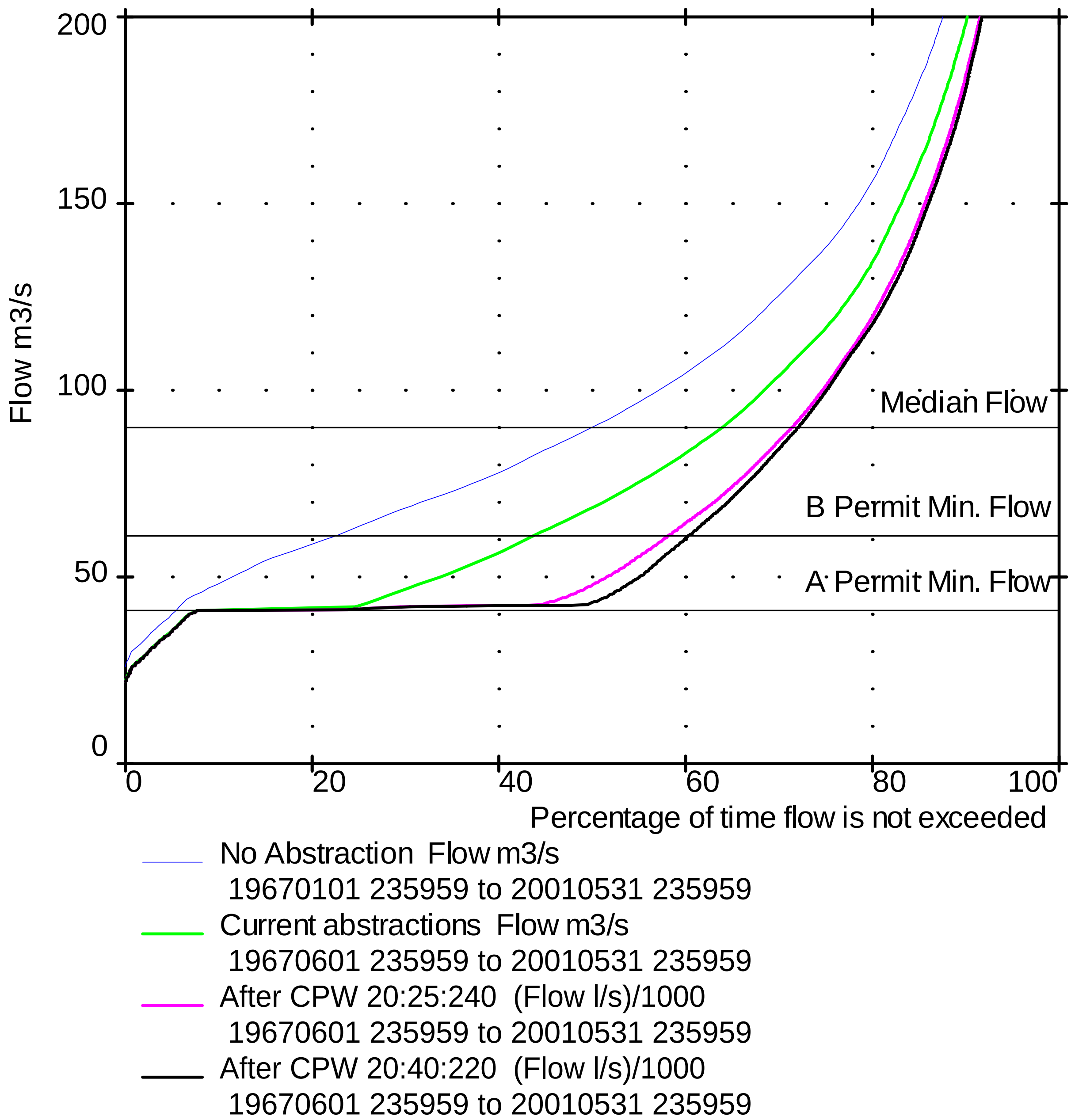

Figure 3. Waimakariri River flow duration curves for the summer (1 November to April 30).

23. The removal of up to 62 m^3s^{-1} from the Waimakariri River affects the number, severity and duration of freshes and floods. Floods are necessary for the appearance and functioning of braided rivers like the Waimakariri. They clear away vegetation to leave bare gravel bars characteristic of braided rivers, and remove periphyton and flush fine sediment to maintain healthy ecosystems. The abstractions reduce the number and duration of small freshes. The extent of the change can be measured by the change in the number of MIN3 and FRE3 events. These are the mean annual number of exceedences of the daily values of 3 times the minimum flow and 3 times the median flow respectively.

24. Figures 4 and 5 show the number and duration respectively of FRE3 events for the before abstraction, with the A Permit takes (before CPW) and after CPW for the two scenarios being considered for the whole year and for the summer. The figures show reductions in the number of events and their duration for both whole year and summer events as the size of the peak take increases, but there is very little difference between the two CPW scenarios. The frequency and duration of FRE3 events for the whole year is reduced by less than 10% when comparing before and after CPW, and the for the summer they are reduced by 11-13%

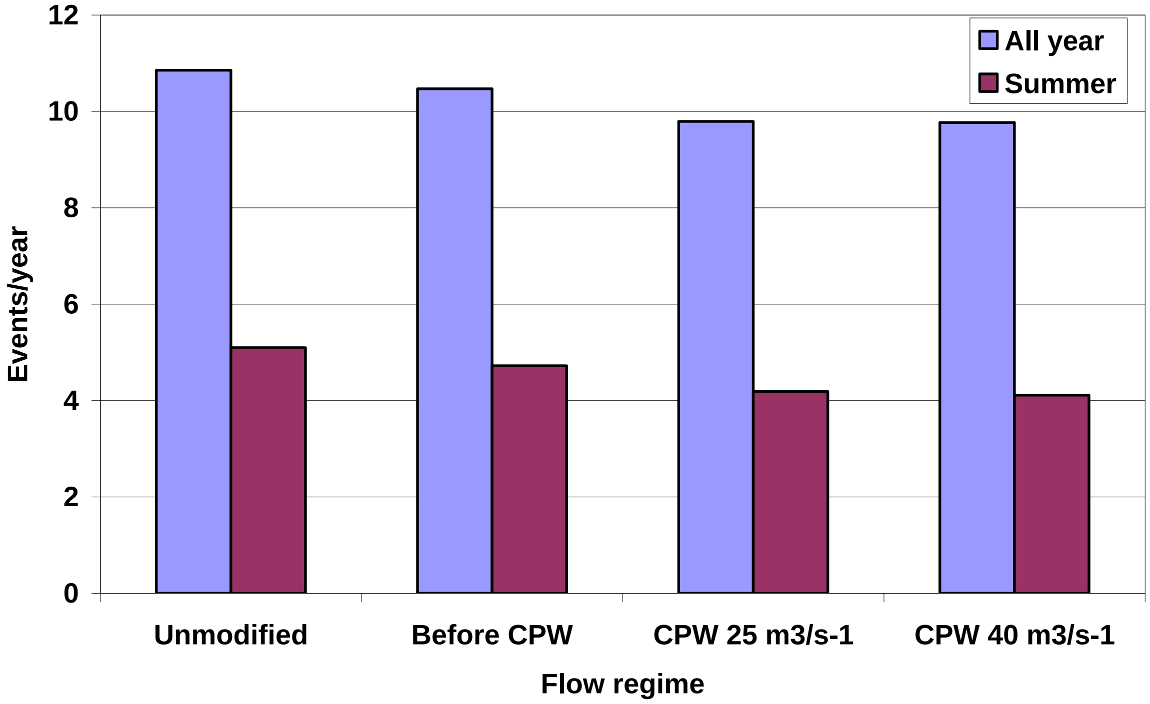

Figure 4. The effect of the various Waimakariri River flow regime scenarios on the average number of FRE3 events (floods greater than 3 times the median flow) for the whole year and for the summer (1 November to April 30).

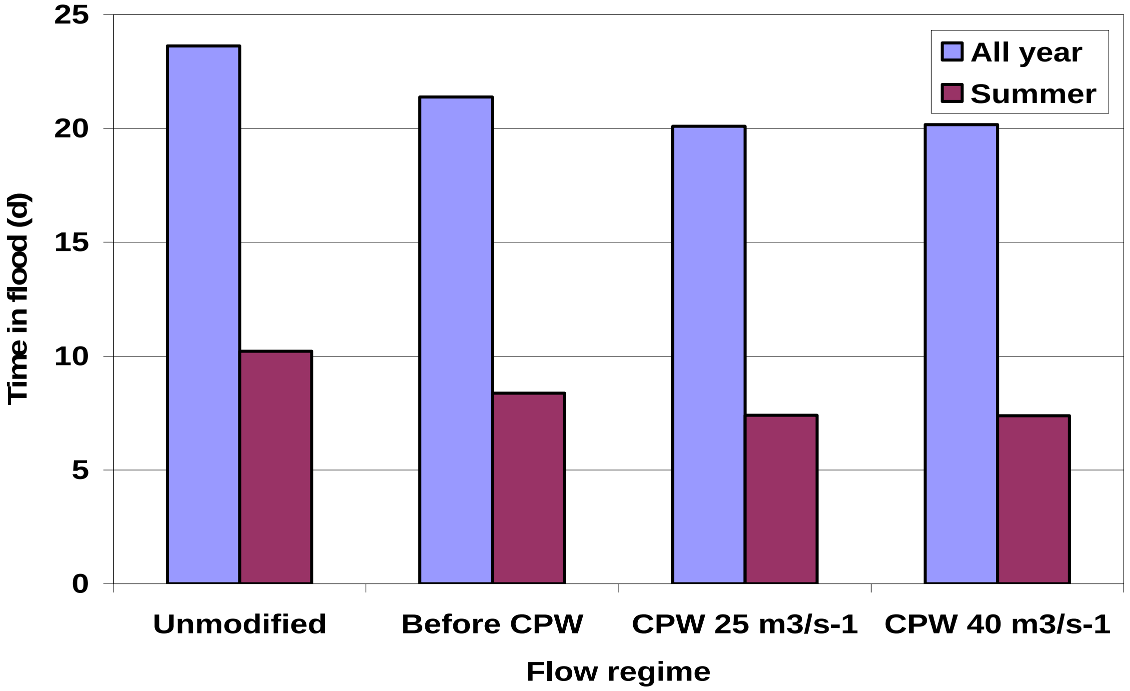

Figure 5. The effect of the various Waimakariri River flow regime scenarios on the average annual duration of FRE3 events (floods greater than 3 times the median flow) for the whole year and for the summer (1 November to April 30).

25. Figures 6 and 7 show the number and duration respectively of MIN3 events for the before abstraction, with the A Permit takes (before CPW) and after CPW for the two scenarios being considered, for the whole year and for the summer. The figures show reductions in the number of events and their durations as the size of the take increases, but there is very little difference between the two CPW scenarios. The frequencies of MIN3 events for the whole year and the summer are reduced by less than 10% when comparing before and after CPW, and the duration of MIN3 events is reduced by between 11% for whole year 25 m^3s^{-1} maximum take scenario to 18% for the summer for the 40 m^3s^{-1} maximum take scenario. There is a substantial reduction (24%-40%) in the duration of MIN3 events when comparing the unmodified and CPW regimes.

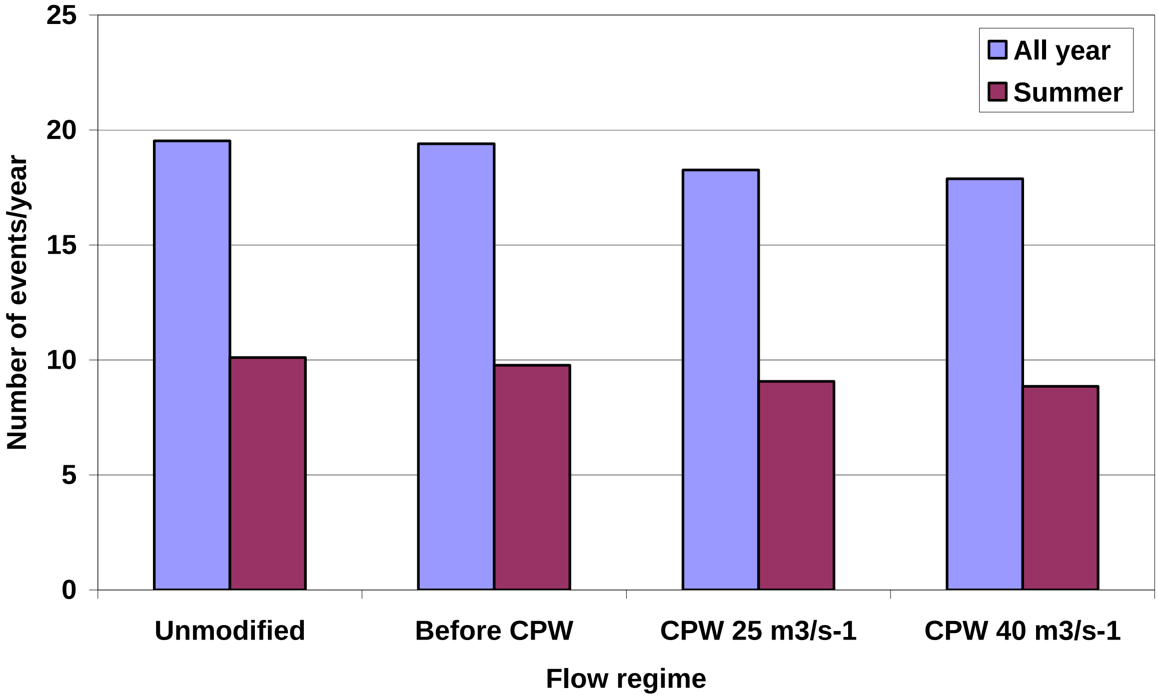

Figure 6. The effect of the various Waimakariri River flow regime scenarios on the average number of MIN3 events (events greater than 3 times the A permit minimum flow) for the whole year and for the summer (1 November to April 30).

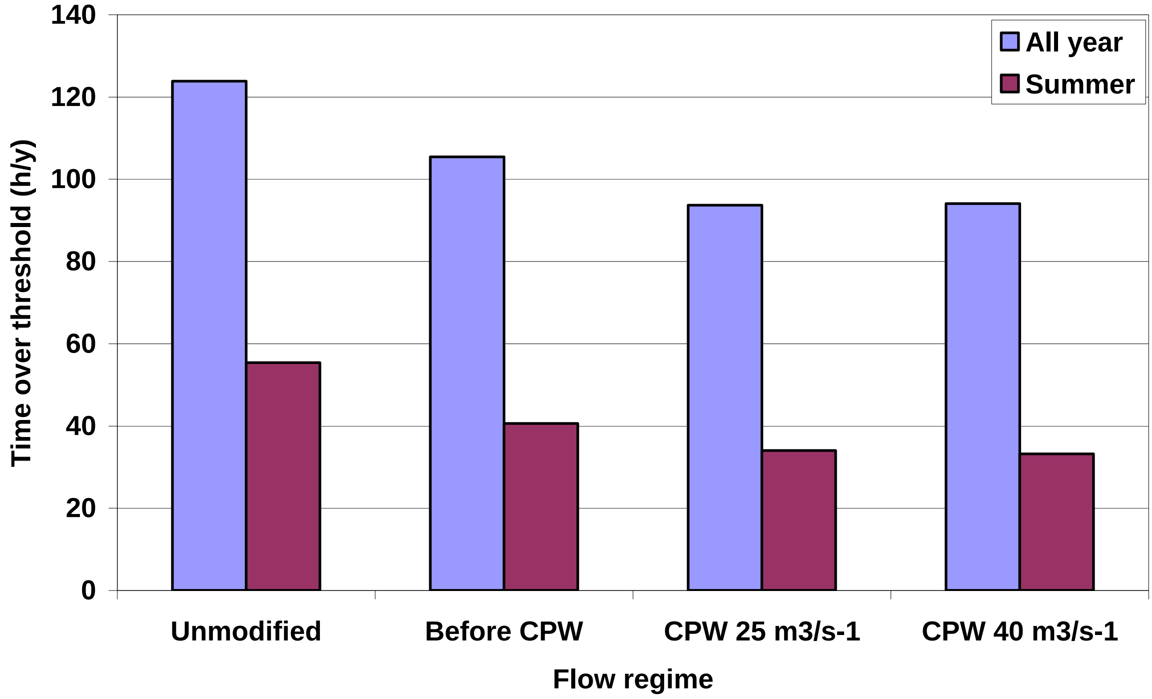

Figure 7. The effect of the various Waimakariri River flow regime scenarios on the average annual duration of MIN3 events (floods greater than 3 times the permit minimum flow) for the whole year and for the summer (1 November to April 30).

26. Figure 8 shows hydrographs for the various scenarios for a dry summer to autumn period. During the dry period, apart from one small fresh there was no abstraction for irrigation although there was continuous abstraction for stock water. At the beginning of the summer flatlining due to the A permit abstraction at 41 m^3s^{-1} is evident as is the additional flatlining due to CPW. The difference between the two CPW scenarios appears small.

27. Figure 9 shows hydrographs for the various scenarios when flows are close to normal. Water is able to be abstracted for almost the whole summer, but the amount available for CPW during March and April is limited. The river shows flatlining at 41 m^3s^{-1} for most of mid December until the end of April with almost half the flatlining being due to CPW. The difference between the two CPW scenarios appears small with only a small additional amount of flatlining due to the 20:40:220 scenario in this hydrograph.

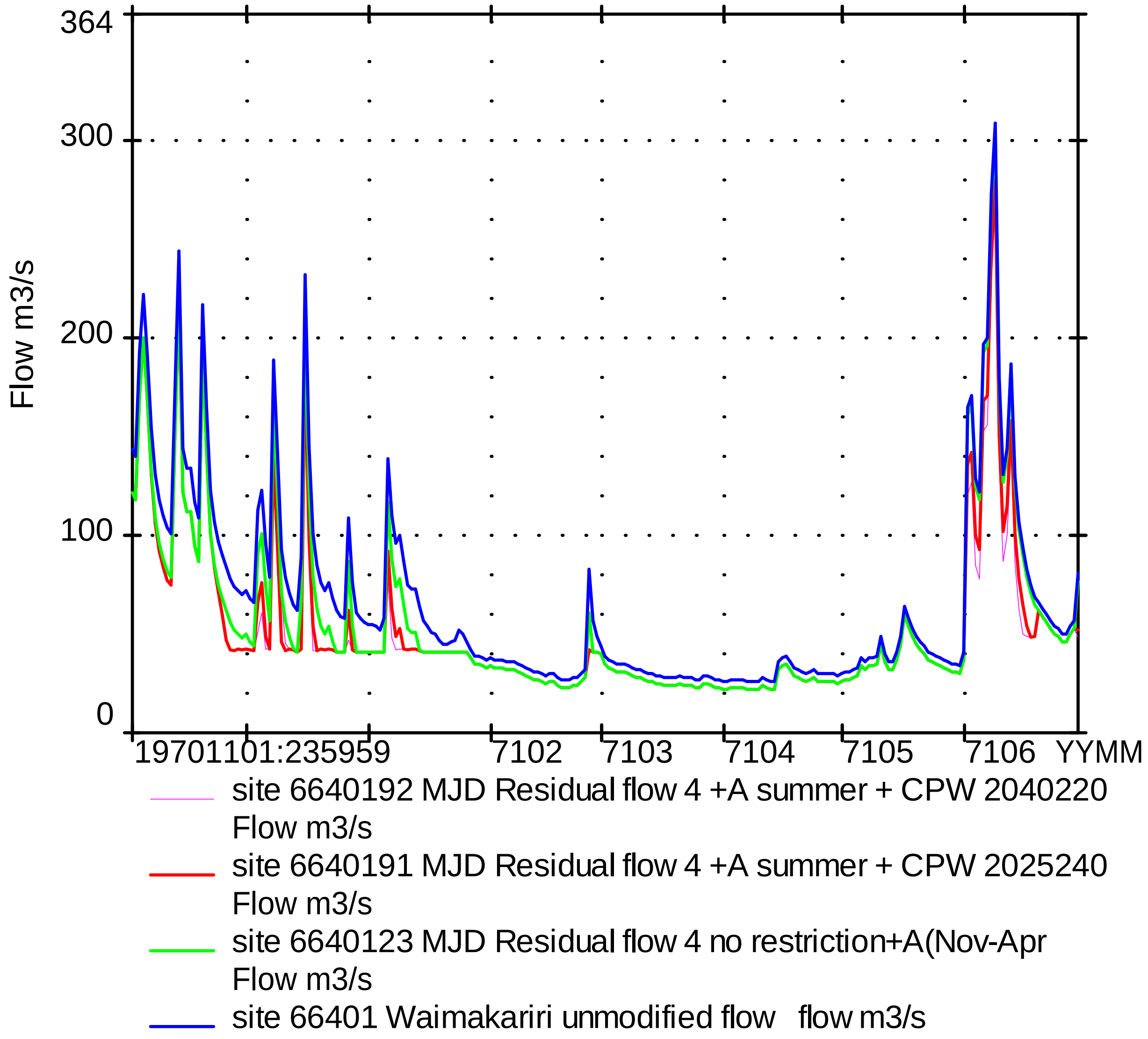

Figure 8: Hydrographs for the Waimakariri River for a dry year showing the change in flow caused by the current A permit abstractions, and the two CPW abstraction scenarios.

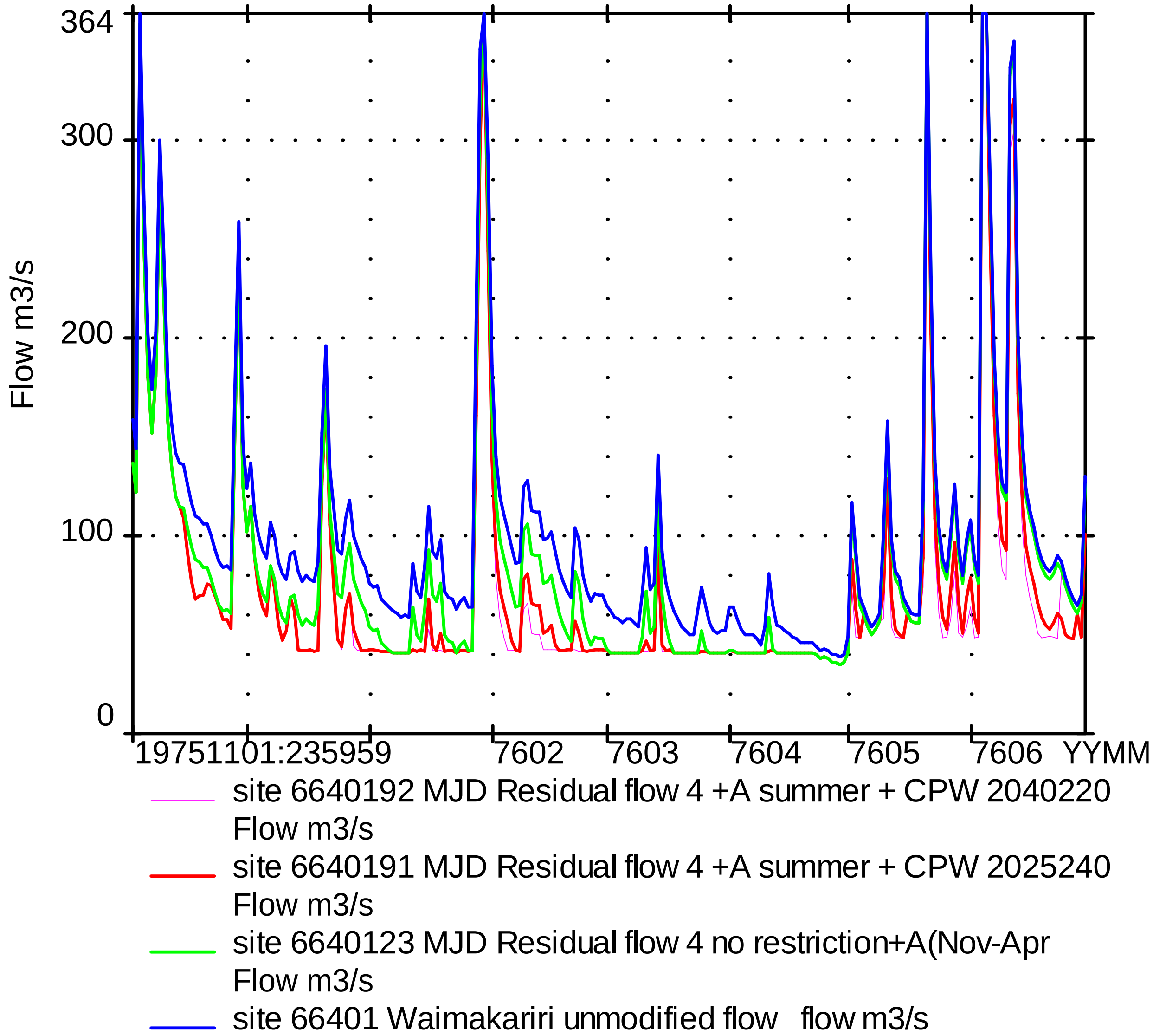

Figure 8: Hydrographs for the Waimakariri River for a normal year showing the change in flow caused by the current A permit abstractions, and the two CPW abstraction scenarios.

28. There has been some concern that the applicant's take will affect the security of supply of A permit holders. In theory there should be no effect, but there is the difficulty in assessing the exact quantity of the unmodified flow because many of the takes are not measured and/or telemetered. However, if the applicant's take is accurately measured and telemetered it should be easy to determine whether any breaches of the minimum flow are due to the applicant. In practice, the flow will be frequently approaching the minimum flow because of abstraction by both CPW and A permit holders and it will require careful management to maintain the flow at or above the minimum flow. If the takes are managed so that B permits are restricted or stopped first then there should be no affect on the security of supply of A permit holders.

Conclusions on the hydrology of the Waimakariri River

29. Flows in the 41 to 150 m^3s^{-1} range will be the most effected because of the combined effects of the current and proposed abstractions. CPW causes a large increase in the time the river spends at the minimum flow of 41 m^3s^{-1}. Thus the flow range affected is greater than indicated by CPW.

30. I agree that the maximum take of 25 m^3s^{-1} will occur about 24% of the time.

31. My simulations show the median flow will be reduced from 84 m^3s^{-1} before CPW to 72 m^3s^{-1} after CPW (a 14% reduction) and during summer (November to April) median flow will be reduced from 69 m^3s^{-1} before CPW to ~44 m^3s^{-1} after CPW (a 30% reduction). These figures are not identical to the applicants due to the difficulty in determining the parameters of the simulation, but the percentage change figures are similar and indicate that the order of change has been correctly assessed.

32. The mean flow will be reduced from 116 m^3s^{-1} before CPW to 107 m^3s^{-1} after CPW (8% reduction) and the summer mean will be reduced from 102 m^3s^{-1} before CPW to 90 m^3s^{-1} and 88 m^3s^{-1} after CPW (11% and 13%) for the 25 m^3s^{-1} and 40 m^3s^{-1} scenarios respectively.

33. River flow will be at the minimum flow of 41 m^3s^{-1} for longer increasing from 10% of the time before CPW to 17% and 19% of the time after CPW for the two scenarios. In summer the time at 41 m^3s^{-1} increases from 18 % before CPW to 34% and 38% of the time after CPW for the two scenarios.

34. CPW will reduce the number and duration of FRE3 (3 times median flow) and MIN3 (3 times the minimum flow) events by less than 10 % (11%-13% summer) for comparing before and after CPW. When comparing no abstraction with CPW there is a 9-19% reduction in the number of FRE3 events and a less than 10% reduction in the number of MIN3 events except for a 12% reduction for summer where up to 40 m^3s^{-1} can be taken.

35. The duration of FRE3 and MIN3 events will reduce by 13% and 18% (40 m^3s^{-} scenario) respectively during summer when comparing before and after CPW. When comparing no abstraction to after CPW the duration of FRE3 events decreases by 15% for the whole year and 28% for the summer (3 days) respectively. When comparing no abstraction to after CPW the duration of MIN3 events decreases by 24% (30 days) for the whole year and 40% (21days) for the summer respectively.

36. In conclusion I can say that the applicants assessment of the effects of the proposed scheme on Waimakariri River flows as detailed in Golder Associates (2007) are in general agreement with my own assessment.

37. With careful management there should be no effect of CPW on the security of supply of A Permit holders.

Review of the hydrology of the Rakaia River

38. The Rakaia River National Water Conservation Order (WCO) (1998) dictates the minimum flows and allocation limits for the Rakaia River. The monthly minimum flows vary between 90 m^3s^{-1} (September) and up to 139 m^3s^{-1} (December) (Table 2). The WCO allows for a total maximum abstraction rate of 70 m^3s^{-1} with 1 to 1 flow sharing above the monthly minimum flows.

39. The best available information (Leo Fietje, Pers. Comm. 23/01/08/) regarding the current allocated amount from the Rakaia River gives a total of 33.84 m^3s^{-1} allocated, leaving just over 36.16 m^3s^{-1} available for allocation.

40. Golder Kingett Mitchell Ltd (March, 2007), on behalf of URS NZ Limited, has assessed the potential effects, including the cumulative impacts of the Blocks 1 to 4, CPW (20 m^3s^{-1} assumed) and the ACWT (20 m^3s^{-1}) on the flows in the Rakaia River therefore I will provide a check of their assessment in the following paragraphs.

41. I have assumed that current users total 33.84 m^3s^{-1} and have modelled the river flows assuming this amount and have called these ‘Bands 1-4’. Any further assessment of existing consents this figure unlikely to change the results significantly. The minimum flow for each of Band increases as the Band number increases. The band level is determined by the timing of the application to take water with the first applications being allocated to Band 1.

42. Appendix 3 outlines the methods I have used to create 3 datasets using the 'natural' flow record from the Rakaia River at Rakaia Gorge/Fighting Hill (site numbers 68501 & 68526) as recorded by ECan/NIWA.

(a) *Residual flow –Bands 1-4 only during October to April (with 1:1 flow sharing above monthly minimum flows)*

(b) *Residual flow – Bands 1-4 only during October to April and CPW only for the whole year (with 1:1 flow sharing above monthly minimum flows)*

(c) *Residual Flow – Bands 1-4, only during October to April and CPW and ACWT for the whole year (with 1:1 flow sharing above monthly minimum flows)*

It is important to note that the above datasets are based on the assumption that the full take for Bands 1-4 occurs during October to April because the takes are used for irrigation and there is currently no significant storage even though the takes are permitted all year. The CPW and ACWT takes are assumed to continue all year because it is likely that any water not used by CPW will be used by ACWT for irrigation and hydroelectric generation. I have used these scenarios because I believe them to be realistic. The assumed abstraction regime for Bands 1-4 will generally give conservative results because in an average year irrigation will only begin some time in October and cease sometime in April but there will be some seasons when irrigation will commence in September and finish in May.

43. I draw your attention to Table 2. On the first row are the minimum monthly WCO flows. The other rows show the flows below which flow sharing begins and above which the full allocation can be taken. Please not that the bottom row allows for an allocation to CPW and ACWT of only 34 m^3s^{-1} rather than 40 m^3s^{-1} as it would appear that there is not 40 m^3s^{-1} of unallocated water left within the maximum amount allow to be abstracted according to the WCO.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WCO minimum flows	124	108	105	97	95	96	91	92	90	106	129	139
Bands 1-4 only (min flow + 2 x Bands 1-4 allocation)	192	176	173	165	163	164	159	160	158	174	197	207
Bands 1-4 + CPW (min flow + 2 x Bands 1-4 allocation + 2 x CPW)	232	216	215	205	203	204	199	200	198	214	237	247
Bands 1-4 + CPW + ACWT (min flow + 2 x Bands 1-4 + 2 x CPW + 2 x ACWT)	264	248	245	237	236	236	231	232	230	246	269	279

Table 2: Assumed river flows (m^3s^{-1}) below which flow sharing begins and above which the full allocation can be taken.

44. Figures 9 and 10 show two different years of flow data, one very dry season (1989-90) and one more typical year (1981-82). The figures show that at low flows no water is available for abstraction and that it is only during freshes that water is available to CPW or CPW+ACWT.

45. In my view the applicant is correct in their assessment that the existing and proposed takes do not result in flat lining of river flow and the flow variability that is evident in Figures 9 and 10 remains after abstraction. At low flows abstraction is limited by the WCO and at very low flows there is no abstraction. It is clear from the plots that during the lower flows when takes are allowed they are primarily by existing consent holders (green line) and the applicant is only able to extract water (red and blue lines) at relatively high flows assuming that CPW does not have access to water that is already allocated. In the winter that water is unlikely to be taken. If the applicant was given access to that water when it was not being used by others then there would be a general reduction in the flow regime.

46. Figures 11 and 12 show flow duration curves for the irrigation season (October to April) and for the full year for the 4 scenarios. It is clear that the existing resource consents take the bulk of the water and the CPW and CPW+ACWT take incrementally less water respectively. The water for CPW is also unavailable for much of the time and only available at higher flows. The Golder Kingett Mitchell Ltd report (March, 2007) states that the proposed CPW takes will not result in flat-lining of river flows or increase the time that the river spends at Mean Annual Low Flow (7 Day) levels and I agree with that view.

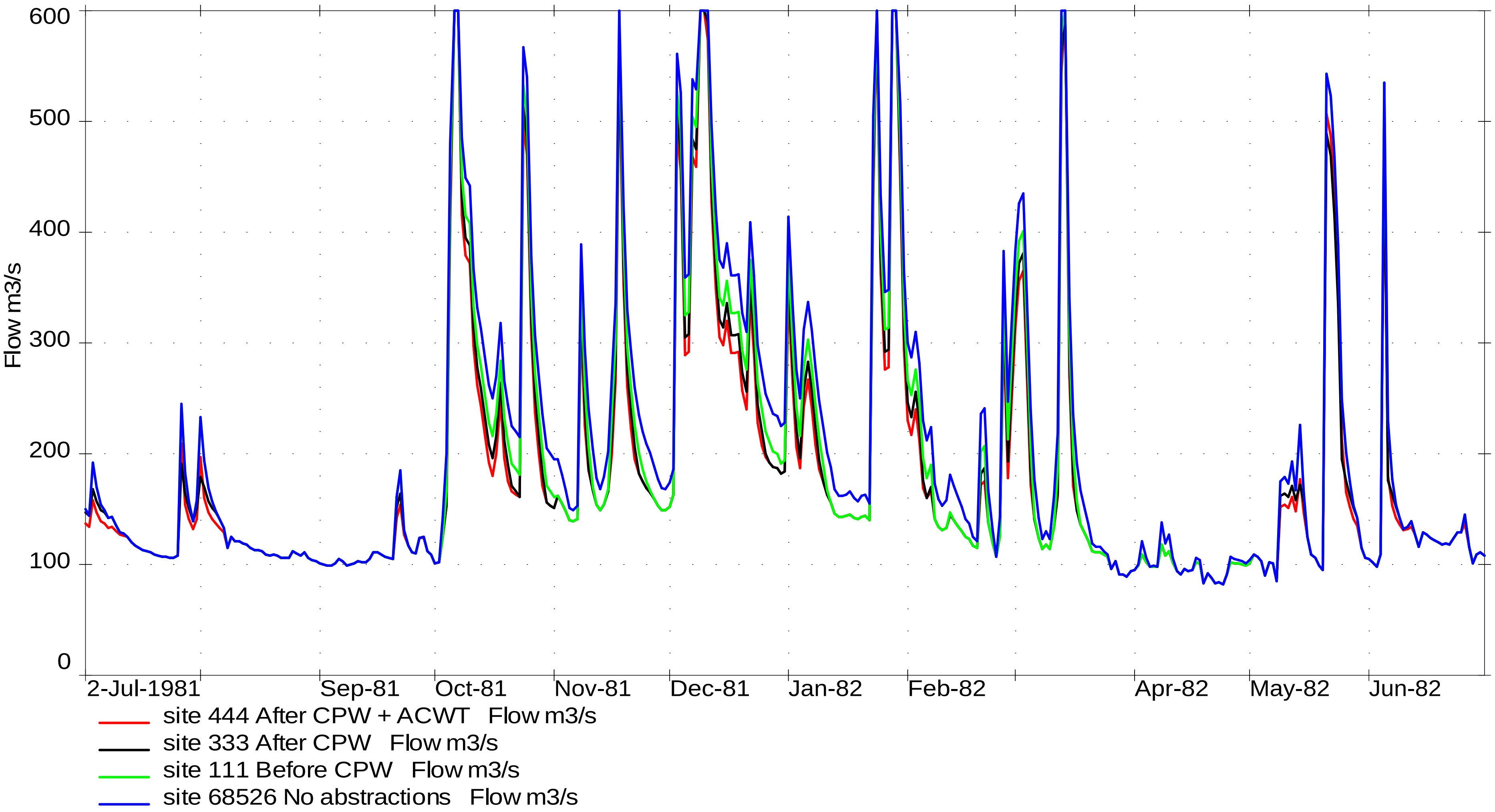

Figure 10: Rakaia River daily flows for Nov 1989- end June 1990 – A relatively dry season.

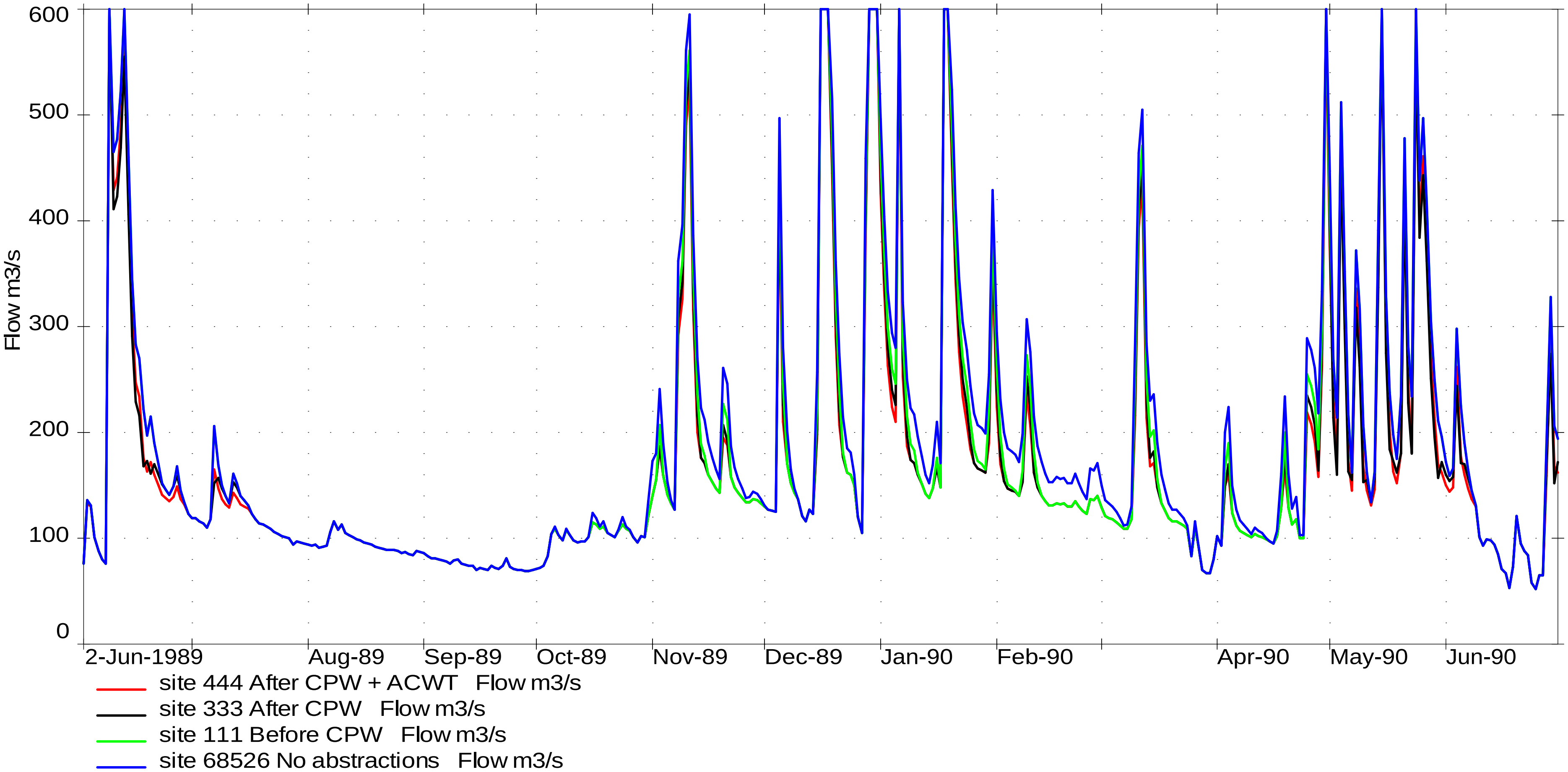

Figure 11: Rakaia River daily flows, for Nov 1981- end June 1982 – more typical season.

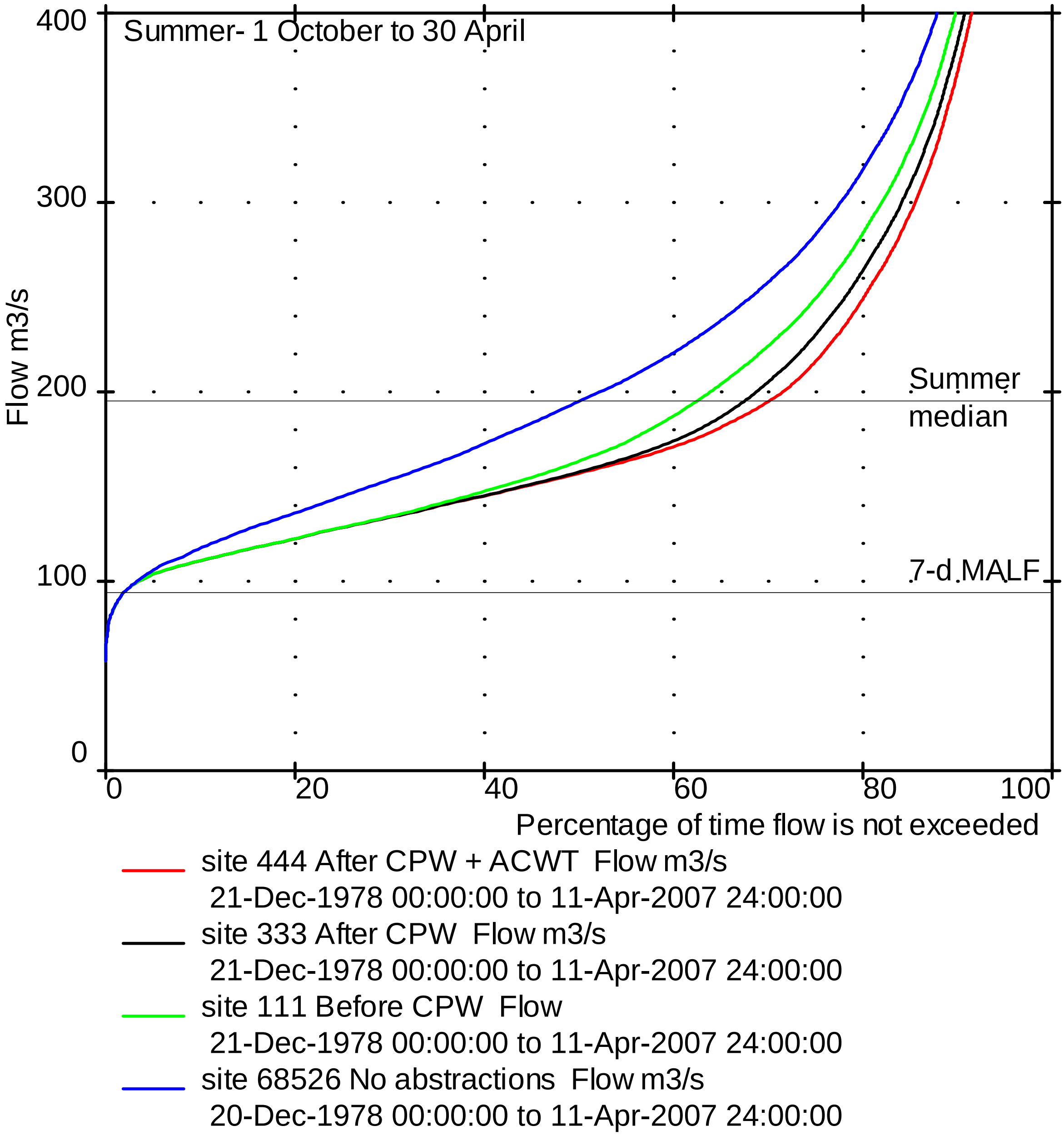

Figure 12. Flow duration curve for the 4 datasets – irrigation season only - for the Rakaia River. Median and 7-day MALF are based on unmodified flows for the whole record (1978-2006).

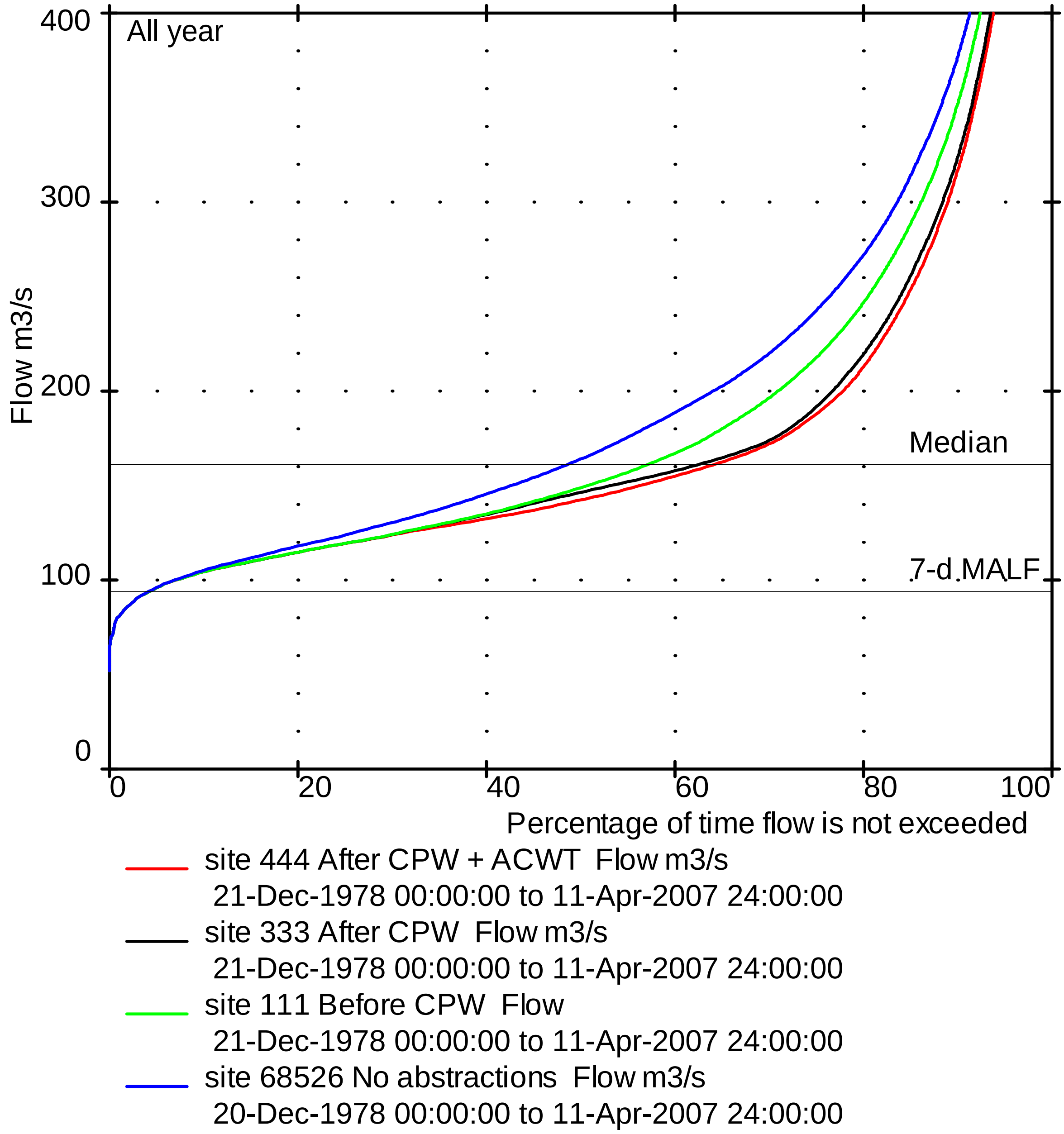

Figure 13. Flow duration curve for the 4 datasets for the full year for the Rakaia River. Median and 7-day MALF are based on unmodified flows for the whole record (1978-2006).

47. Flow statistics have been calculated for each dataset to highlight the change to the natural flow regime with the proposed takes. Table 2 shows that the Mean Annual Low Flow (7 day) will not change from the current Band 1-4 only regime to the proposed Band 1-4 + CPW + ACWT regime, many of the other flow statistics will be affected by less than 7%, but the percentages of time flows of 188 m^3s^{-1} and 242 m^3s^{-1} are exceeded is reduced by 22% and 25% respectively.

	Rakaia River at Gorge/Fighting Hill (natural)	**CURRENT (Before CPW) Residual with Blocks 1-4 only**	PROPOSED (After CPW) (1) Residual with Blocks 1-4 and CPW	**PROPOSED (After CPW+ACWT (2) Residual with Blocks 1-4 and CPW and ACWT**	% Change from CURRENT to PROPOSED (2)
7 day MALF	94.8	**93.9**	93.9	**93.9**	0
Annual Mean	216	**201**	191	**188**	-6
Winter mean	166	**166**	154	**154**	-7
Summer mean	250	**226**	217	**211**	-7
Annual Median	161	**149**	146	**142**	-5
Winter median	132	**131**	131	**129**	-2
Summer median	195	**163**	158	**157**	-4
% time > 242 $m3s^{-1}$ (1.5xMedian)	24	**21**	17	**16**	-24
% time > 188 $m3s^{-1}$ (2xMALF)	38	**32**	26	**25**	-22
% time > 106 $m3s^{-1}$ (mean of min flows)	88	**80**	80	**80**	0

Table 2: Changes to flow statistics for 5 datasets for the Rakaia River (1979-2006)

48. Another way of viewing this information can be seen in the cumulative frequency plots (Figures 12 and 13). This shows the time the river will be at or below the 7-day MALF (94.8 m^3s^{-1}) will not change with the proposed takes. It is also clear from these graphs that largest changes to the flows occur over the range of 180 m^3s^{-1} to 250 m^3s^{-1}.

49. With regard to the effect on smaller freshes and up to FRE3 (3xMedian), the Golder Kingett Mitchell Ltd (March, 2007) reports states that there will be a 21% reduction, and that this is considered significant.

50. To determine the effects of the applications on freshes and floods, for each scenario the number of freshes per year and the number of days of flooding was calculated where the mean daily flow was greater than the thresholds. Figure 14 shows that the there is not dramatic change in the number of floods per year between scenarios. The largest change between the status quo and status quo + CPW + ACWT was a decrease from 19 to 17.3 floods per year or a 9% reduction for floods greater than 1.5 times the median flow (242 m^3s^{-1}).

51. Figure 15 shows the number of average days per year that the river is above the various thresholds. The greatest change is between the unmodified flow and the status quo. The greatest difference between the status quo and the status quo + CPW + ACWT is a decrease for floods greater than 1.5 times the median flow (242 m^3s^{-1}) where the number of days in flood is predicted to reduce from 73 to 57 days per year (21% reduction). However, the number of floods and the time in flood for thresholds between 2 times the 7-day MALF (188 m^3s^{-1}) and 2 times the median flow (322 m^3s^{-1}) has changed almost as much as floods greater the 1.5 times the median flow.

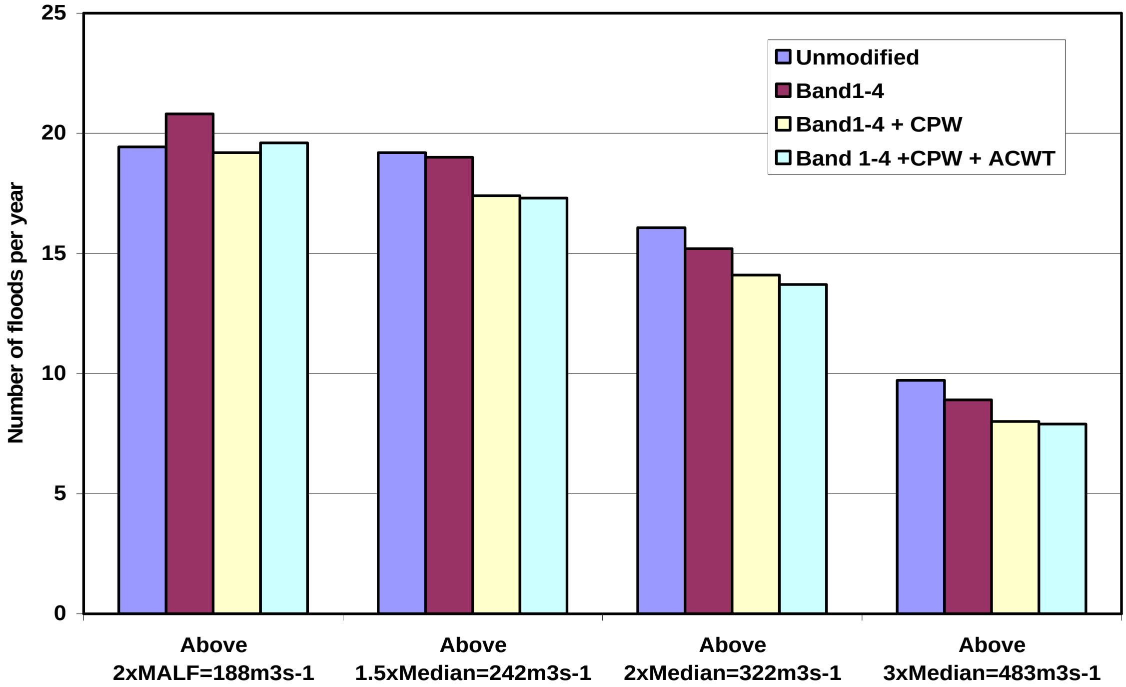

Figure 14. The effect of the takes on the number of floods per year above thresholds.

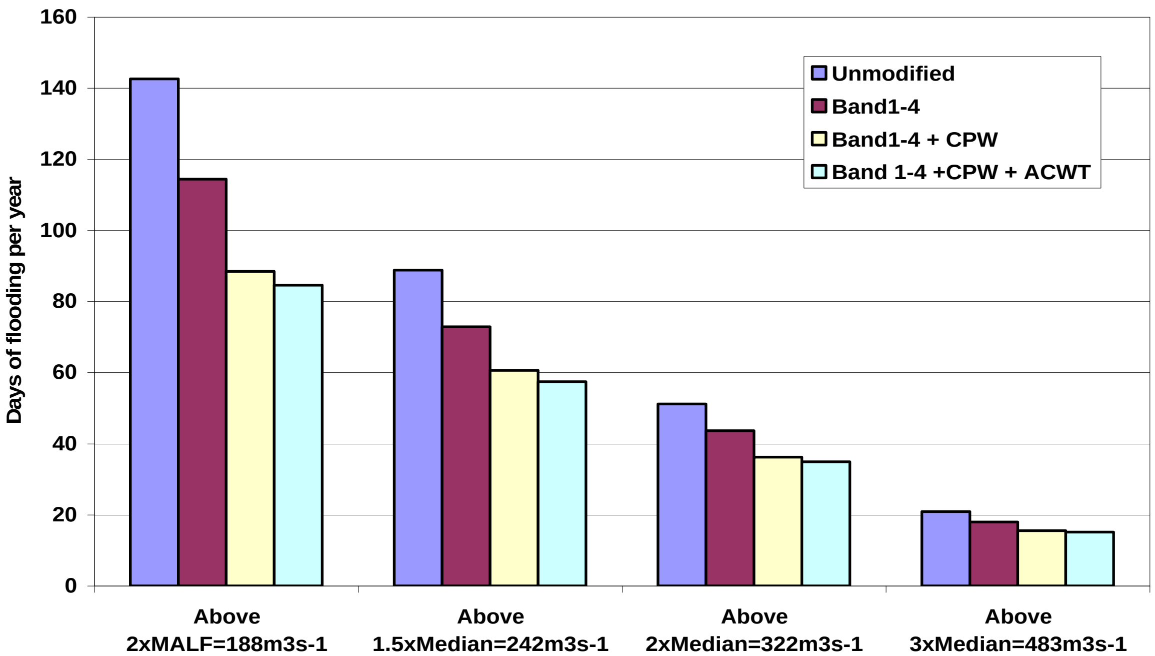

Figure 15. The effect of the takes on the number of days of flooding per year above thresholds.

Conclusions for Rakaia River Analysis

52. I am in general agreement with the conclusions made by Golder Kingett Mitchell (2007) on the effects on the Rakaia River. There will be no increase in time the river spends at or around the WCO minimum flows, or at the 7-day MALF. We are also in agreement that there will be a reduction in median flows in the river and a significant reduction in the number of days the river would spend above smaller fresh levels.

BYWASH FLOWS

53. Bywash flows are defined as flows in irrigation canals that are not required by irrigators and which are discharged into receiving waters or natural or artificial wetlands. Small (0.2-1.5 m^3s^{-1}) bywash flows are required in the normal course of operation of the scheme to ensure that the last irrigators down a supply race can draw their full allocations.

54. Normal operational bywash flows can be exceeded in at least two circumstances:

(a) If there is some mistiming of the release of water for an irrigator and the uptake of water by the irrigator. Waimakariri Irrigation Limited who also take from the Waimakariri River operate a large sophisticated irrigation scheme between the Waimakariri and Ashley Rivers, with remote controlled gates that automatically adjust to provide the requested flows in races. Nevertheless on a daily basis there are excess bywash flows greater than designed operational bywash flows. These happen because of the mistiming as indicated above and because takes may be temporarily suspended when travelling irrigators are moved from one run to another. Regardless of how sophisticated a scheme is once water is released into a canal and is not used as planned it must be lost as spill. As such spills occur in what is regarded as a well run scheme it would seem prudent for the applicant to design and plan for such occurrences in their proposed scheme. If water was distributed in pipes rather than canals there would be no issues with bywash flows.

(b) In an emergency situation when there is a district wide power cut and water cannot be pumped out of canals for irrigation or when farmers cease pumping because of heavy rainfall.

55. During normal operations the bywash water will be released into constructed wet lands and will most likely soak into ground water. The Applicant states that the effect will be less than minor and I agree that will be the case for most of the normal discharges, providing the wetland is adequately sized.

56. The AEE for Effects of additional bywashes dated 4 October 2006 states that the maximum rate of bywash for the two additional bywashes will be 0.4 and 0.3 m^3s^{-1} discharging into wetlands of 0.1-0.2 and 0.1 ha respectively. The AEE stated that the *soils of the wetland will be permeable enough to absorb water through the soil profile to the groundwater table* and *that they will not have any surface water connection* to the adjacent watercourse.

57. I calculate that at the maximum nominal operational flow rate the wetland would have to absorb or infiltrate between 0.72 and 1.44 m per hour or between 17.8 and 34.6 m per day. McIndoe (2007) regards soils having infiltration rates of the order of 0.06 to 0.1 m per hour as having very rapid infiltration rates. Thus the maximum infiltration rates required of the wet land are an order of magnitude higher than could be reasonably expected of them.

58. I calculate that the bywash flows would have to be as low as 0.028 – 0.05 m^3s^{-1} depending on the area of wetland to infiltrate into soil regarded as having a high infiltration rates. Such bywash flow rates are probably lower than would be required for operational bywashes. If the water was to be ponded in the wetland then higher inflows may be able to be infiltrated. My conclusion is that the wetland areas for the bywashes do not have sufficient area to infiltrate the inflows that could be expected.

59. The operational bywash to the Rakaia River at the State Highway One Bridge is stated to be 1.5 m^3s^{-1} and I have doubts that such a large flow could be processed by a wetland. A release of 2.7

m^3s^{-1} into the Eyre River in September covered an area of previously dry river bed of about 12 ha after 23 days (Steffens and Callander 2007).

60. The issue of mistiming of releases and uptake by irrigators does not appear to have been addressed by the AEE. I assume that any excess flow greater than the design operational bywash will be diverted directly into the receiving waters or else the excess flow would have the potential to wash out or overwhelm the constructed wet lands. It is not clear from the AEE how the diversion of the excess flow would occur and at what flow rate it would occur. Possibly there needs to be a condition to ensure that any flow that exceeds the wetland design capacity is treated as an emergency spill and diverted into the receiving water.

61. The emergency spills appear to have been down played by the applicant.

- The AEE states the spills will be of brief duration. One of the larger canals is about 30 km long and is interconnected with others in the net work so there is a substantial amount of water to drain. It would take 7 to 8 hours to drain at the peak flow rate for the large canal to drain and possibly double that when all the interconnecting canals draining into the large canal are considered.
- While the individual emergency spills to the Selwyn River or into Selwyn River tributaries close to their confluence to the Selwyn River are relatively small for the most part (2-8.5 m^3s^{-1}) spillage from all them would release up to 30.5 m^3s^{-1} to a dry or very low flow river bed (Table 1). If such an emergency spill occurred when the bed was dry and the weather fine, anyone on the Selwyn River within or downstream of the scheme would be in grave danger. The public safety issues of such a discharge need to be seriously addressed and conditions given so people in the river are given a warning when emergency spills occur. Table 1 sets out the names of the emergency spill locations and their emergency peak flows (s92 request response 19 March 2007 Tipler/Lewthwaite).

River	Spill location	Emergency peak flow (m^3s^{-1})
Selwyn	Hawkins Rd	3.3
Waianiwaniwa	Coal Track Rd	3
Selwyn	Near Waianiwaniwa confluence	2.5
Hororata	u/s Gillanders Rd	1
Hawkins	Coal Track Rd	3
Selwyn	Coal Track Rd near Stranges Rd	8.5
Selwyn	Old South Road	3.5
Selwyn	Highfield Rd	7
TOTAL		**31.8**

Table 1. Locations and emergency peak bywash flows into the Selwyn River.

62. The water quality of bywash flows appears to have been have been given little attention by the applicant and any potential issues will be commented on by Ms Johnston, Ms Hayward and Dr Meredith.

63. The water quality of the smaller normal operational discharges should not be an issue as they are to be discharged into natural or artificial wet lands where suspended sediment, nutrients and bacteria will for the most part be stripped out by the wetlands.

64. Where operational bywash flows are larger than planned (i.e., there is a mismatch between the water released down a channel and that taken up by farmers) there are at least two possible outcomes. Where water is discharged into the two major rivers there is unlikely to be an issue as it is most likely to be similar to what is in the rivers (unless it comes from the reservoir), but discharges in to the Selwyn River or its tributaries are likely to be of poorer quality at least from a suspended sediment view point than existing flows in the rivers, except when they are in flood.

65. Emergency bywash flows into the Selwyn during no or low flows are also likely to be of lower quality than any existing flow except during floods. The difference between the extra operational flows and the larger emergency bywash flows is the possibility of latter reaching the permanent flow section of the river that has low suspended sediment because of its source in springs and upwelling flows. In that case there would be a dramatic change in the water quality and the bywash flows would have a similar detrimental effect on water quality as normal flood flows. Even if the bywash water was of good quality as it was discharged from the canals it would pick up sediment as it moved down river.

Mitigation of bywash

(a) The use of artificial wetlands for operational bywash is commended providing they are appropriately sized.

(b) If the water as distributed in pipes rather than canals bywash flows would be eliminated.

(c) One way of dealing with excess operational bywash flows would be to have an area of border-dyking that excess bywash flows could be diverted to. Waimakariri Irrigation Limited in their irrigation scheme has a number of such border-dyke areas that successfully process excess operational bywash water.

Conclusions on bywash flows

(a) Bywash flows cannot be avoided unless the water is distributed in pipes.

(b) The use of artificial wetlands to dispose of operational bywash flows is to be commended, however it appears that they much too small to infiltrate the flows they could receive.

(c) Emergency spills have be cast as brief events but the largest could flow at the full discharge rate for 8 hours and in practice flows lower than the maximum could continue for much longer than 8 hours.

(d) An emergency spill worst case scenario is the discharge of 31.8 m^3s^{-1} into the Selwyn River or its tributaries at locations close to their confluence with the Selwyn River. A discharge of this magnitude into dry river bed is hazardous and appropriate measures need to be taken to warn anyone in the river bed.

(e) Excess operational bywash water could be managed with an appropriately sized border-dyke irrigation area.

Key CPW conclusions regarding the geomorphic effects of CPW

66. This section presents my understanding of the key conclusions reached by CPW in regard to geomorphic effects of CPW on the beds and mouths of the Waimakariri and Rakaia Rivers. These understandings come primarily from memos dated 22 March 2007 and 4 December 2007 by Dr Mabin.

(a) There are no issues regarding CPW affecting river mouth closure because there is too much river energy.

(b) There is no issue with sediment transport in either river because both rivers are undersupplied with bedload.

(c) That suspended sediment sediment concentrations will reduce downstream of the extraction points.

(d) CPW will not have any effect on sand transport through the Waimakariri River mouth because the tidal effect is greater than any effect of reduction in flows.

(e) There will be no significant effect on bedload transport because CPW will not significantly affect the bed load transporting flow range and the river is undersupplied anyway.

(f) There will be no effect on channel mobility because there will not be any significant changes in the frequency of bankfull events.

67. I will consider each of these conclusions in turn as the whole subject has been given a light treatment by the applicant and is backed up with few facts and calculations and with several misconceptions. The lack of relevant numbers has made it difficult to make an independent assessment.

68. In regard to river mouth issues there is more to consider than just whether the mouths will remain open or not. The issues are more to do with floods moving sand out of the Waimakariri River tidal reach and with floods re-centring the mouth of the Rakaia River.

69. The Rakaia mouth (like most river mouths in the Canterbury Bight), is often offset several km north from the river centreline, due to the northward directed littoral drift and oblique wave approach. This offset lengthens the river path to the ocean, so the lagoon has to build up a head of water to overcome the added friction – and some degree of flooding can occur around the lagoon even at low flows at high tide. When river floods come down, they tend to blow open the mouth directly opposite the main river, but until the opening is made, the flood waters rise in the lagoon and cause more extensive flooding. Also, with prolonged low flows, there is some thought that the bar opposite the river thickens, at least sometimes, making it harder for the river to cut a re-centred opening. In turn, this can lead to more extensive flooding and perhaps no new break-out opposite the river at all. This effect doesn't seem to have been considered, but it would seem to be the most likely side effect of CPW at the Rakaia mouth.

70. At the Waimakariri the river plus tide energy appears to be small in relation to wave energy. The presence of only a small, much flattened delta attests to the importance of wave energy redistributing the river sand.

71. The view that there is no issue with sediment transport in either river because both rivers are undersupplied with bedload demonstrates a slight appreciation of both rivers. The 22 March 2007 memo considers that the presence of armour (bed surface coarsening) reflects under-utilised bedload transport capacity. Some bed-surface coarsening is to be found in even well-supplied river reaches. The Hicks (2005) report referenced referred to the lower Waiau river which, by virtue of Lakes Manapouri and Te Anau upstream, may fairly be regarded as undersupplied with bed material and is generally well armoured in consequence, but it is a very different river compared with the Rakaia and Waimakariri Rivers. It is well known that the lower Waimakariri River has reaches that are both degrading and aggrading, and aggradation is a clear sign that the river is supplied with more bed material than it can handle. There may possibly be some subtle CPW effects such as an upstream shift of the hinge point between aggradation and degradation in the lower Waimakariri River, which may have implications for flood control at Christchurch. I would therefore have expected a more thorough assessment, assessing the effects of a changed flow regime on a reach by reach basis, bearing in mind the geomorphic setting.

72. Key information is lacking – e.g., on the bedload transport by flow band before and after the scheme. It is also hard to pin down key details on the proposed rules for extracting water during freshes and floods – e.g., at what discharge during freshes and floods will water diversion from the big rivers cease?

73. The FRE3 parameter appears to be miss-applied by treating the FRE3 flow as the threshold at which the bed surface armour breaks. Duncan and Woods (page 7.3, Freshwaters of New Zealand, 2004), regard FRE3 is an indicator of the frequency of ecological disturbance, rather than the FRE3 flow specifying the threshold of bed surface mobility. Indeed, I doubt that the FRE3 is a useful index here anyway, because with a drop in the median flow with CPW, the FRE3-flow will decrease but the entrainment threshold may not be expected to change. Generally, care needs to be used when making geomorphic predictions using simple ecological indices.

74. While a 25 m^3s^{-1} extraction is unlikely to have a significant effect on the Waimakariri River geomorphology, there is little good factual support for this in the information provided.

75. It is unlikely that suspended sediment concentrations will reduce down stream of the extraction points. The suspended load is largely washload (silt and clay) and is supply limited, so diverting part of the flow into a canal will not alter the concentration in the water left in the river. There is some evidence for a gradual reduction in suspended sediment concentration in the down stream direction as it gets trapped in the boundary layer but this mechanism is not flow dependent. Not a big issue, though.

76. The mechanism for sand transfer through the Waimakariri River mouth is more likely to be flushing by floods and freshes when the tide is blown out than by tidal action. It is also possible that sand is sucked back in by the flood tide at low flows. The analysis here is light, with no figures presented on tidal prisms, what happens during floods, low flow periods, etc. However, it is unlikely to be an issue due to the importance and high frequency of freshes and floods.

77. There is little numerical justification to justify the conclusions that CPWS will have no significant effect on bed load transport. For example, I couldn't find the 0.61% reduction in the duration of the 450-550 m^3s^{-1} flow band in GKM (2007), so I don't know if this was the absolute reduction in duration or the relative one. For example, a reduction in duration by 0.61% of a year could be significant if the original duration is only a few % of a year (as it appears to be in Figs 2.3 and 2.4 of GKM 2007). There is no information about the changes in the size and duration of flows higher than FRE3 and their effect on bed load movement. The analysis requires re-doing more thoroughly. The notion of the Rakaia being under-supplied with bed material because it shows some surface armouring is inappropriate and has not been justified. However, I suspect that they have ended up with reasonable conclusion but without any numerical justification.

78. I agree that there shouldn't be any significant effect on channel mobility for the reasons given – based on my experience observing the Waimakariri, the braid pattern tends to be reset/changed significantly only during bankfull or near-bankfull events.

Conclusions regarding the geomorphic effects of CPW

79. No consideration appears to have been given to the effect of prolonged low flows leading to a build up of the barrier at the Rakaia River mouth making it harder, at least sometimes, for the river to cut a re-centred opening. In turn, this can lead to more extensive flooding and perhaps no new break-out opposite the river at all.

80. Suspended sediment concentration is unlikely to reduce down stream of the intakes.

81. Sand flows through the Waimakariri mouth are unlikely to be affected by CPW but it is likely to be because sand flushing by the frequent floods rather than by tidal flows.

82. The effect of CPW on bedload transport is likely to be small but no numerical information has been presented to justify that view. The applicant's view that the effect will be small because rivers are undersupplied with sediment is unsupported.

References:

Duncan, M.J., Woods, R.W. 2004. Flow regimes. IN Harding, J.; Mosley, M.P.; Pearson, C.P.; Sorrell, B., Eds. Freshwaters of New Zealand. New Zealand Hydrological Society, Wellington. p7.1-7.14.

Glova, G.J. and Duncan, M.J. (1985). Potential effects of reduced flows on fish habitats in a large braided river, New Zealand*. Transactions of the American Fisheries Society 114:*165-181.

Golder Associates. Dec 2007. Response to request for further information regarding ecological effects: Central Plains Water Scheme. 30 p.

Golder Kingett Mitchell. March 2007. Central Plains Water: Effects on the Rakaia River, fish screening issues and reservoir water quality. 25 p.

McIndoe, I., Edkins, R. 2007. Irrigation application rate and production under centre-pivots. Abstract of NZ Hydrological Society conference “Water and Land” Rotorua 20-23 November 2007. p59, 60.

Steffens, C., Callander, P. 2007. Land use activities to enhance groundwater availability – The Eyre River recharge trial. Abstract of NZ Hydrological Society Conference “Water and Land” Rotorua 20-23 November 2007. p94, 95.

Appendix 1:

The Waimakariri River Regional Plan and consented water use – de Joux

The Waimakariri River Regional Plan (WRRP) sets out the regional council's policies objectives and rules for taking water from, and discharging contaminants into, the Waimakariri River and its tributaries. The WRRP became operative in October 2004. The key points relating to the taking of water are:

(a) A minimum flow of 41 m^3s^{-1}; and
(b) An "A" water allocation block of 22 m^3/s for abstraction when the "unmodified flow" exceeds 63 m^3s^{-1}; and
(c) All water in excess of the "unmodified flow" of 63 $m^3s^{-1}$is available for abstraction as a "B" block allocation.

The WRRP does not specify any sharing of flows between instream and out of stream users.

The "unmodified" flow is defined in the Plan as the rate of flow in the river calculated by the Canterbury Regional Council as if there were no abstractions. The minimum flow site is identified as being "below Woodstock" and the site for the assessment of the "unmodified" flow is at OHB. Woodstock generally refers to the section of the Waimakariri above the Gorge Bridge to the confluence with the Kowhai River.

Conditions on existing resource consents refer to the minimum flow (41 m^3s^{-1}) as being the "unmodified" flow at OHB as opposed to the "unmodified" flow below Woodstock.

To determine the likely impact that the proposed CPW abstraction will have on the hydrology of the Waimakariri River, it is necessary to first derive a time series of "unmodified" flows from which the effects of historic abstractions have been removed. Having derived the "unmodified" flows, it is then possible to model the impacts that both the existing and the proposed CPW abstractions will have on the hydrology of the River.

To carry out the required modelling I received the following information:

Time series of instantaneous river flow – site 66401 Waimakariri River at OHB. Data for the period 01/01/67 to 21/02/07 supplied by Environment Canterbury; and

Time series of instantaneous intake abstraction – site 66450 Waimakariri Irrigation Ltd (WIL) intake at Brown's Rock. Data for the period 19/02/99 to 21/02/07 supplied by WIL.

Modelling the "unmodified" flow

The assumptions used in this model are as follows:

Historic stock-water use is 4.0 m^3s^{-1} and is not subject to restriction at times of low river flows.

Prior to the WRRP becoming operative, resource consents for the abstraction of water for irrigation purposes were required to cease abstractions whenever the flow in the Waimakariri River at OHB was less than 37 m^3s^{-1} [1]. It is noted that this flow rate is the measured flow, not the "unmodified" flow.

Maximum consented irrigation takes during the specified periods (from ECan consent information) are shown in Table A1.

Table A1: Total irrigation demand

Season start	Maximum rate (m^3/s)
Pre 1968	Nil
1969-87	1.6
1988-92	1.8
1993-98	2.7
1999-07	2.7 + WIL Irrigation[2]

[1] Eg condition 1 of consent CRC916302B specifies "The taking of water in terms of this permit from the Waimakariri River shall cease whenever the flow in the Waimakariri River, as estimated by the Canterbury Regional Council, at the Old Highway Bridge recorder site (map reference M35:818-547) falls below 37 cubic metres per second."

Irrigation restrictions for the periods shown in Table A1 are presumed to be applied pro rata in accordance with the historic 37 m^3s^{-1} minimum flow at OHB.

Prior to the granting of the Waimakariri Irrigation Ltd intake consents there has been no requirement by the regional council for consent holders to record the rate and volume of take from the river. In order to model the unmodified flow at OHB, certain assumptions regarding the extent of historical abstractions had to be made.

Irrigation demand varies from month to month throughout each irrigation season. Estimates of average monthly irrigation demand have been assessed by a number of authors and are shown in Table A2.

Table A2 Monthly irrigation demand.

Source	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Attewell	0%	0%	0%	62%	78%	92%	100%	75%	58%	36%	0%	0%
Scarf	0%	0%	25%	60%	85%	100%	100%	85%	60%	25%	0%	0%
PDP	0%	0%	8%	25%	68%	8%	99%	76%	62%	16%	0%	0%
Modelled	0%	0%	25%	30%	70%	90%	100%	85%	60%	25%	0%	0%

Pattle Delamore Partners (PDP, 2006) presented evidence in support of resource consent applications by Ngai Tahu Properties Ltd. They describe monthly irrigation demand data for the period 1967 to 2004 based on soil moisture modelling for the WIL scheme. Although this provides a more realistic indication of the variability of demand from one year to another, unless the moisture deficit is calculated on a daily basis, the results will underestimate actual use. This is because the use of a monthly deficit estimate ignores the fact that the soils could be in deficit for long periods during the month before any rainfall occurs.

Although individual irrigators have the ability to regulate and schedule their abstractions in accordance with soil moisture deficits, it is extremely difficult to manage the application of water within a large irrigation scheme on the same basis. In the case where a scheme does not have the capacity to supply all farmers at the same time it is necessary to roster the water. This requires farmers to utilise water at times when soil moisture may not be in deficit. In such cases, the use of variable monthly irrigation demand figures for modelling purposes will produce an underestimation of the actual water usage.

For the purpose of the model I have used the values shown in the 5th row of Table A2. For example, if the total consented irrigation take in October 1994 was 2.7 m^3s^{-1} then the assumed average demand would be 2.7 m^3s^{-1} x 30% = 0.81 m^3s^{-1}. This method was only applied to the unmeasured irrigation abstractions. The actual water usage from the WIL was used in the model.

[2] WIL consents allow for up to 2.1 m^3/s for Waimakariri District Council stockwater supply. The WIL intake abstraction less 2.1 m^3s^{-1} is assessed as being used by WIL for irrigation and/or augmentation.

Appendix 2

The data sets used for determining the effect of CPW on Waimakariri River flows.

Dataset 1: Unmodified flows

The Waimakariri River modelling I carried out was based on an unmodified flow series compiled by Mr de Joux of Environmental Consultancy Services. Appendix 1 above sets out the information and assumptions he used to compile the unmodified record. The resultant series was in terms of mean daily flows and so all subsequent data sets and analysis is on the basis of mean daily flows.

Dataset 2: The current residual flow.

This dataset is based on dataset 1 less the A permit take of 22 m^3s^{-1} from 1 November to 30 April. If the flow was greater than 62 m^3s^{-1} then the 22 was deducted from the unmodified flow. If the flow was between 62 m^3s^{-1} and 45 cumecs then the residual flow was set at 41 m^3s^{-1}. At lower flows and during winter the residual flow was the unmodified flow less 4 m^3s^{-1}. The 4 m^3s^{-1} flow is the unrestricted stock water take.

Dataset 3: CPW 20:25:240 plus A permit.

URS supplied a demand data set labelled 20:25:240 where 20 indicates a maximum take of 20 m^3s^{-1} from the Rakaia River, 25 indicates a maximum take of 25 m^3s^{-1} from the Waimakariri River and 240 is the active storage in the reservoir in millions of cubic metres. The Rakaia river take is given priority and I assume the Waimakariri demand series takes into account the modelled historic irrigation demand for the scheme as modified by flow scheduling issues within the scheme. This demand series was used as it appeared that that was the most recently favoured scheme configuration.

During the summer if the flow was less than 63 m^3s^{-1} then only A permit water was deducted as detailed for dataset 2. If it was more than 63 m^3s^{-1} the residual was the unmodified flow less the Waimakariri demand series less 22 m^3s^{-1}. In winter if the flow was less than 67 then the flow was the residual less 4 m^3s^{-1}. If the unmodified flow was more than 67 then the residual flow was the unmodified flow less the Waimakariri demand series less 4 m^3s^{-1}.

Dataset 4: CPW 20:40:220 plus A permit.

URS supplied a demand data set labelled 20:40:220 where 20 indicates a maximum take of 20 m^3s^{-1} from the Rakaia River, 40 indicates a maximum take of 40 m^3s^{-1} from the Waimakariri River and 220 is the active storage in the reservoir in millions of cubic metres. The Rakaia river take is given priority and I assume the Waimakariri demand series takes into account the modelled historic irrigation demand for the scheme as modified by flow scheduling issues within the scheme. This demand series was used as it appeared that that was the scheme configuration that reflected the takes detailed in the resource consent application.

During the summer if the flow was less than 63 m^3s^{-1} then only A permit water was deducted as detailed for dataset 2. If it was more than 63 m^3s^{-1} the residual was the unmodified flow less the Waimakariri demand series less 22 m^3s^{-1}. In winter if the flow was less than 67 then the flow was the residual less 4 m^3s^{-1}. If the unmodified flow was more than 67 then the residual flow was the unmodified flow less the Waimakariri demand series less 4 m^3s^{-1}.

Appendix 3:

Details of Rakaia River flow modelling

I have created 3 datasets using the 'natural' flow record from the Rakaia River at Rakaia Gorge/Fighting Hill as recorded by NIWA for 1978-2006.

- Residual flow before CPW –Bands 1-4 only (with 1:1 flow sharing above monthly minimum flows) (33.84 m^3s^{-1} abstraction from October to April).

- Residual flow after CPW – Bands 1-4 and CPW only (with 1:1 flow sharing above monthly minimum flows) (53.84 m^3s^{-1} abstraction from October to April and 20 m^3s^{-1} from May to September).

- Residual Flow after CPW + ACWT– A Block, CPW and ACWT (with 1:1 flow sharing above monthly minimum flows) (70 m^3s^{-1} abstraction from October to April and 36.16 m^3s^{-1}frm May to September).

  The modelling I have carried out assumes and includes:

- The full take for Bands 1-4 during October to April because the takes are used for irrigation and there is currently no significant storage even though the takes are permitted all year. The assumed abstraction regime for Bands 1-4 will generally give conservative results because in an average year irrigation will only begin some time in October and cease sometime in April but there will be some seasons when irrigation will commence in September and finish in May

- The full take for CPW and ACWT all year because it is likely that any water not used by CPW will be used by ACWT for irrigation and hydroelectric generation.

- 1:1 sharing between the river and abstractors.

- Recent analysis by ECan (L Fietje Pers. Comm. 25/7/07) shows that the current allocated amount from the Rakaia River gives a total of 33.84 m^3s^{-1} allocated, leaving just over 36.16 m^3s^{-1} available to allocate.

- The CPW and ACWT takes commence when the flow is twice 33.84 m^3s^{-1} above the WCO monthly minimum flow and the full takes can commence at 107.7 m^3s^{-1} and 140 m^3s^{-1} above the WCO monthly minimum flow for the CPW and CPW + ACWT takes respectively.

- Data was available for the Rakaia River at Fighting Hill between 1978 and 2006.