

29 June 2009

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## MEMORANDUM

**FROM :** DARREN LEFTLEY

**TO :** ANNA VELTMAN  
cc Tim Davie, Jeanine Topélen

**SUBJECT :** WAIMAKARIRI PLAN REVIEW – B ALLOCATION

The aim of this memo is to provide a general description of the flow regime of the Waimakariri River and to discuss the impacts of four allocation models on this flow regime.

### Natural Flow Regime

The natural flow regime of the Waimakariri River is assumed to be the mean daily flow series produced by Richard De Joux<sup>1</sup> and is an estimate derived from the recorded flow at Old Highway Bridge for the period January 1967 to February 2007. Figure 1 below shows the mean monthly naturalised flows for the Waimakariri River at Old Highway Bridge.

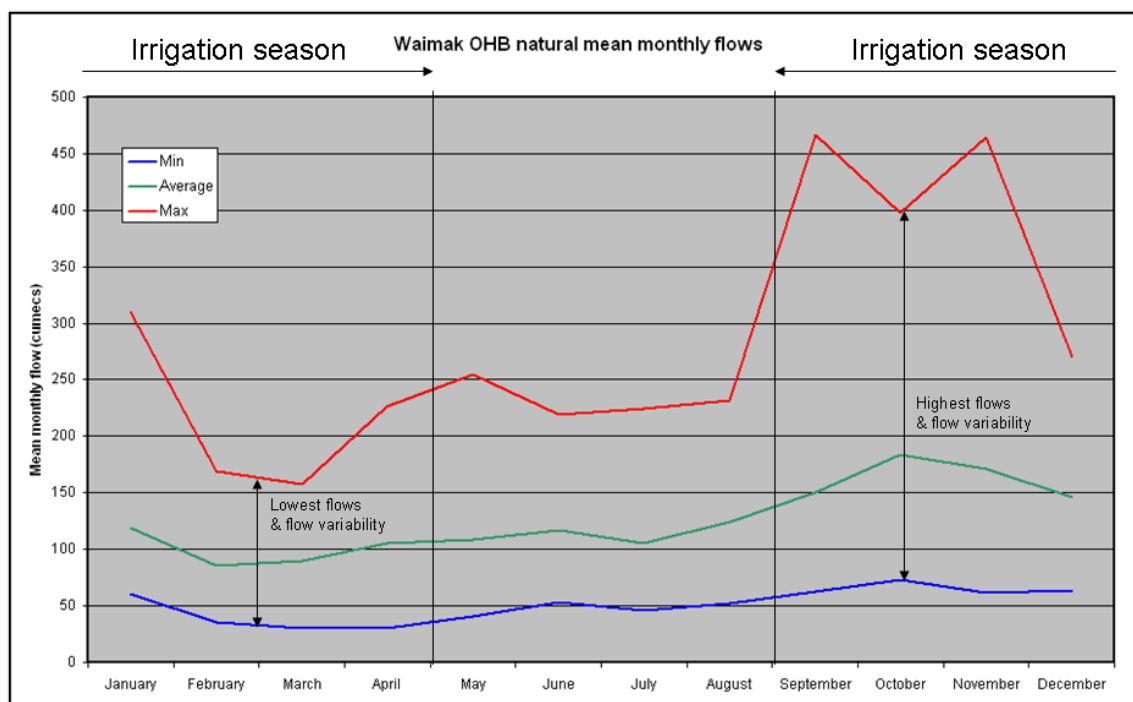


Figure 1 mean monthly naturalised flows at Old Highway Bridge

<sup>1</sup> 2007 naturalised flow record submitted as evidence to the CPW hearings and agreed by all parties

Figure 1 shows that the lowest flows occur in the period January to April and also shows that generally the flow variability, the difference between high and low flows, is lowest in this period. This is a period which would have a lower reliability for out of stream takes. The winter period between May and August has higher low flows and flow variability and would most probably be associated with lower average temperatures and lower evapotranspiration rates. The period between September and November has the highest flows and greatest flow variability. This flow variability is mostly driven by significant North West weather events producing rainfall and snowmelt in the upper catchment. This period would give the highest reliability for out of stream takes.

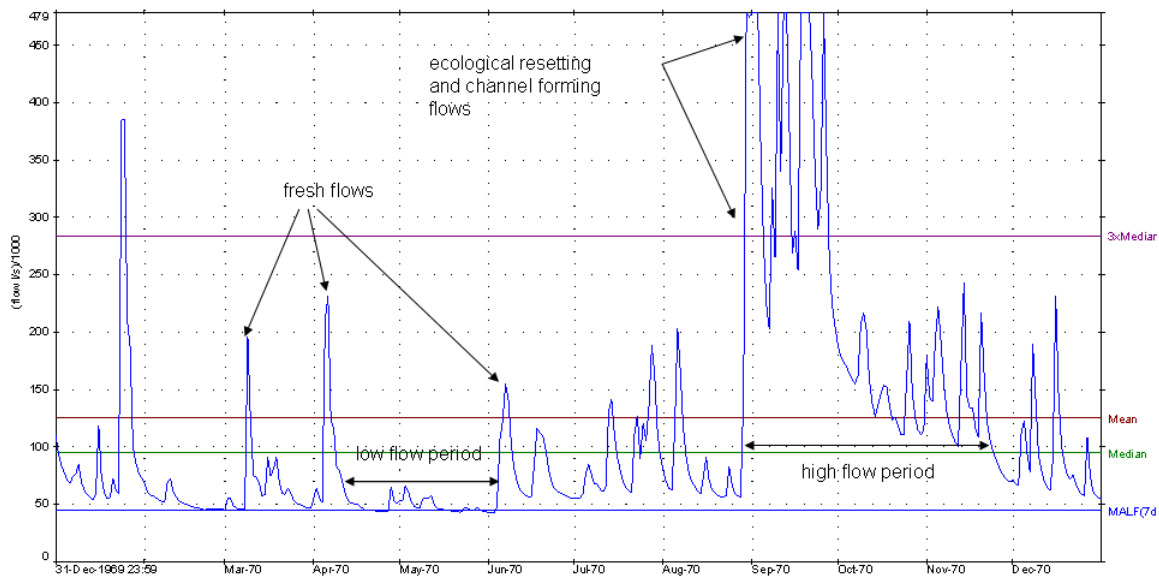


Figure 2 1970 flow time series at Old Highway Bridge

The natural flow regime has other important features which are best illustrated by an annual time series of mean daily flow. The year shown in Figure 2 is 1970 which was a “dry summer” year but serves to illustrate the important features. The first point to note is that low flow periods are normally interspersed with fresh flows which are important ecologically. The period between these fresh flows is an important consideration for the health of the river.

Higher flows, above 3 times the median, are important for flushing periphyton, resetting the gravels and for channel forming, changes to the frequency of these events are an important consideration for any allocation model.

### Current Flow Regime

The natural flow regime has already been modified by out of stream uses for irrigation, stock water and domestic use. These modifications were granted for individual consents under the policies of the existing Waimakariri River Regional Plan.

The current plan allows for out of stream takes within an A Block allocation of 22 m<sup>3</sup>/s and subject to an unmodified (naturalised) minimum flow of 41 m<sup>3</sup>/s, based on the measured flow at the Old Highway Bridge recorder site. The A Block is currently fully allocated although not fully utilised. This is best illustrated in Figure 2 which shows the naturalised, recorded and fully utilised A Block flow duration curves for the full flow record from 1967.

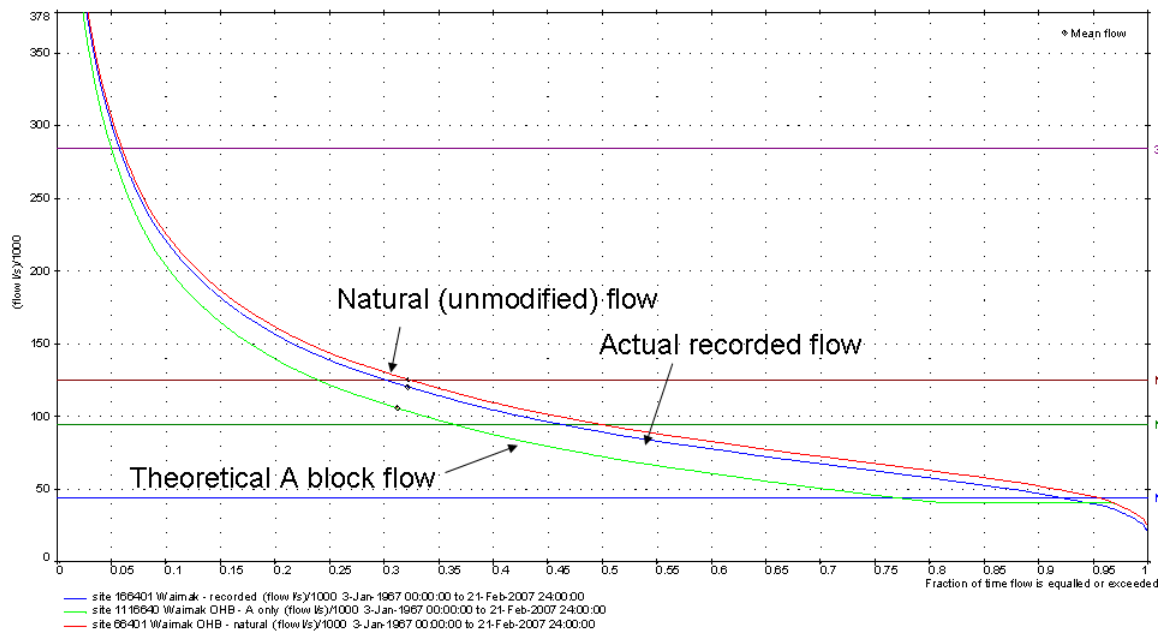


Figure 3 flow duration curves for Old Highway Bridge

Figure 3 shows that the recorded flow (blue line) has very limited flat lining and is closer to the naturalised flow (red line) than it is to the A Block curve. This illustrates that the average utilisation over the last 40 years has been much less than the theoretical fully utilised A block curve (green line). This is because irrigation takes have only been consented fully in the last 10 years and normally would only take water in the irrigation season (Oct-Apr).

Figure 4 shows a flow duration curve with the same time series but for the last 10 years only and only for the period January-April when irrigation demand would be at its highest.

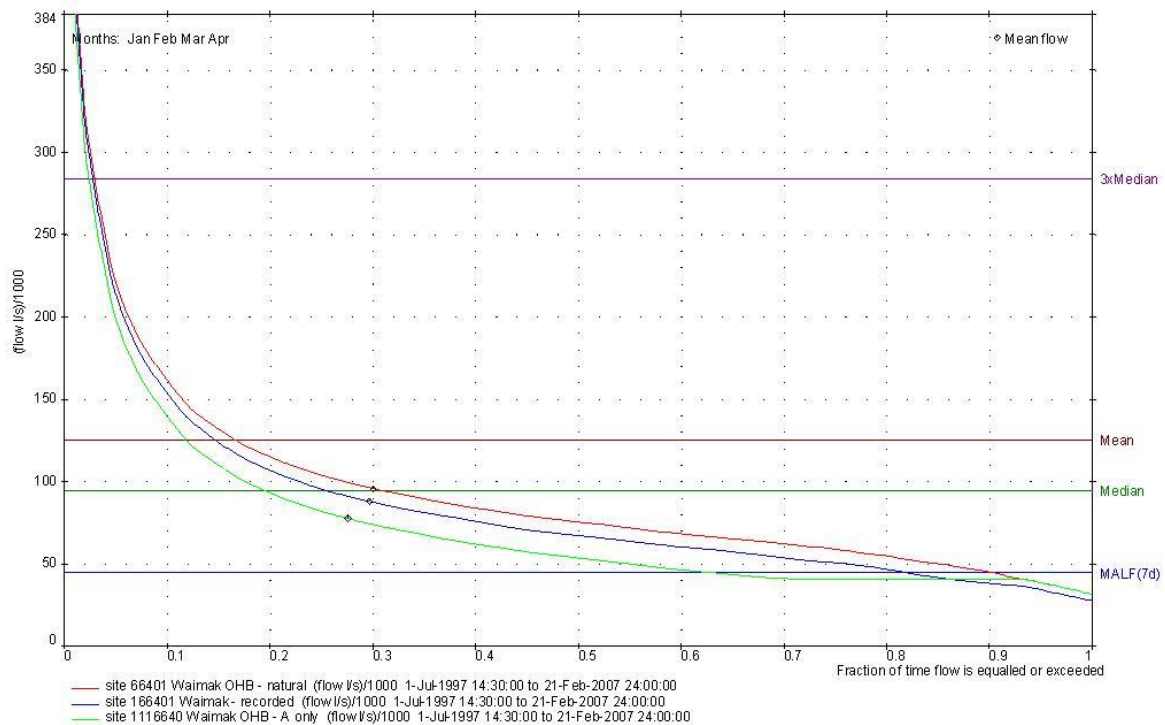


Figure 4 flow durations curves for 1997-2007 and January-April only

The average take is approximately 30%-40% of the maximum allocation, this is further supported by reviewing the average monthly take by Waimakariri Irrigation Company. Although the take varies, over the last 10 years the average monthly take has been approximately 30% with a maximum of 80% and a minimum of 4%.

The main conclusion is that although the takes have increased over the last 10 years the river flow regime has yet to experience the full effects of a fully utilised A Block.

Therefore a fully utilised A Block curve (green line) is theoretical and shows what would happen if 22m<sup>3</sup>/s was taken out the river every day of the year for the full flow record, except during periods of partial and full restrictions. This abstraction regime would lead to flat lining at 41m<sup>3</sup>/s and flow reductions of 22m<sup>3</sup>/s. The flat lining is caused when partial restrictions are in operation. Without this control flows would be below 41m<sup>3</sup>/s for much longer periods than would occur naturally and this would have significant impacts on in stream values.

Directly above the A Block is an unlimited B Block which currently has approximately 1.7m<sup>3</sup>/s allocated. The theoretical effect of an unlimited B Block, without a gap, would be to increase the frequency of flat lining at 41m<sup>3</sup>/s, becoming more pronounced as the B Block is further allocated and leading to a greater reduction of flow. This would have a significant effect on in stream values, fresh flows, flow variability and reliability of supply.

### **Future flow regime options under a plan review**

There are a very large number of possible flow regimes derived from different gap sizes, gap suspension periods, different B Block size, partial restrictions, 1:1 flow sharing etc. It is also likely that each one of these flow regimes will have a different reliability of supply for out of stream takes and will affect in stream values differently. The final choice of flow regime will depend on the objective which the plan is trying to achieve. For example a larger gap will protect in stream values better but will lead to a lower reliability for out of stream takes. Therefore if the plan wishes to protect in stream values as its principle objective then a larger gap should be sought, if it wishes to achieve the highest reliability for out of stream uses then no gap would be better.

Maurice Duncan (Duncan 2008), presented to council a number of different flow regimes and recommended a gap size of 27m<sup>3</sup>/s, suspended during the winter and a B Block size of 40m<sup>3</sup>/s. He also recommended a C Block of 5-10m<sup>3</sup>/s without a gap. He assumed that the A Block would only be utilised during the period 1<sup>st</sup> October to 31<sup>st</sup> April.

Council requested that other scenarios be assessed and that the impact on particular hydrographs were considered. External consultation also highlighted that 1:1 flow sharing had considerable support and should be assessed.

In response to these requests the following four allocation models have been analysed and are presented in detail here. It is worth noting that over 25 separate models have been analysed but these final four appear to represent the most balanced scenarios in terms of the conflicting interests of in stream values and out of stream reliability.

The four allocation models are:

- Gap = 30m<sup>3</sup>/s all year, B Block = 20m<sup>3</sup>/s
- Gap = 30m<sup>3</sup>/s all year, B Block = 40m<sup>3</sup>/s
- 1:1 flow sharing, B Block = 20m<sup>3</sup>/s
- 1:1 flow sharing, B Block = 40m<sup>3</sup>/s

The impacts of the four models have been assessed by comparing statistics of the rivers flow regime as well as the reliability of supply to out of stream users. The statistics are also supplemented by flow duration curves to further detail the impacts suggested by the statistics.

The flow statistics are grouped into three categories: flow variability, flow value range and reliability of supply. Flow variability describes the impact the different models would have on flows flat lining and fresh flows. Flow value range describes the impact the different models would have on flows in the range 50-150 m<sup>3</sup>/s. This is the in stream value range described in Duncan (2008). Reliability of supply describes the impacts on out of stream takes. The statistics assume that all of the allocated water is taken every day of the year, except where partial and full restrictions would apply. i.e. all water available for abstraction is taken.

## Flow Variability

Table 1 flow variability statistics

	flow variability (median)					
	days at 41 m <sup>3</sup> /s (A min flow)	days at 71 m <sup>3</sup> /s	days below 50 m <sup>3</sup> /s	max consecutive days between flows 130 m <sup>3</sup> /s	No. peaks at 284 m <sup>3</sup> /s (Fre3)	max consecutive days between flows 284 m <sup>3</sup> /s
natural	0	0	18	57	10	110
recorded	0	0	34	57	10	112
A only	52	0	100	68	10	115
gap 30, B = 20	52	49	100	70	8	135
gap 30, B = 40	52	75	100	82	7	142
1:1 sharing, B = 20	52	0	131	70	8	135
1:1 sharing, B = 40	52	0	131	82	7	142

Table 1 provides a summary of the flow statistics for each of the four scenarios and also shows the comparison with the natural flow, a fully utilised A Block allocation and actual recorded flow. The table shows that flat lining at 41m<sup>3</sup>/s is a consequence of the A Block and is unchanged with a B Block as long as there is a gap or 1:1 flow sharing. A gap will introduce a threshold at 71m<sup>3</sup>/s, the number of days flat lining occurs is then determined by the size of the B Block, with a block size of 40m<sup>3</sup>/s giving more days of flat lining than a B Block of 20m<sup>3</sup>/s. The 1:1 flow sharing models do not result in additional flat lining, as all flows are shared above the top of the A Block.

When comparing the natural flow curve with the A Block curve the number of days below 50m<sup>3</sup>/s increases by 92 days. A further B Block allocation with a gap keeps this figure unchanged whereas 1:1 flow sharing increases the number of days below 50m<sup>3</sup>/s from 100 to 131, regardless of the B Block size.

The impact on the number of and interval between fresh flows of 130m<sup>3</sup>/s and 284m<sup>3</sup>/s is greater for a larger block size than a smaller block size. The smaller the block size the greater the retention of the natural variability and frequency of fresh flows. There is no difference in the impact between a gap size of 30m<sup>3</sup>/s and 1:1 flow sharing. The reason for this is that a gap size of 30m<sup>3</sup>/s is insufficient to affect these larger flows.

## Flow Value Range

Table 2 flow value range statistics

	flow value range (median)			
	days flows between 50 m <sup>3</sup> /s - 100 m <sup>3</sup> /s	max consecutive days flows between 50 m <sup>3</sup> /s - 100 m <sup>3</sup> /s	days flows between 50 m <sup>3</sup> /s - 150 m <sup>3</sup> /s	max consecutive days flows between 50 m <sup>3</sup> /s - 150 m <sup>3</sup> /s
<b>natural</b>	166	27	253	47
<b>recorded</b>	165	25	245	44
<b>A only</b>	133	17	197	27
<b>gap 30, B = 20</b>	159	20	211	31
<b>gap 30, B = 40</b>	190	26	211	34
<b>1:1 sharing, B = 20</b>	126	16	169	24
<b>1:1 sharing, B = 40</b>	145	19	185	26

Table 2 provides a summary of the flow statistics for each of the four scenarios and also shows the comparison with the natural flows, a fully utilised A Block allocation and actual recorded flows. The table shows that a gap increases the number of days within the flow range 50 -150m<sup>3</sup>/s when compared to 1:1 flow sharing. A larger B block has more influence in increasing the number of days in the flow range 50 -100m<sup>3</sup>/s than the flow range 50 -150m<sup>3</sup>/s. A similar effect is shown for the maximum consecutive days the flow is within the range.

This suggests that having a gap is a more suitable allocation model for the protection/enhancement of the flow value range than 1:1 flow sharing. The larger B block size is then important for further enhancing the flows in the range 50 – 100 m<sup>3</sup>/s.

## Reliability of Supply for out of stream users

There are a number of different ways to express reliability of supply, in Table 3 below reliability is expressed as the average number of days when out of stream takes will be fully restricted, partially restricted or unrestricted. The statistics have been produced for the whole year as well as for different periods of the year: January to April, May to August and September to December

Table 3 reliability of supply statistics

	reliability of supply for abstraction based on natural flow record (average)											
	January - April			Jul -Aug and May - June			September - December			total		
	no. days no restriction	no. days partial restriction	no. days full restriction	no. days no restriction	no. days partial restriction	no. days full restriction	no. days no restriction	no. days partial restriction	no. days full restriction	no. days no restriction	no. days partial restriction	no. days full restriction
A only	78	33	10	97	23	2	116	6	0	290	63	12
gap 30, B = 20	28	13	79	39	16	68	70	18	34	137	47	181
gap 30, B = 40	21	21	79	29	26	68	55	33	34	104	79	181
1:1 sharing, B = 20	34	44	43	46	51	26	78	37	6	159	132	75
1:1 sharing, B = 40	17	60	43	25	72	26	47	68	6	90	200	75

Table 3 summarises the impacts of the different models on reliability of supply statistics. The table shows that for all periods 1:1 flow sharing with a B Block of 20m<sup>3</sup>/s provides more days without restrictions than having a gap with an equivalent B Block size. 1:1 flow sharing with a B Block of 20m<sup>3</sup>/s also has fewer days in full restrictions but more days in partial restriction than having a gap of 30m<sup>3</sup>/s and a B Block of 20m<sup>3</sup>/s.

The reliability of supply for all scenarios is highest in the September to December period when river flows are generally higher.

The reliability of supply for the B Block allocation is much less than the A Block allocation. Reliability is lowest in the January to April period when flows are at their lowest and most of the available water will be taken by the A Block users.

Reliability can also be expressed by considering the volumes of water which can be taken under the four allocation models. These statistics are shown in Table 4 below and represent the average annual quantity which can be abstracted during the year and in each of the three periods.

Table 4 volumes of water taken under four allocation models

	annual available volume for abstraction based on natural flow record (average)			
	January - April	Jul -Aug and May - June	September - December	total
	volume (Mm <sup>3</sup> )*	volume (Mm <sup>3</sup> )*	volume (Mm <sup>3</sup> )*	volume (Mm <sup>3</sup> )*
A only	183	213	228	622
gap 30, B = 20	59	81	136	275
gap 30, B = 40	101	139	243	483
1:1 sharing, B = 20	90	119	170	378
1:1 sharing, B = 40	133	178	277	587

\*Units are Mm<sup>3</sup> = million cubic metres

The greatest volume of water can be taken by the A Block, which is unsurprising. The second largest take of 587 Mm<sup>3</sup> occurs with an allocation model of 1:1 flow sharing with a B Block of 40m<sup>3</sup>/s. The largest portion of the take is in the period September - December and the smallest portion in the period January – April. The next largest is with a gap of 30m<sup>3</sup>/s and B Block of 40m<sup>3</sup>/s. This total of 483 Mm<sup>3</sup> is 104 Mm<sup>3</sup> lower than 1:1 flow sharing with the equivalent B Block size.

Therefore, both the number of days in full restrictions and the total volume of water available for abstraction shows that 1:1 flow sharing gives a higher reliability than having a gap of  $30\text{m}^3/\text{s}$ .

## Conclusions

The flow regime of the Waimakariri River has been modified by out of stream takes consented under the current plan. The existing plan has no gap between the A allocation block and the B allocation block which is unlimited. If water was fully allocated under this plan then the river flow could theoretically be flat lined at  $41\text{m}^3/\text{s}$  for very long periods and offer little to in stream values, users and the life supporting capacity of the river.

The plan revision gives an opportunity for different future flow regimes to be considered so that a sustainable regime can be agreed. The number of possible future flow regimes is very large and over 25 have been analysed and statistics considered. The results show that different allocation models place a different balance between in stream use and out of stream takes. For example a large gap and smaller B Block size will favour the objective of maximising in stream values, alternatively 1:1 flow sharing with a small B block would favour the objective of maximising the reliability for out of stream takes.

The four allocation models which have been presented after external and internal consultation are:

- Gap =  $30\text{m}^3/\text{s}$  all year, B Block =  $20\text{m}^3/\text{s}$
- Gap =  $30\text{m}^3/\text{s}$  all year, B Block =  $40\text{m}^3/\text{s}$
- 1:1 flow sharing, B Block =  $20\text{m}^3/\text{s}$
- 1:1 flow sharing, B Block =  $40\text{m}^3/\text{s}$

The statistics show that a gap provides a flow regime which offers more benefits to the in stream values than 1:1 flow sharing but at the expense of out of stream reliability. In contrast 1:1 flow sharing provides more reliability to out of stream users but less flows for in stream values and maintaining flow variability.

The block size is an important consideration for flow variability which is reduced by increasing the block size. However, an increased block size provides an enhancement to flows in the value range  $50 - 100 \text{m}^3/\text{s}$  and also gives out of stream users access to larger volumes of water.

These results and tensions between values are not unexpected and would exist for any proposed allocation models. If the objective is to strive for a balance then these final paragraphs on 1:1 flow sharing may assist.

A 1:1 flow sharing model has been used on the Rakaia River with the allocation starting at the minimum flow. The benefits of such a model compared with an A Block allocation are shown in Figure 5 below. There is a distinct advantage for in stream values where the flow duration curve (blue line) for 1:1 flow sharing is above the flow duration curve (green line) for an A block allocation. In this example for the Waimakariri River this occurs from  $41\text{m}^3/\text{s}$  to  $63\text{m}^3/\text{s}$ , the point where the lines cross over. This allocation model also prevents flat lining and where there is uncertainty over the minimum flow at least provides a proportion of the flow to the river. The disadvantage is that the reliability for out of stream users will be worse when compared to the existing A Block allocation model.

However, for the Waimakariri River a 1:1 flow sharing regime has only been considered from the top of the A Block. The benefits which have been outlined above cannot be achieved

because the A Block allocation is already having a major theoretical impact above and at the minimum flow. Flow sharing from the top of the A Block therefore appears unbalanced in that the river has already been depleted by the A Block without any benefit to in stream values or uses and therefore sharing the next proportion of the flow would overall favour out of stream takes. A more balanced approach would be to allocate the next proportion of the flow to the river and the in stream values and uses, this can be achieved with a gap.

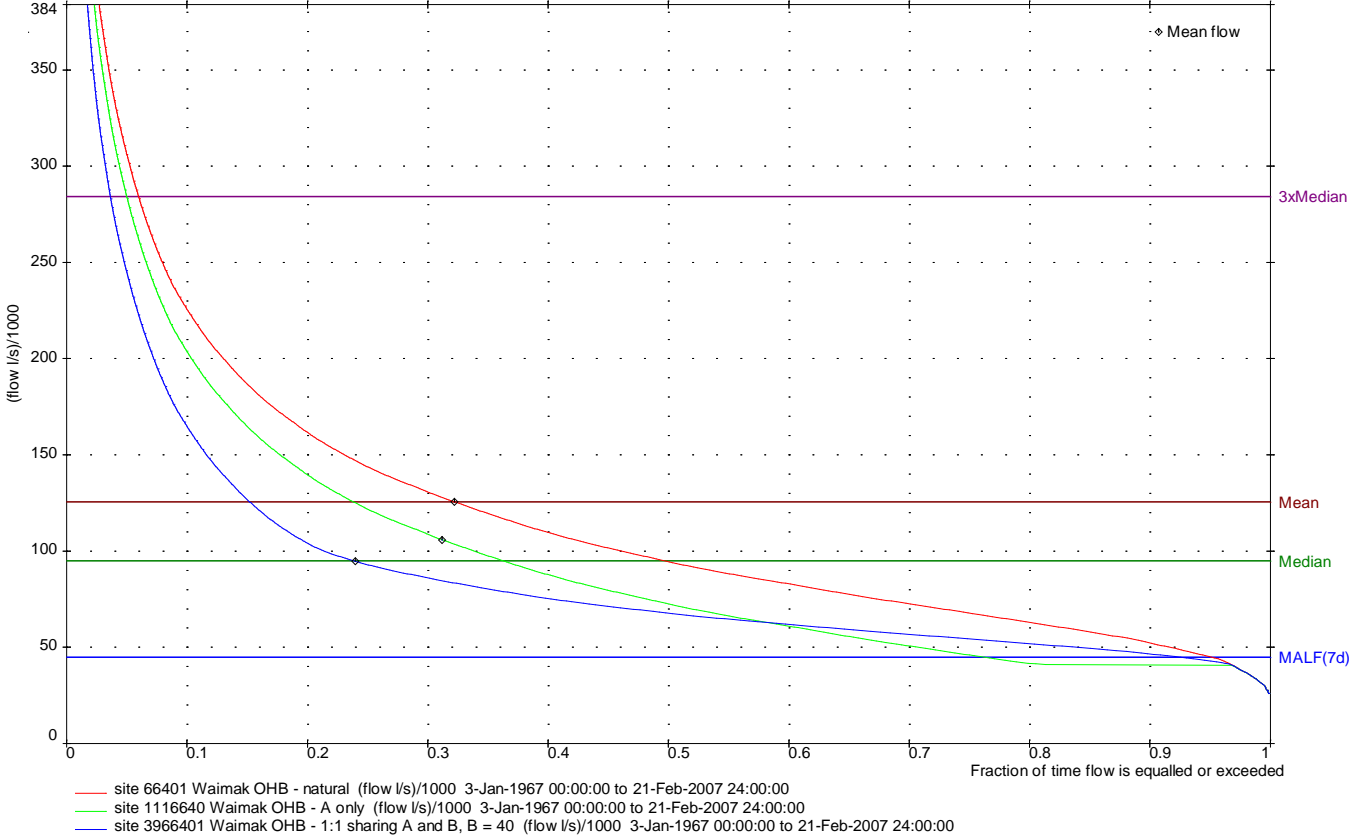


Figure 5 1:1 flow sharing from the minimum flow

**Further information requested by Councillors**

1. The reliability of supply for the existing B Block users

Table 5 Reliability of supply statistics comparison for existing B Block allocation

	reliability of supply for abstraction based on natural flow record (average)											
	January - April			Jul -Aug and May - June			September - December			total		
	no. days no restriction	no. days partial restriction	no. days full restriction	no. days no restriction	no. days partial restriction	no. days full restriction	no. days no restriction	no. days partial restriction	no. days full restriction	no. days no restriction	no. days partial restriction	no. days full restriction
A only	78	33	10	97	23	2	116	6	0	290	63	12
current no gap, B = 1.7	75	3	43	96	1	26	114	1	6	285	5	75
gap 30, B = 20	28	13	79	39	16	68	70	18	34	137	47	181
gap 30, B = 40	21	21	79	29	26	68	55	33	34	104	79	181
1:1 sharing, B = 20	34	44	43	46	51	26	78	37	6	159	132	75
1:1 sharing, B = 40	17	60	43	25	72	26	47	68	6	90	200	75

Table 5 shows that from January to April the existing B Block users would have, on average, 43 days of full restriction and 3 days of partial restriction. This is lower than the A Block users but better than a fully allocated larger B Block with or without a gap.

2. The impact of a 45m<sup>3</sup>/s gap on flow and reliability statistics

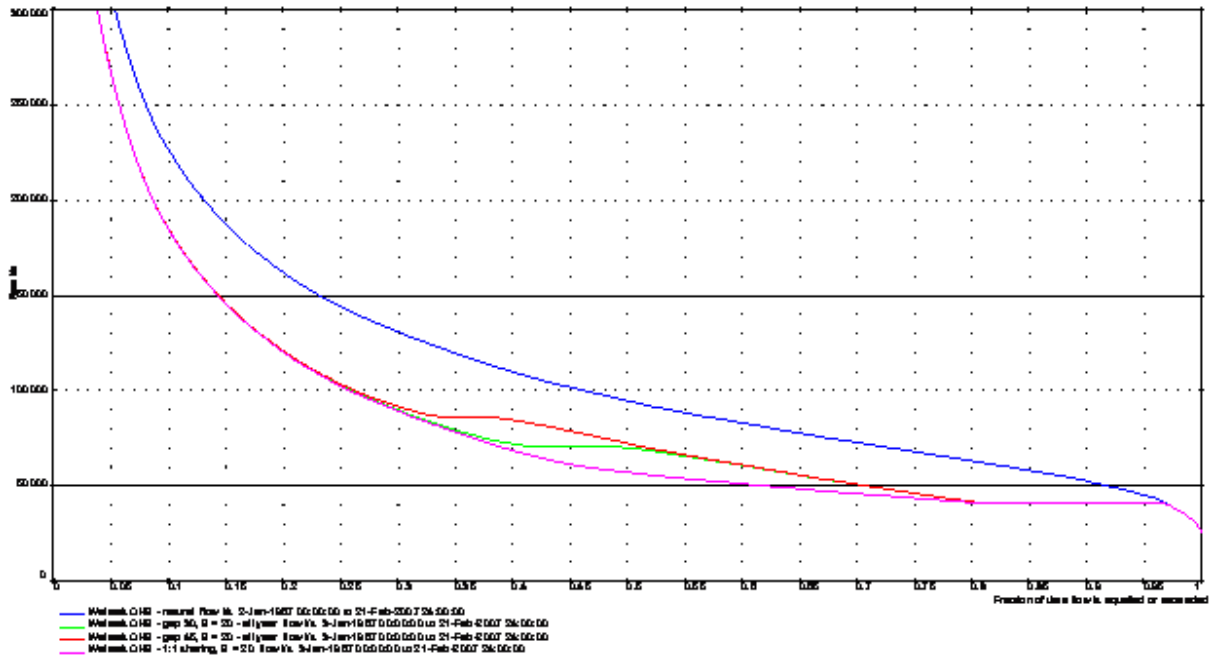


Figure 6 Flow duration curves showing different gap sizes

Figure 6 shows the difference between a gap of 30m<sup>3</sup>/s and a gap of 45m<sup>3</sup>/s plus comparisons with the natural curve and 1:1 flow sharing. All models that are shown have a B allocation block of 20m<sup>3</sup>/s. The larger gap does keep flows nearer to the natural flow curve for longer and protects the flows in the range 71m<sup>3</sup>/s to 86m<sup>3</sup>/s. However the length of time the flows are within the in stream value range 50m<sup>3</sup>/s – 100m<sup>3</sup>/s is the same for both gap sizes. Therefore, there is no difference in the flow statistics that have been used for allocation model comparison. This would suggest that the gap size does not provide any benefit in terms of flow variability or for flows in the in stream value range. The reason for this is that the gap size is not large enough to affect the average flows in the range 50 -100m<sup>3</sup>/s.

## References

Duncan, M. 2008: Waimakariri River: B/C Block allocation review. *ECan report No. R08/67*