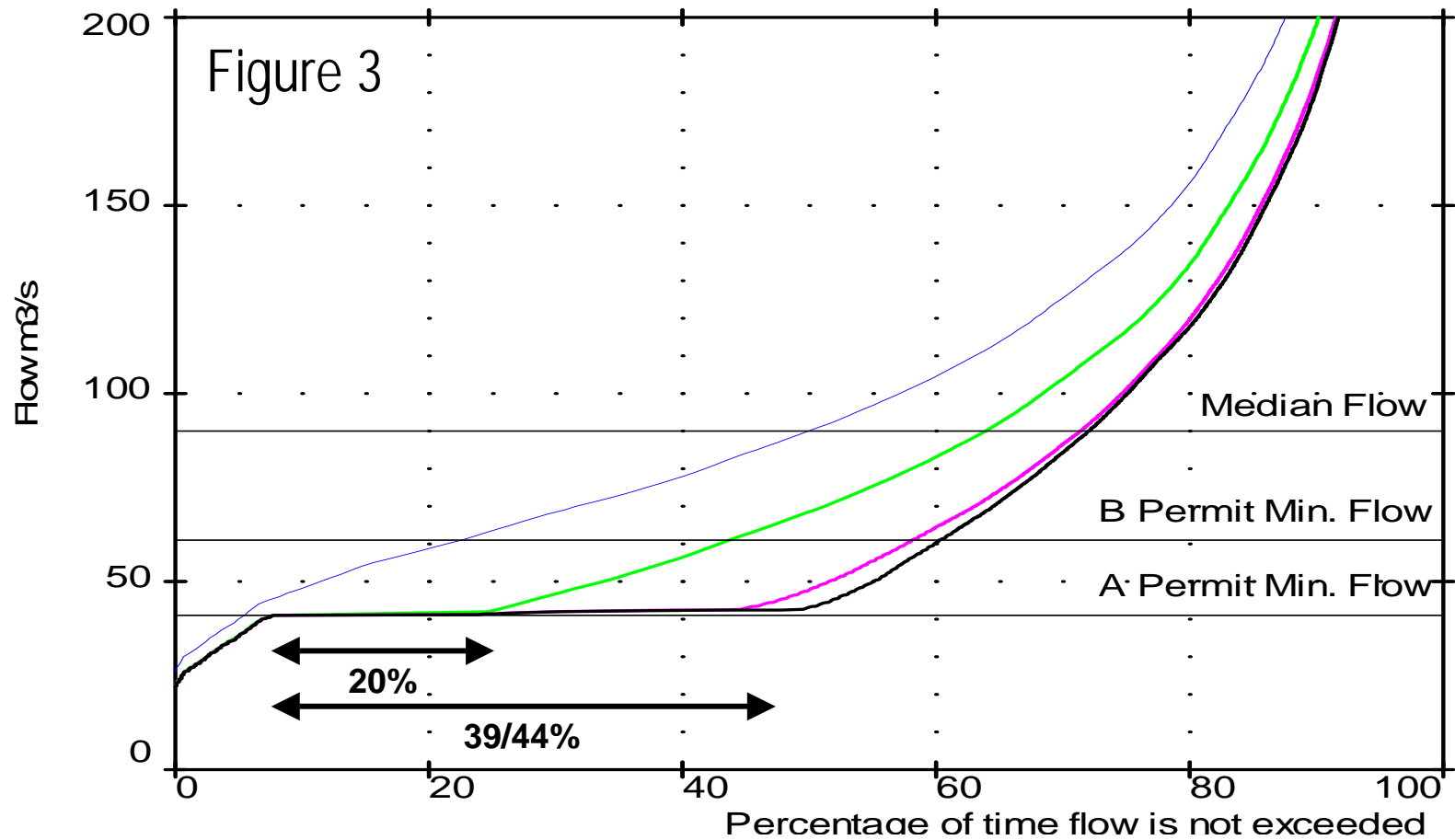


- Initial brief of evidence
- Supplementary evidence
- New information

- Waimakariri River hydrology
- Rakaia river hydrology
- Bywash concerns
- Sediment transport concerns

Waimakariri flow duration curves-summer



- Unmodified (no abstraction)
- With current take
- With current take and CPW 25 m³/s take
- With current take and CPW 40 m³/s take

Waimakariri River flow statistics (Table 1)

	Unmodified	Before CPW (A Permit)	After CPW 20:25:240	After CPW 20:40:220
	(m ³ s ⁻¹)	(m ³ s ⁻¹)	(m ³ s ⁻¹)	(m ³ s ⁻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	964	960	960
Maximum flood	1939	1917	1917	1917

(Summer data
in brackets)

- The main affect of CPW will be to ~ double the period the flow is flat-lined at $\sim 41 \text{ m}^3\text{s}^{-1}$
- Flow in the range $40\text{-}150 \text{ m}^3\text{s}^{-1}$ mostly affected with the median flow reducing by about 30%.
- The flat-lining and flow reduction effects instream values and recreation.
- The hydrological changes have been reported fairly by CPW and F&G.

- I agree in general with the conclusions drawn by CPW and F&G witnesses regarding the affect of the proposal on the Rakaia River.
- There will be no increase in the time the river spends at the 7d-MALF or WCO minimum flows.
- Median flows will reduce
- Reduction in the number of freshes.

- I question whether the wetlands are large enough to absorb the bywash flows.
- They are sized using infiltration rates for bare shingle.
- Will wetlands with plants and enough soil to support them have the same infiltration rate as bare shingle?
- I believe the emergency spills into the Selwyn River and tributaries could be very large and this possibility has to be well managed
- Excess operational bywash flows could be dealt with border dyke irrigation areas.

- I agree with Dr Tim Davies that the presence of bed armour in the two rivers does not indicate under-utilised bed load capacity, thus a reduction in flow could lead to river bed aggradation in theory.
- But no evidence of aggradation from current Canterbury irrigation schemes.
- River bed aggradation could be mitigated by ceasing abstraction during flood events ($>500 \text{ m}^3\text{s}^{-1}$)
- Water takes are unlikely to significantly reduce suspended sediment concentrations downstream of the take.
- The river mouths are unlikely to be affected by the proposed abstractions.

- I agree with the hydrological affects of the schemes as reported by CPW and F&G
- The major affect is on the Waimakariri River where flow will be held at $\sim 40 \text{ m}^3\text{s}^{-1}$ for long periods of time.
- Bywash soakage areas need to be adequately sized and large emergency bywash flows need to be managed appropriately.
- There is a potential for river bed aggradation if large flood flows are diminished by abstraction.

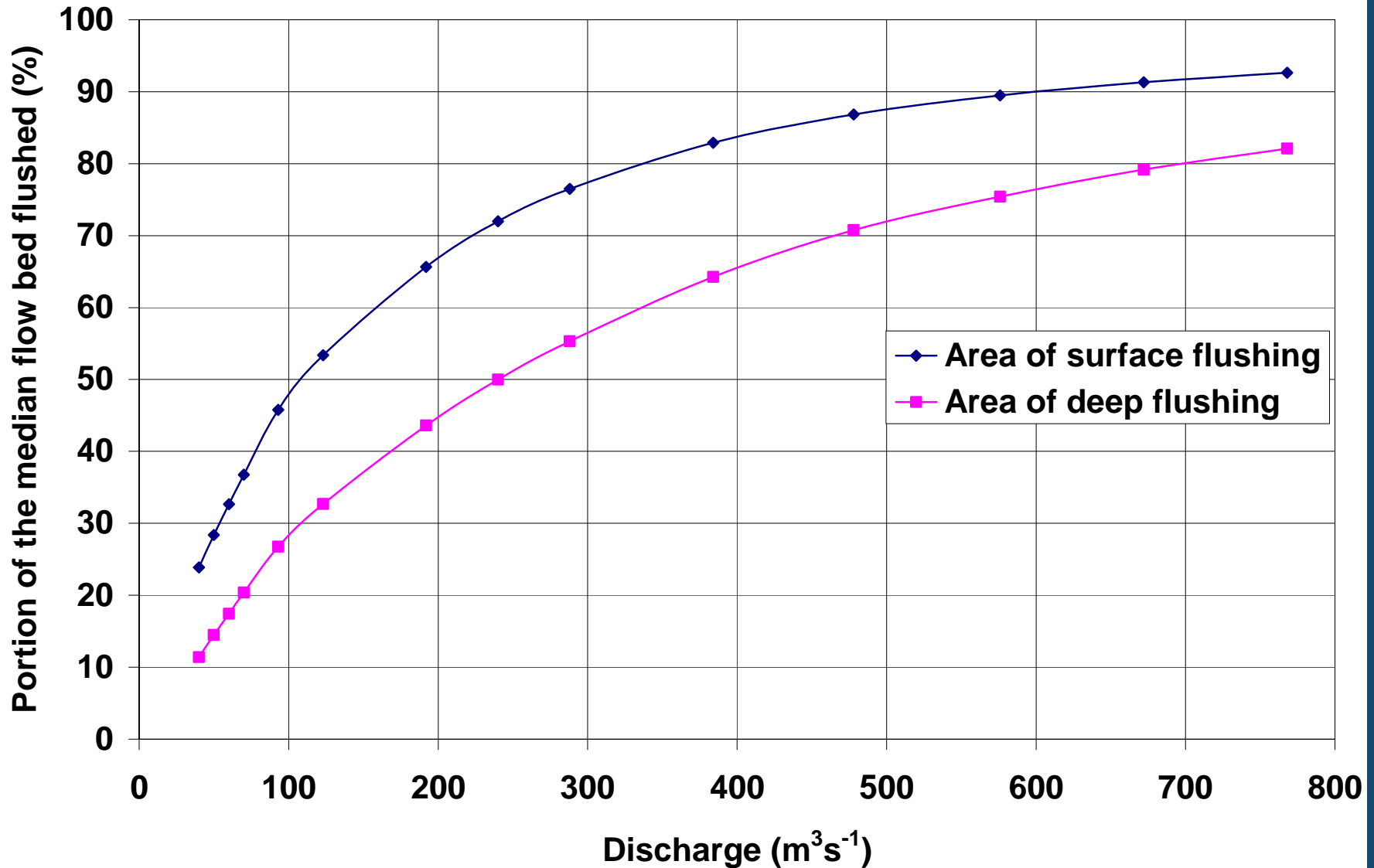
- The 2D hydrodynamic model of the Waimakariri River at Crossbank
- Use of the model to investigate sediment transport and its ecological significance to algae and invertebrates.
- Alternative take regimes: flow sharing and gaps between allocation blocks.
- Other issues.

Waimakariri at Crossbank 2D hydrodynamic model

- I helped collect the field data for the model, ran the model, and supplied depth and velocity data that other witnesses have used.
- “2D” and “dynamic”
- The smaller, 2m x 2m grid version of the model is best.
- I also used the model to predict bedload sediment transport at a range of flows to see when periphyton and invertebrates might be disturbed, and to find out when most sediment transport occurs.

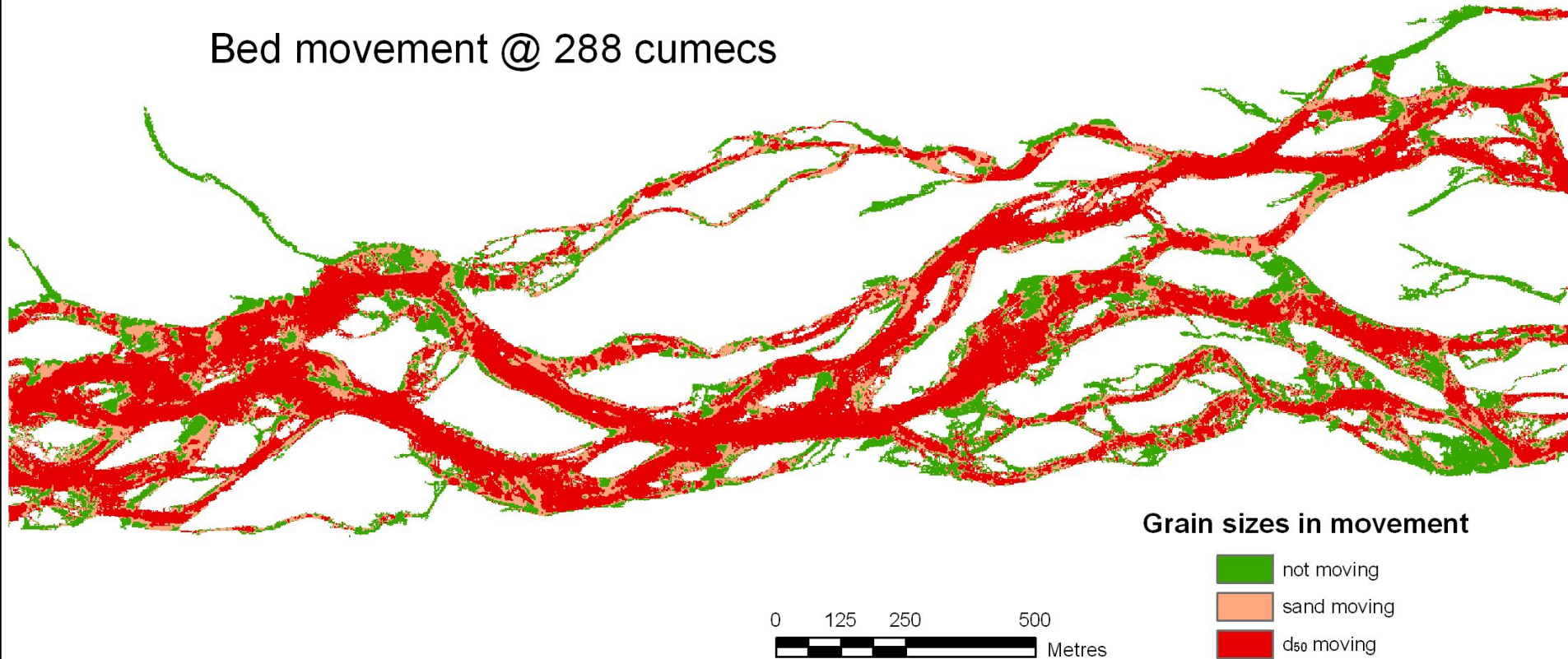
- Bed disturbance criteria for surface flushing of fine sediment and bed armour taken Milhous (1998) as used for the Waitaki consent hearings.
- Filamentous algae disturbance from 2 times pre-existing flow (Biggs and Close 1989) or velocity criteria (Jowett 2003).
- Invertebrate resetting from FRE3 (Sagar 1986) or ~80% (Jowett et al. 2008) modelled bed disturbance

Median flow bed disturbance

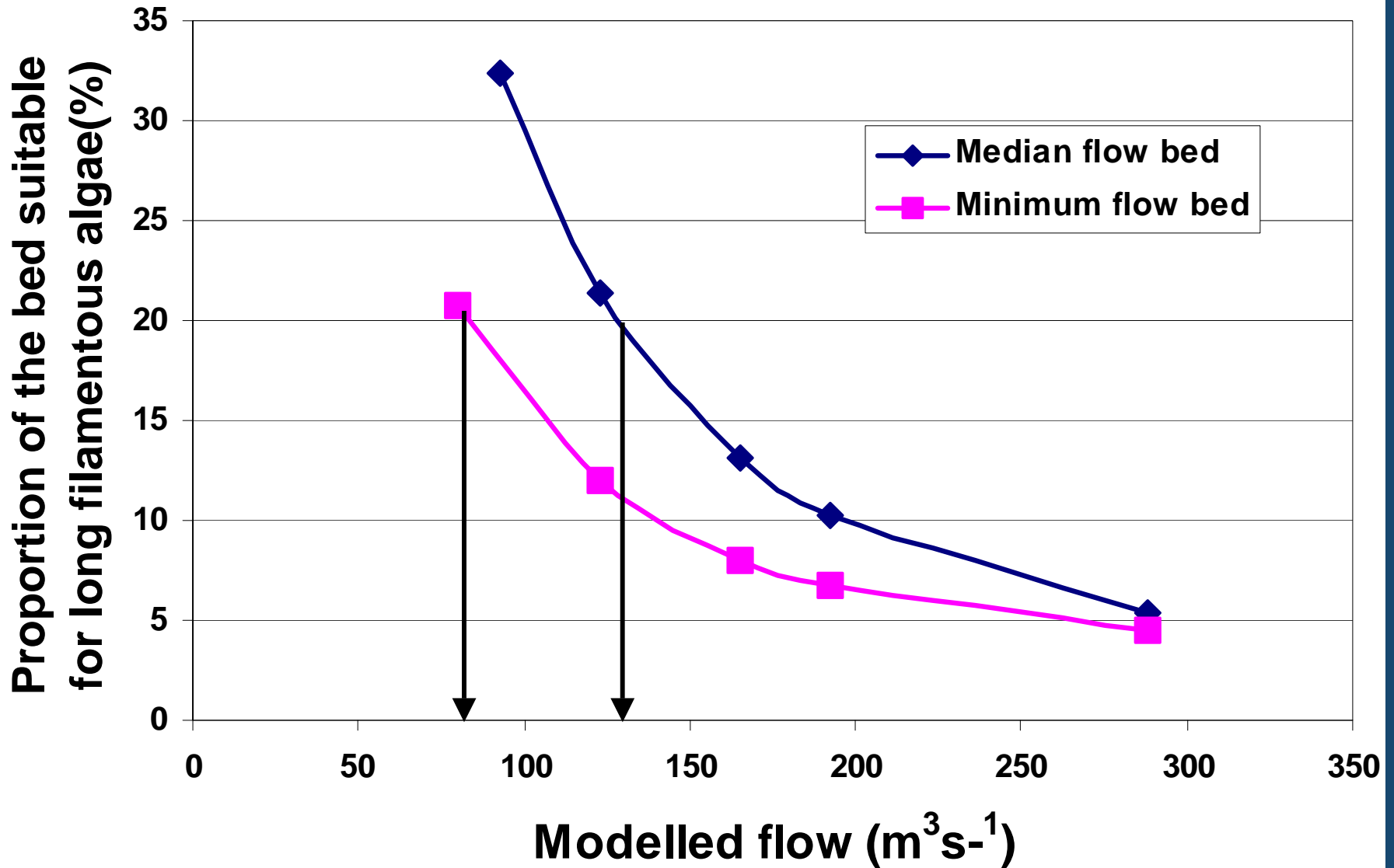


There is no threshold, just gradual increases

Bed movement @ 288 cumecs



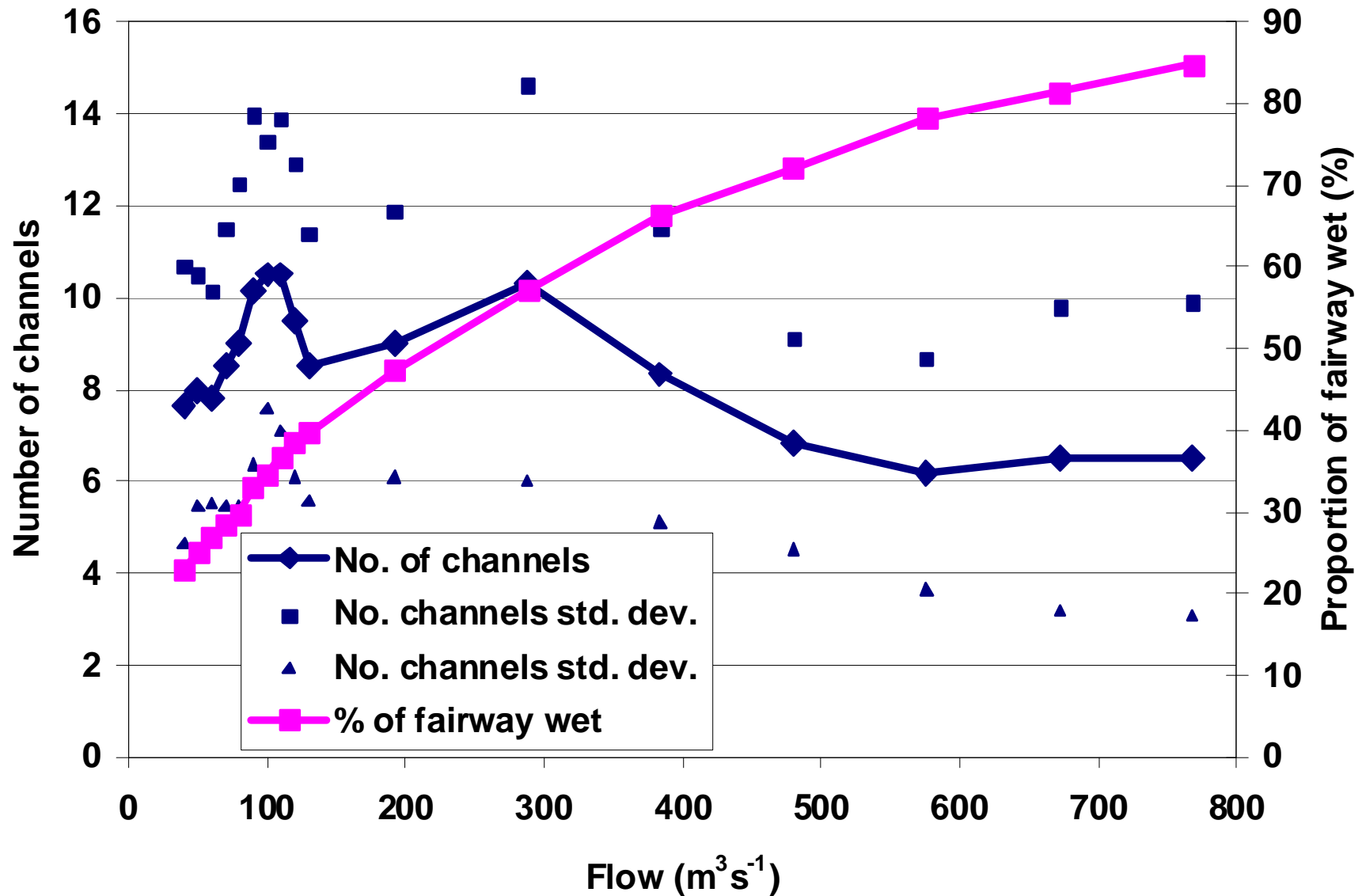
- Flow suggested by Sagar (1986) for invertebrate resetting.
- 77% surface flushing ~ 80% suggested by Jowett et al (2008) for invertebrate resetting.



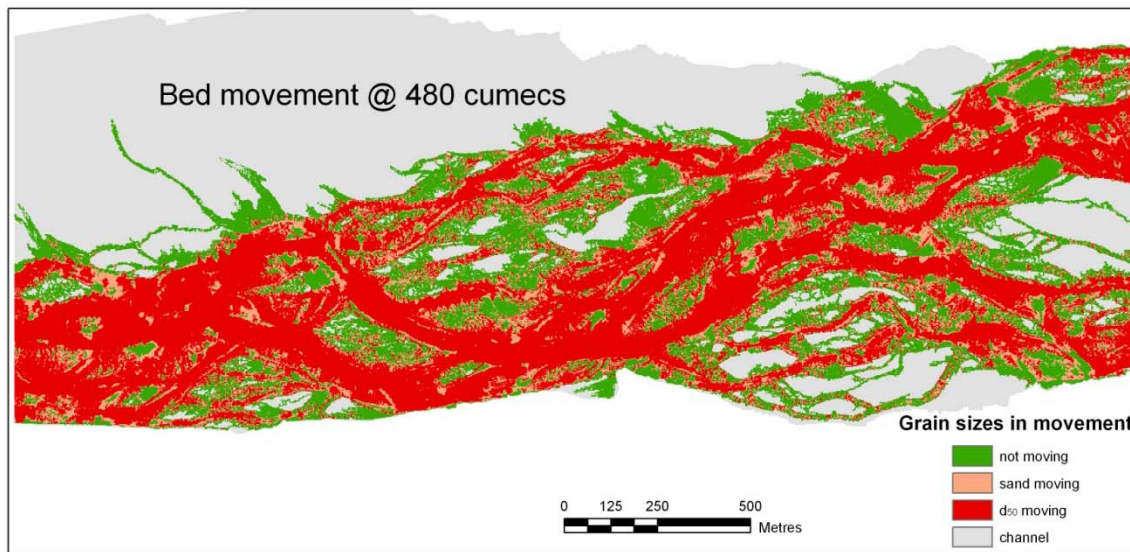
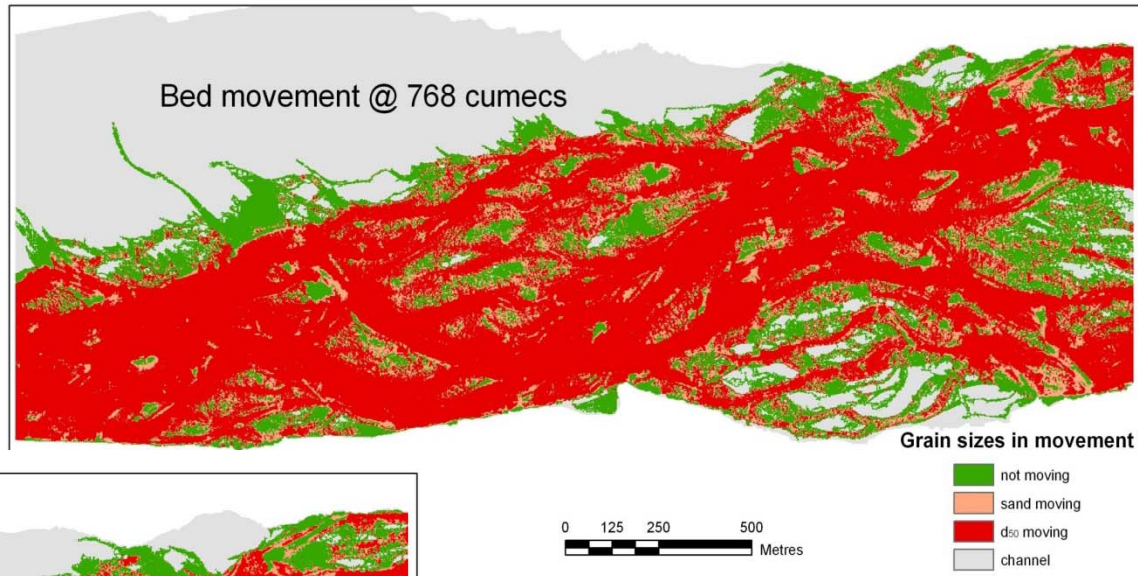
- Bed material survey 8 Feb. Flow $\sim 40 \text{ m}^3\text{s}^{-1}$
- $542 \text{ m}^3\text{s}^{-1}$ flood 16 Feb.
- Repeat visit 22 Feb. Flow $\sim 64 \text{ m}^3\text{s}^{-1}$
- Channels inspected for bed movement, periphyton and invertebrates
- Minor braids variable disturbance
- Major braids fully disturbed
- Flood disturbance consistent with modelling

- Change the flow value suggested for proposed condition CRC061972 from $100 \text{ m}^3\text{s}^{-1}$ to $130 \text{ m}^3\text{s}^{-1}$

Braiding pattern and flow



Morphological change & flow



Little morphology change at low flows, some at 500 m^3s^{-1} and major changes when flows $>800 \text{ m}^3\text{s}^{-1}$

- Aggradation at intakes is a theoretical possibility
- Any affect would probably be masked by waves of gravel moving past intakes
- There are large takes on Canterbury intakes that have been in place for decades and there is no evidence of aggradation, e.g., RDR
- Any aggradation at gallery intakes could be managed

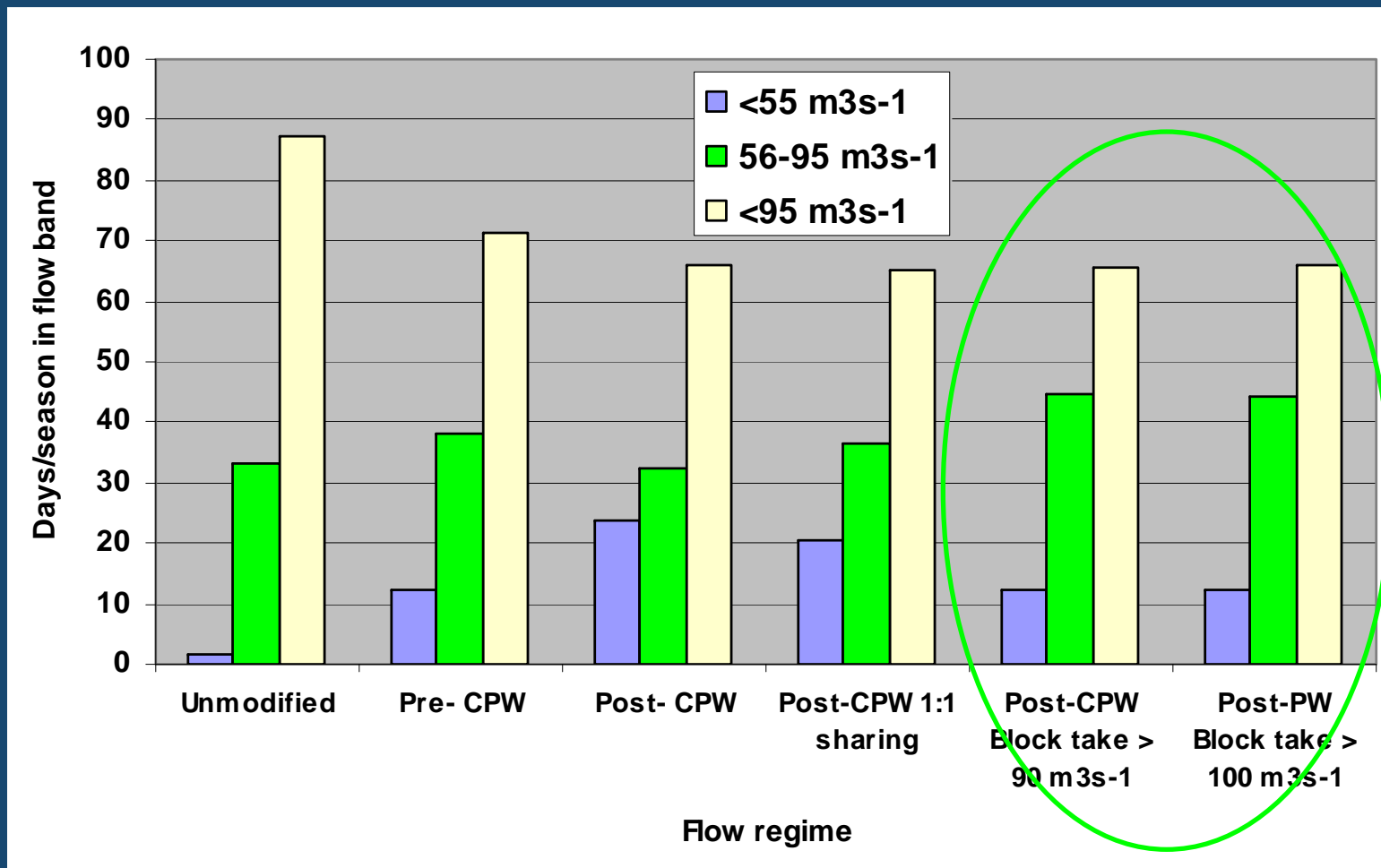
- A flow gap between A & B Blocks would ensure B Block takes do not affect A takes
- There is currently a gap between A and B Blocks
- Recession flows make estimation easier.
- The new telemetered water-level recorder at Otarama will allow confident estimation of flows during recessions and floods so that A Block reliability of supply can be better protected and floods can be harvested.

- Why?
 - To reduce flat lining at $41 \text{ m}^3\text{s}^{-1}$
 - To increase the frequency of flows $> 41 \text{ m}^3\text{s}^{-1}$
- Potential benefits:
 - Increase frequency of flushing flows
 - Increase the number of islands for birds
 - Increase the frequency of flows suitable for salmon angling and other recreational pursuits
 - To increase the wetted area for invertebrates
- Scenarios examined:
 - Flow sharing 1:1 of the B Block allocation
 - Taking B Block water when flow $> 90 \text{ m}^3\text{s}^{-1}$
 - Taking B Block water when flow $> 100 \text{ m}^3\text{s}^{-1}$

- Increased flows will have some positive flushing affect
- Flows of $>130 \text{ m}^3\text{s}^{-1}$ best
- Best instrument to ensure flushing is to allow freshes after 21 days of low flows to remain uncaptured until unmodified flows exceed $130 \text{ m}^3\text{s}^{-1}$ or for two days whichever happens sooner.

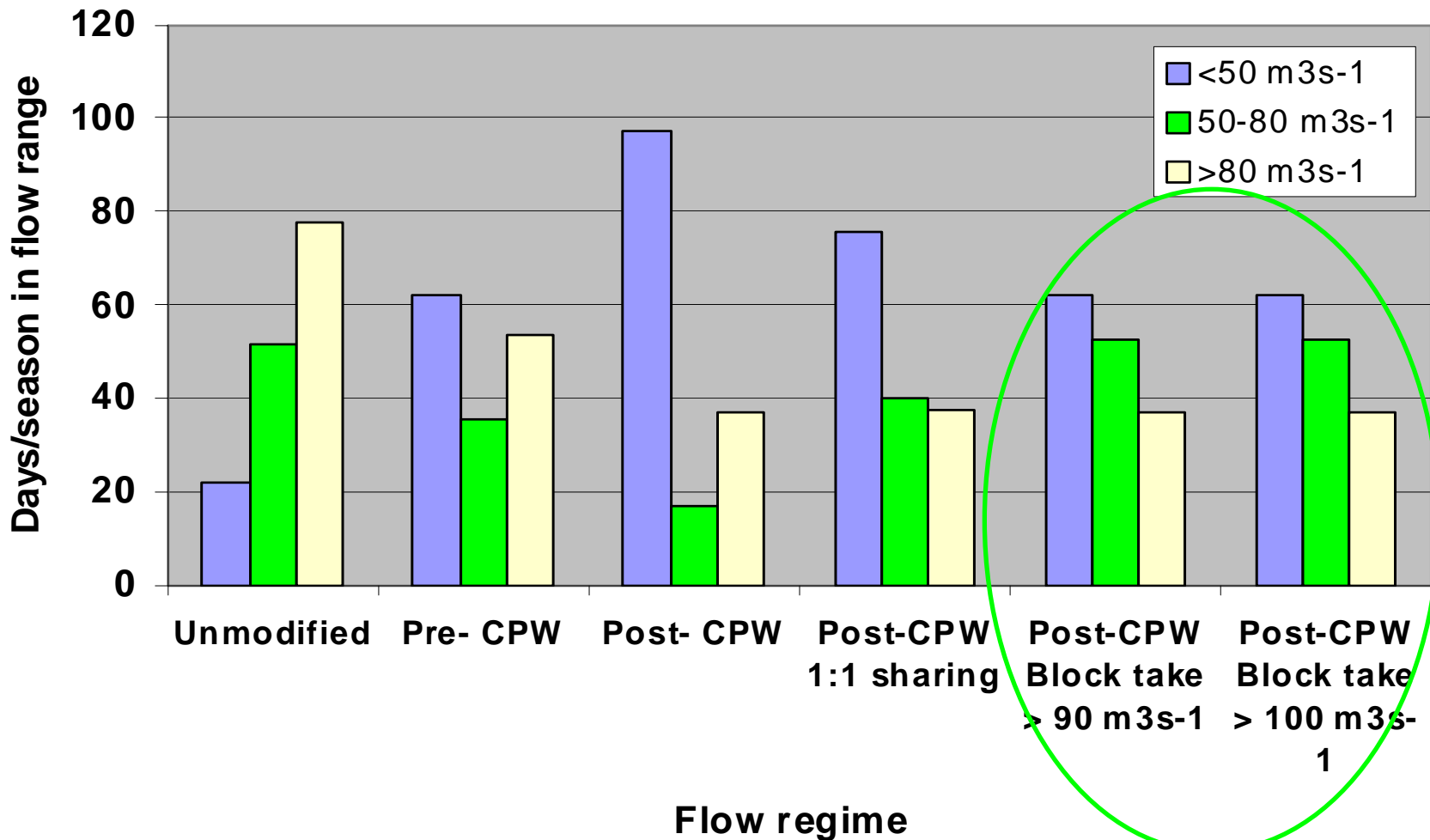
Increased number of islands

- Preferred flows of 60-90 m³s⁻¹ to maximise the number of islands for riverbed nesting birds.
- Time period September –December (Hughey evidence)



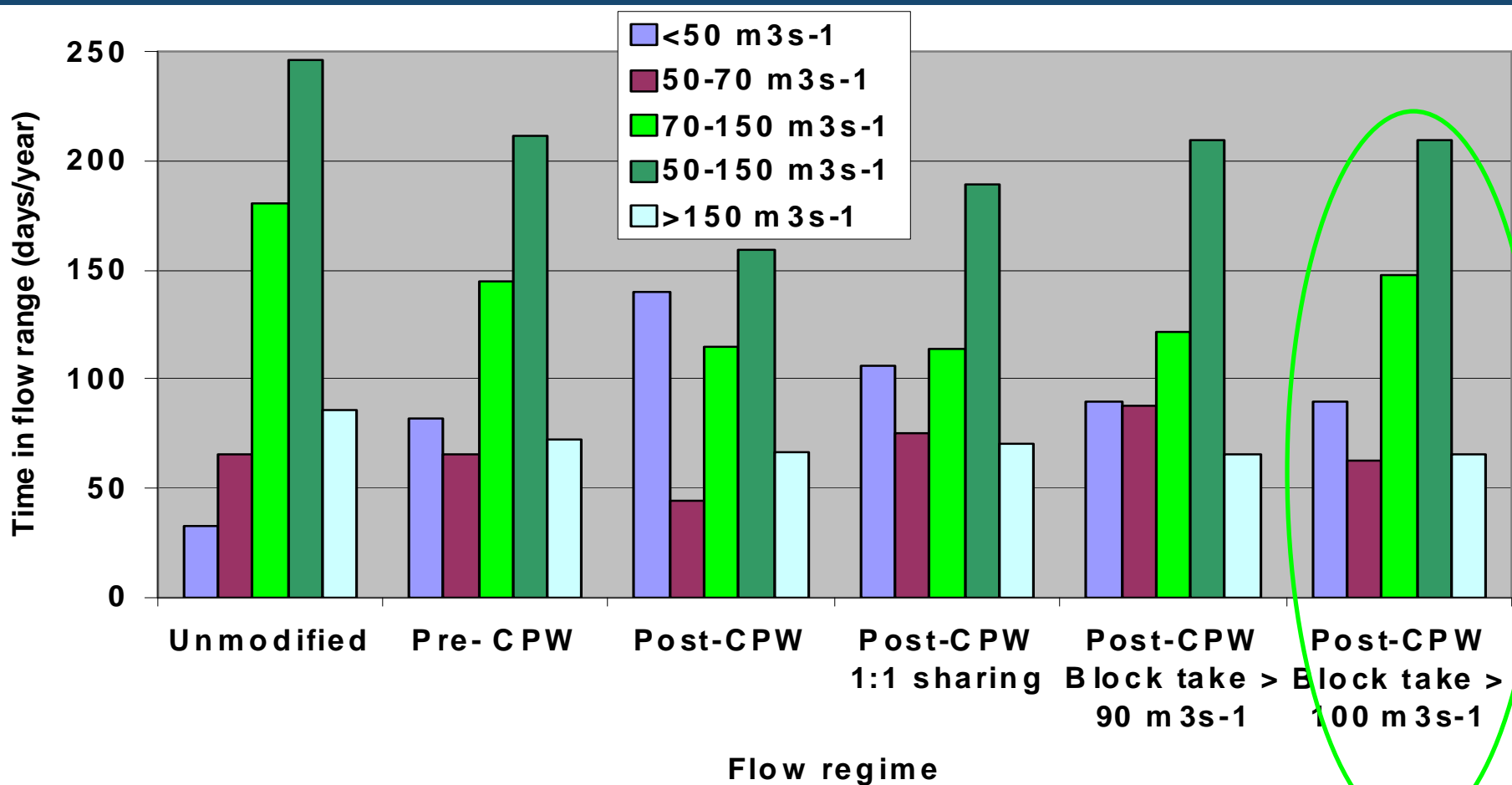
Increased salmon angling days

- Preferred flow 50-80 m³s⁻¹ in Dec –April (Hayes evidence)



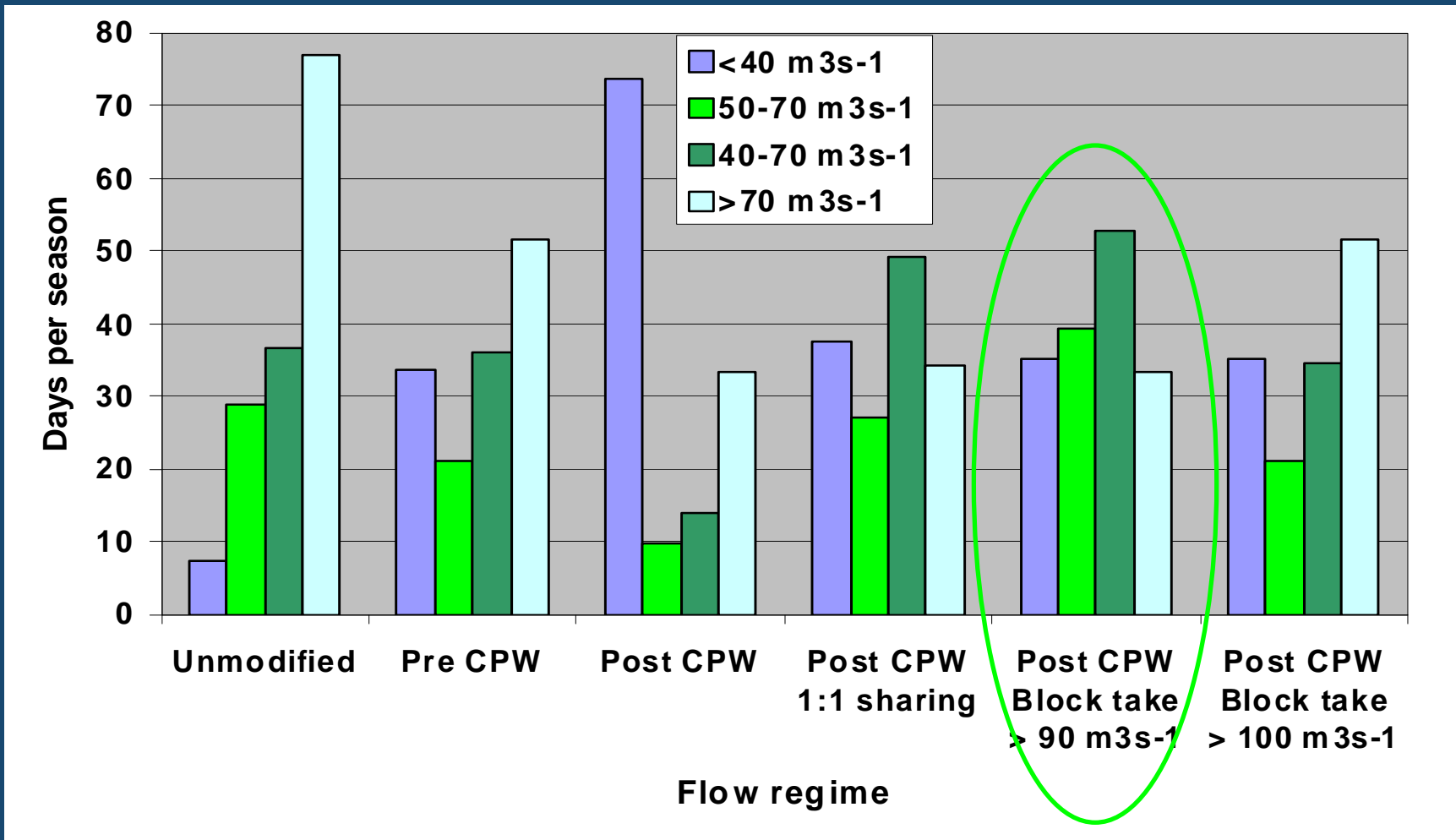
Increased flows for kayaks

- Preferred flow range 70-150 m³s⁻¹ , 50 – 70 m³s⁻¹
OK. All year. (Ward-Holmes evidence)



Increased flows for jet boats

- Preferred flow range $50-70 \text{ m}^3\text{s}^{-1}$, $40 - 70 \text{ m}^3\text{s}^{-1}$ OK. December to March. (Adams evidence).

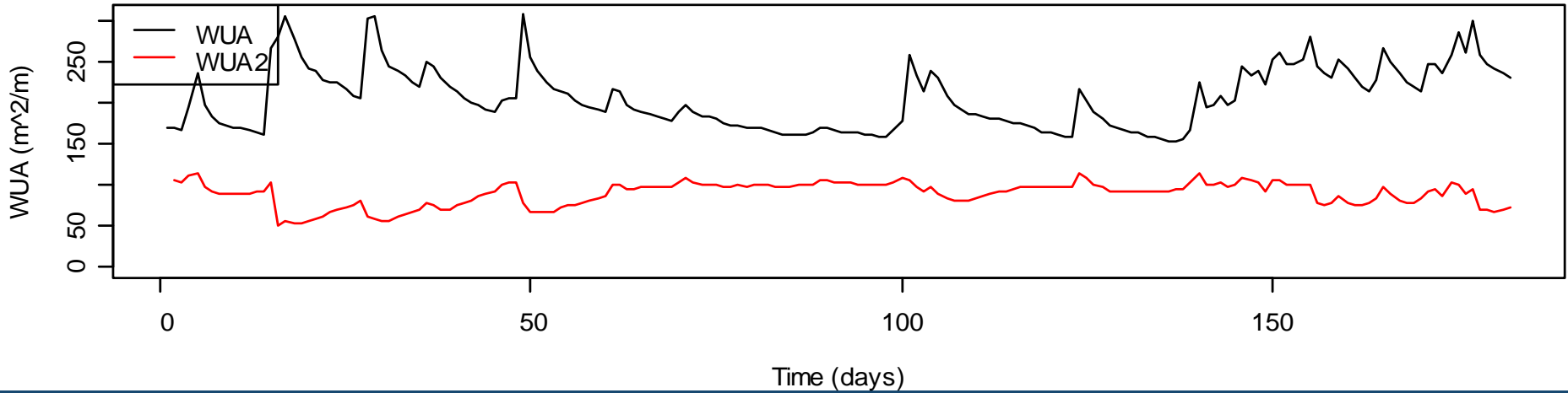


- Invertebrate production not necessarily equivalent to WUA.
- Other factors are:
 - flushing by floods
 - The time for populations to build up.
- NIWA and Cawthron staff have modelled these factors based on relationships for :
 - WUA for invertebrates vs flow
 - Bed disturbance and flow
 - Time between full bed disturbance and full colonisation of the bed of (15 days) Sagar (1983)

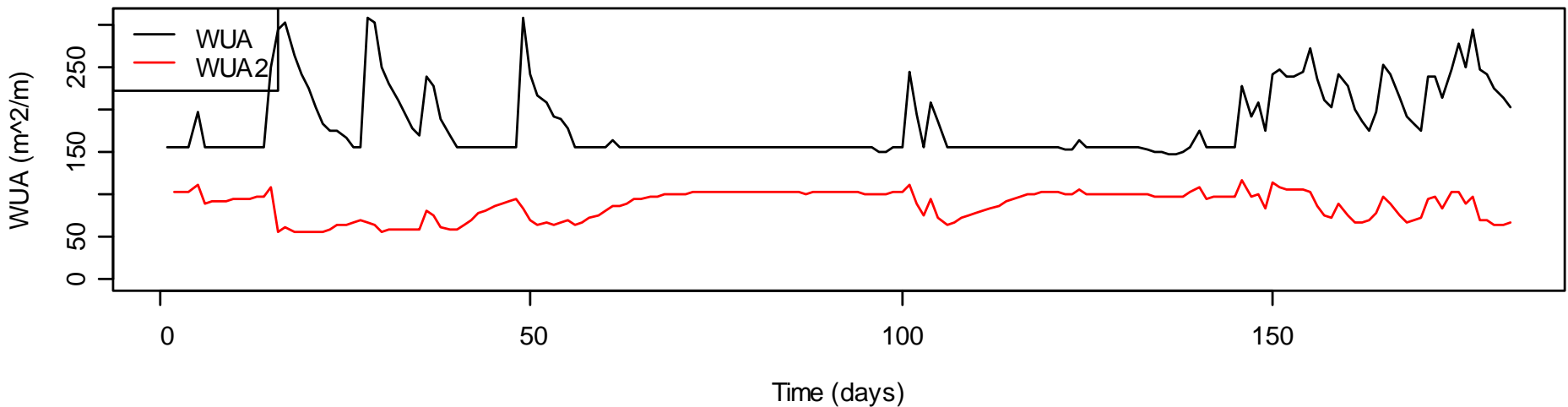
- *Deleatidium* WUA = population if there is no bed flushing
- Bed flushing reduces *Deleatidium* population
- WUA determined by depth and velocity and unrelated to bed flushing.
- Re-colonisation is linear

Results for an average summer

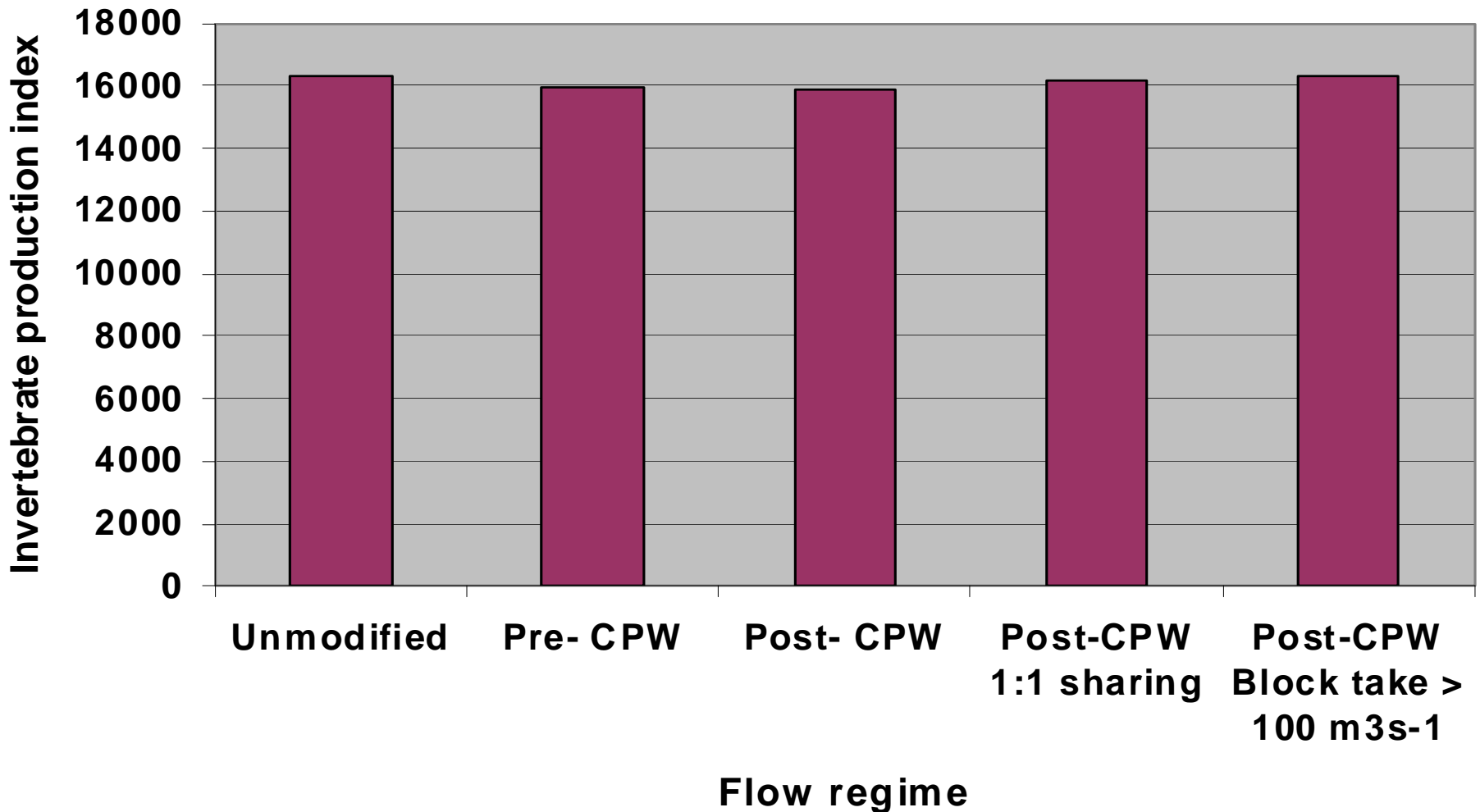
Unmodified



Post CPW



- Model was run for each flow scenario for December to May for an average year (1989/90)



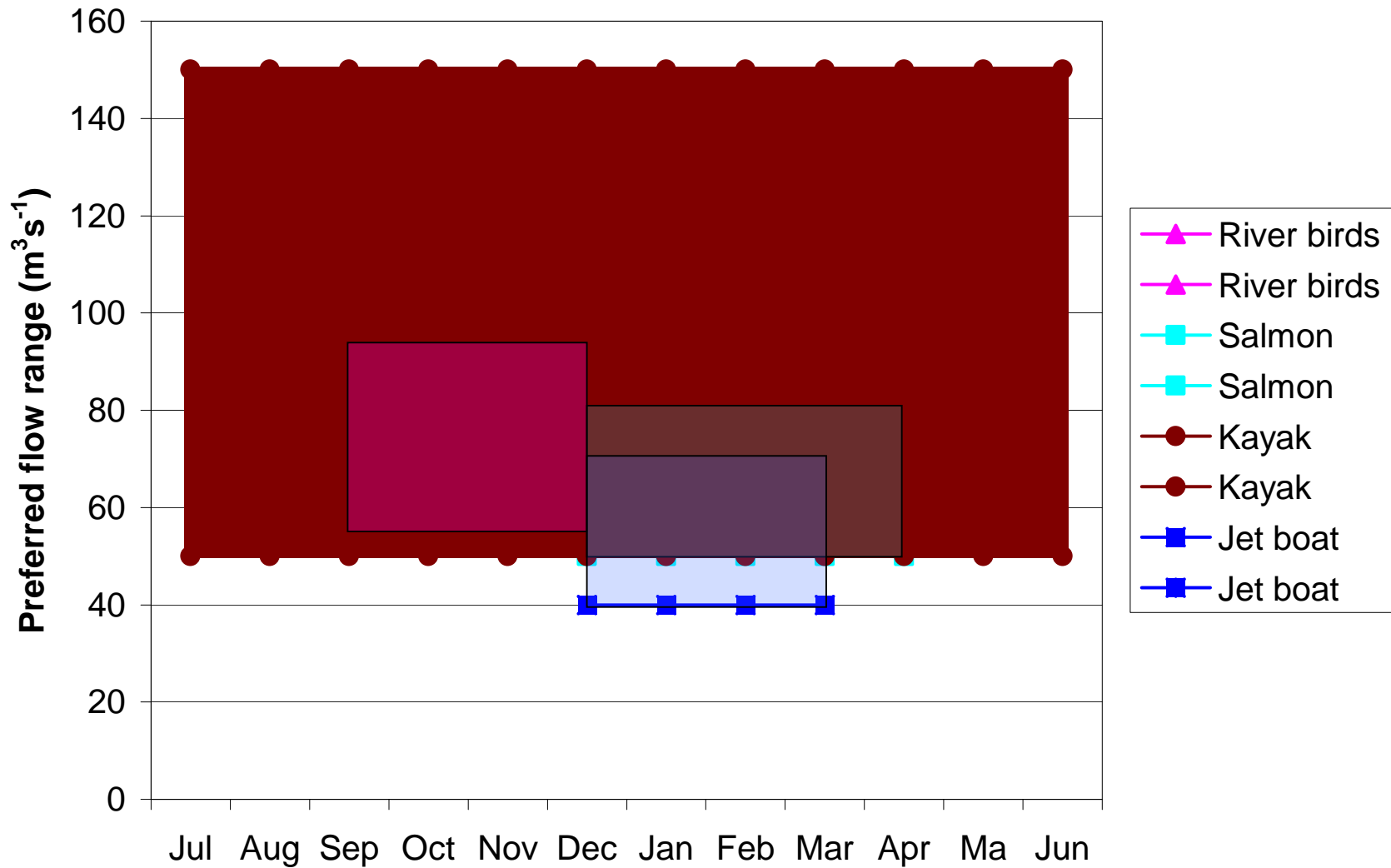
- Benthos reset at FRE3 flows = $288 \text{ m}^3\text{s}^{-1}$
- Long filamentous algae scoured from 80% of the mean flow bed at $130 \text{ m}^3\text{s}^{-1}$
- CRC061972 – Change trigger flow to $130 \text{ m}^3\text{s}^{-1}$
- Braid intensity maximum at 10.5 at $\sim 100 \text{ m}^3\text{s}^{-1}$
- Channel forming flows start at 500-800 m^3s^{-1}
- Aggradation at abstraction points could be managed. No historical precedent in Canterbury
- The Otarama water-level recorder will ease take management of flood and low flow takes

- B Block flow sharing 1:1 and flow gaps between the A and B Block allocations are better than no sharing or gaps for recreational activities and river bed nesting birds.
- Flow gaps have better outcomes than 1:1 flow sharing, with abstraction at flows $>90 \text{ m}^3\text{s}^{-1}$ being the best option of those examined.
- Preliminary time series modelling of invertebrate production shows no material difference between alternative take options.

- ECan asked me to look further at alternative B Block take regimes for the Waimakariri River.
- Options:
 - Limit the size of the block
 - Flow sharing
 - Flow gap between blocks
 - Rules for flushing and channel forming flows
 - No take days for formal recreational occasions

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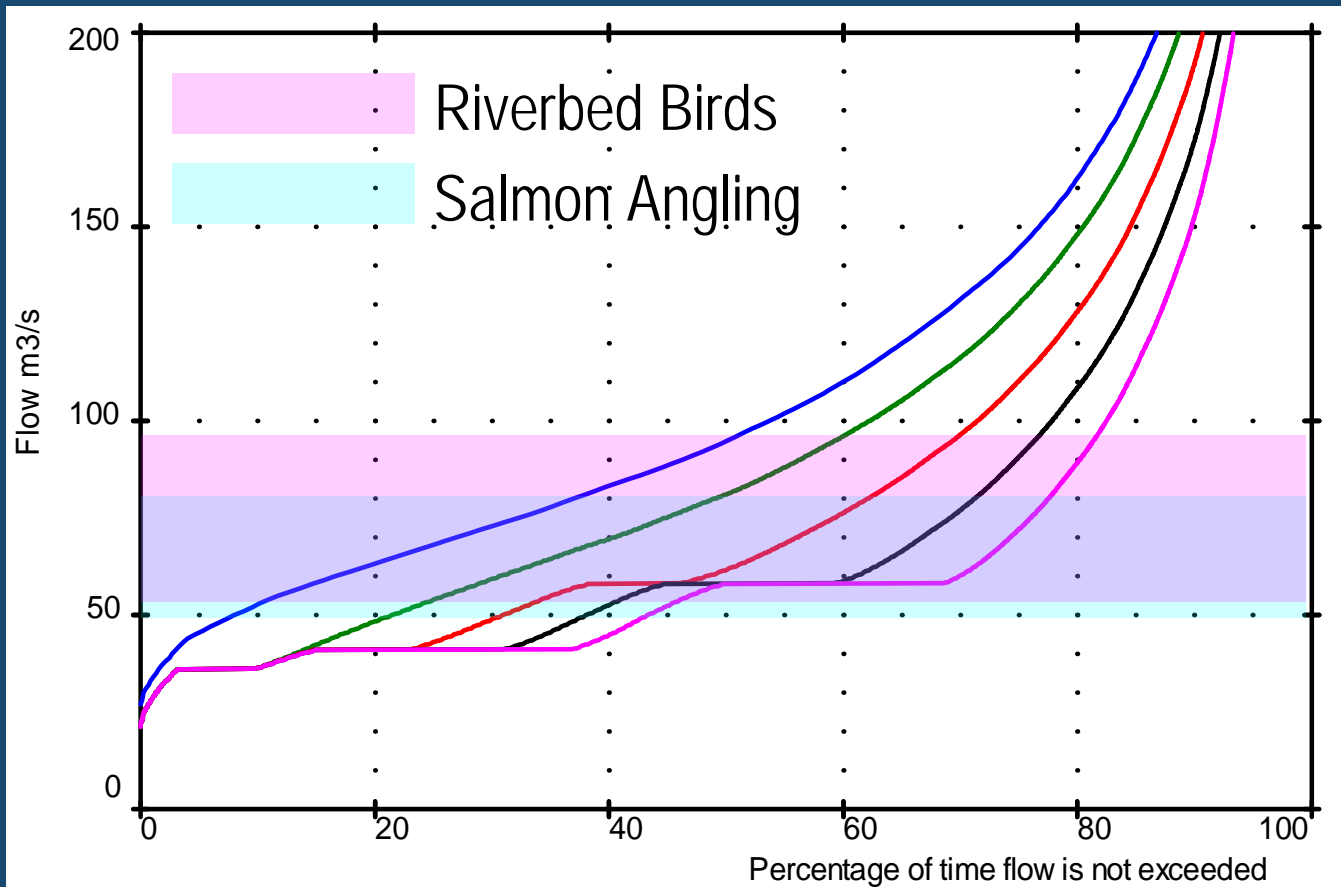
Preferred flow ranges



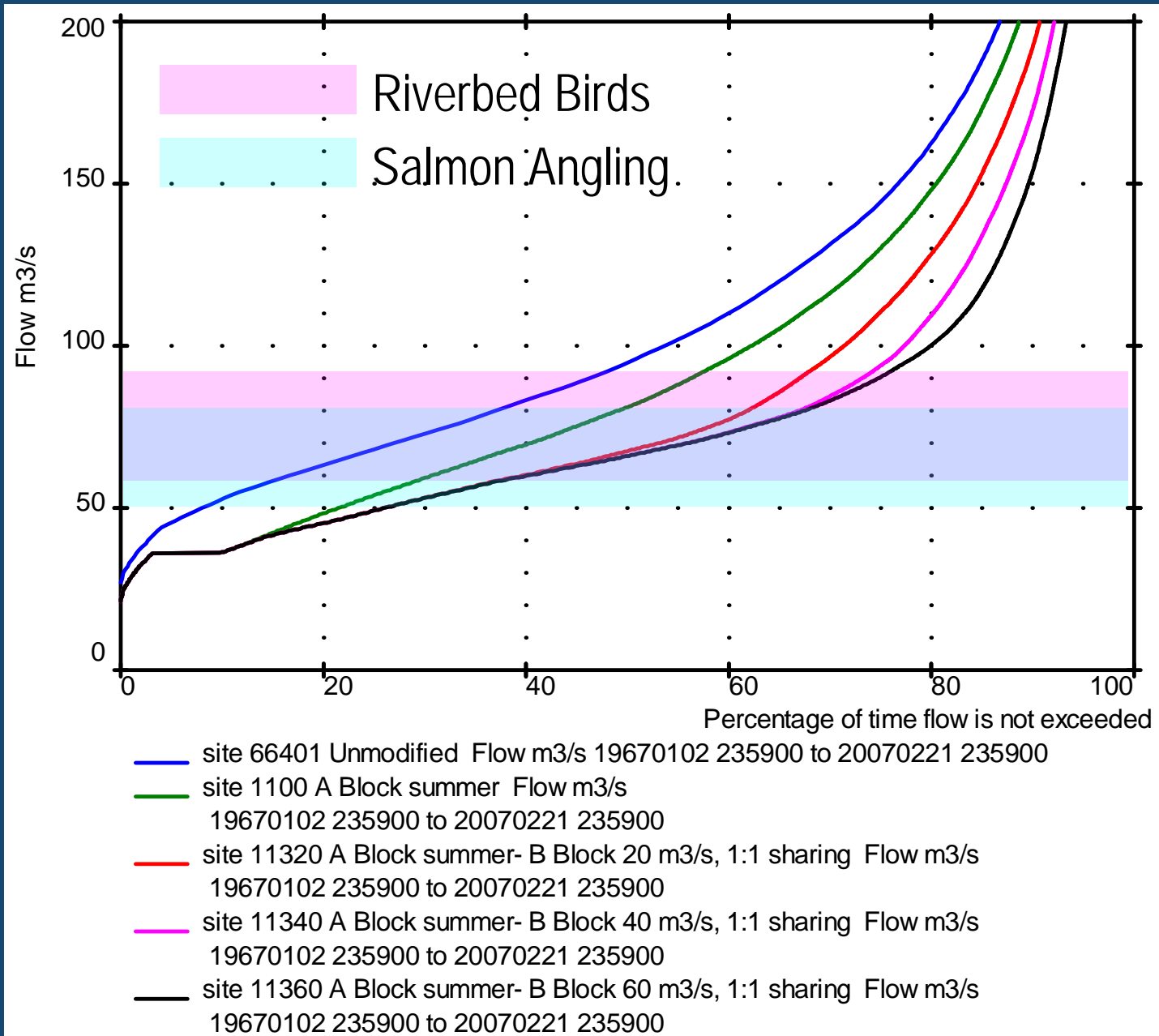
- I analysed the following regimes for their affect on preferred flow ranges, take volumes and reliability of supply:
 - Takes of 20, 40 and 60 m^3s^{-1}
 - 1:1 flow sharing
 - A to B Block gaps of 7, 17, 27 and 37 m^3s^{-1} so the B Block would begin to be taken at 70, 80, 90 and 100 m^3s^{-1} (unmodified flow)

- Unmodified flow as per Richard de Joux
- A Block of $22 \text{ m}^3\text{s}^{-1}$ of which $4.896 \text{ m}^3\text{s}^{-1}$ was stock water taken all year with the rest of the A Block taken only in summer.
- B Block taken all year

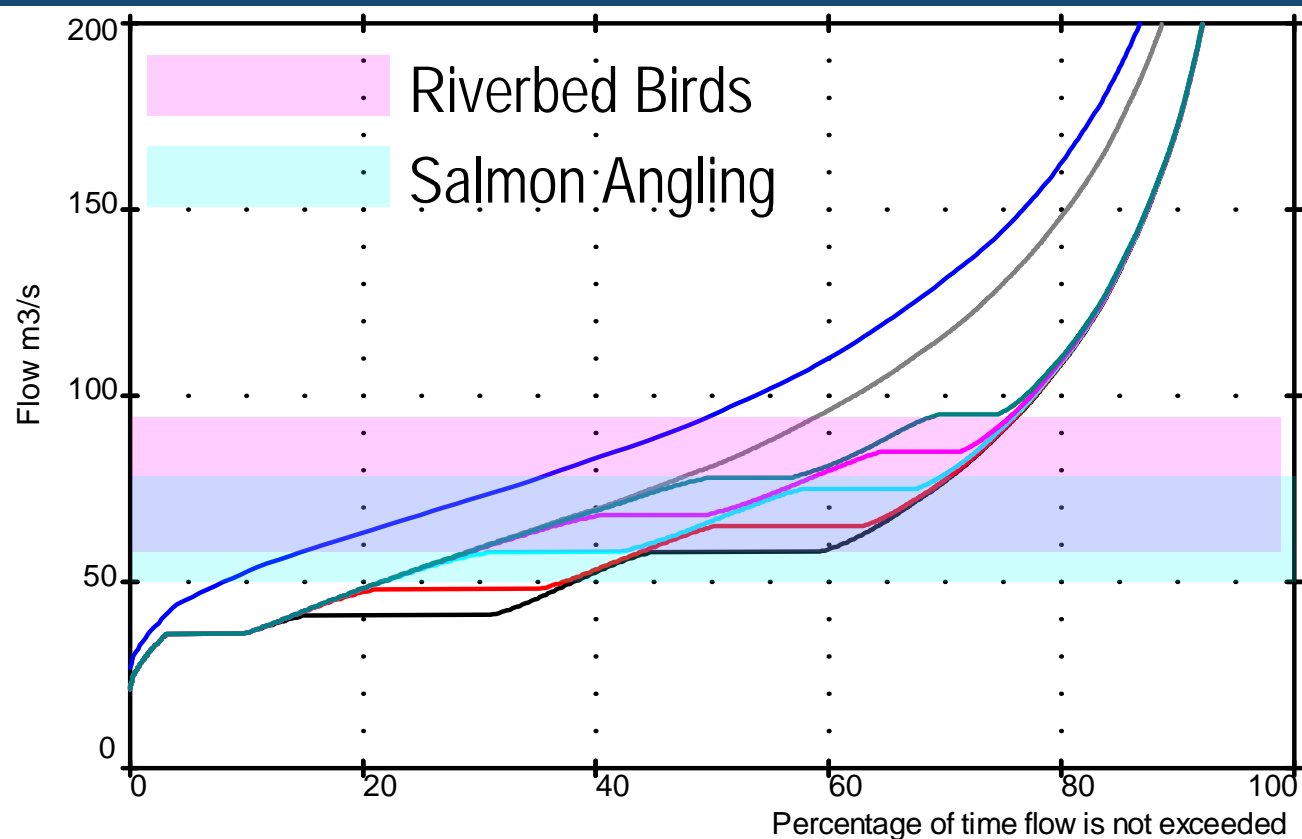
Different sized B Blocks



- site 66401 Unmodified Flow m³/s
19670102 235900 to 20070221 235900
- site 1100 A Block summer Flow m³/s
19670102 235900 to 20070221 235900
- site 1120 A Block summer- B Block 20 m³/s Flow m³/s
19670102 235900 to 20070221 235900
- site 1140 A Block summer- B Block 40 m³/s Flow m³/s
19670102 235900 to 20070221 235900
- site 1160 A Block summer- B Block 60 m³/s Flow m³/s
19670102 235900 to 20070221 235900

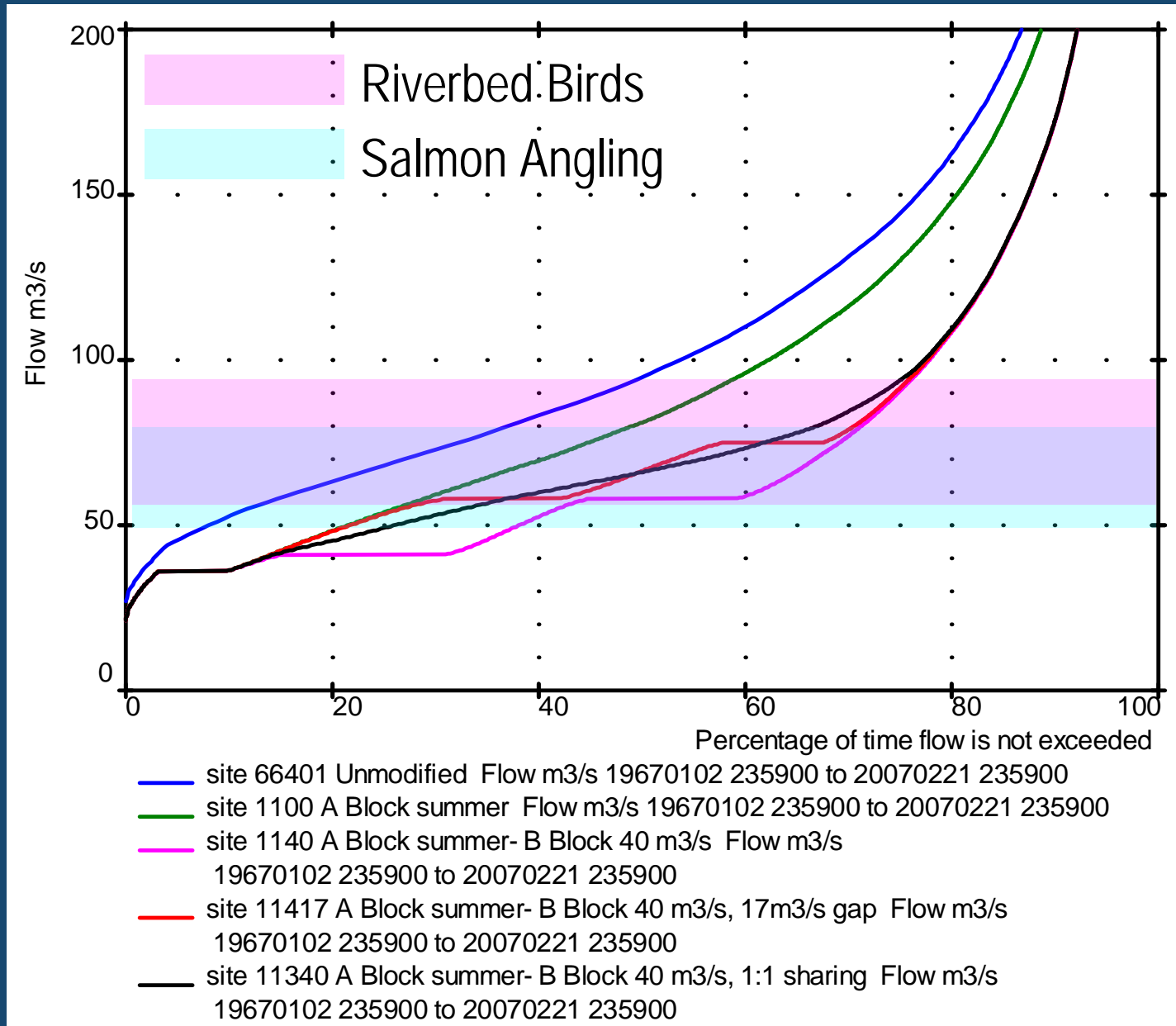


Different flow gaps: 40 taken m^3s^{-1}



- site 66401 Unmodified Flow m^3/s 19670102 235900 to 20070221 235900
- site 1100 A Block summer Flow m^3/s 19670102 235900 to 20070221 235900
- site 1140 A Block summer- B Block 40 m^3/s Flow m^3/s 19670102 235900 to 20070221 235900
- site 11407 A Block summer- B Block 40 m^3/s , 7 m^3/s gap Flow m^3/s 19670102 235900 to 20070221 235900
- site 11417 A Block summer- B Block 40 m^3/s , 17 m^3/s gap Flow m^3/s 19670102 235900 to 20070221 235900
- site 11427 A Block summer- B Block 40 m^3/s , 27 m^3/s gap Flow m^3/s 19670102 235900 to 20070221 235900
- site 11437 A Block summer- B Block 40 m^3/s , 37 m^3/s gap Flow m^3/s 19670102 235900 to 20070221 235900

Comparison: 40 m³/s takes



Quantifying the differences

	Unmodified	A Block	A summer+	A summer+	A summer+
		summer	40 m ³ s ⁻¹ B 0 gap	40 m ³ s ⁻¹ B 1:1 sharing	40 m ³ s ⁻¹ B 17 m ³ s ⁻¹ gap
Sept - Dec					
% time at 55-95 m ³ s ⁻¹	26.5	31	36	45	54
Dec - Apr					
% time at 50-80 m ³ s ⁻¹	24	25.5	11.5	31	41

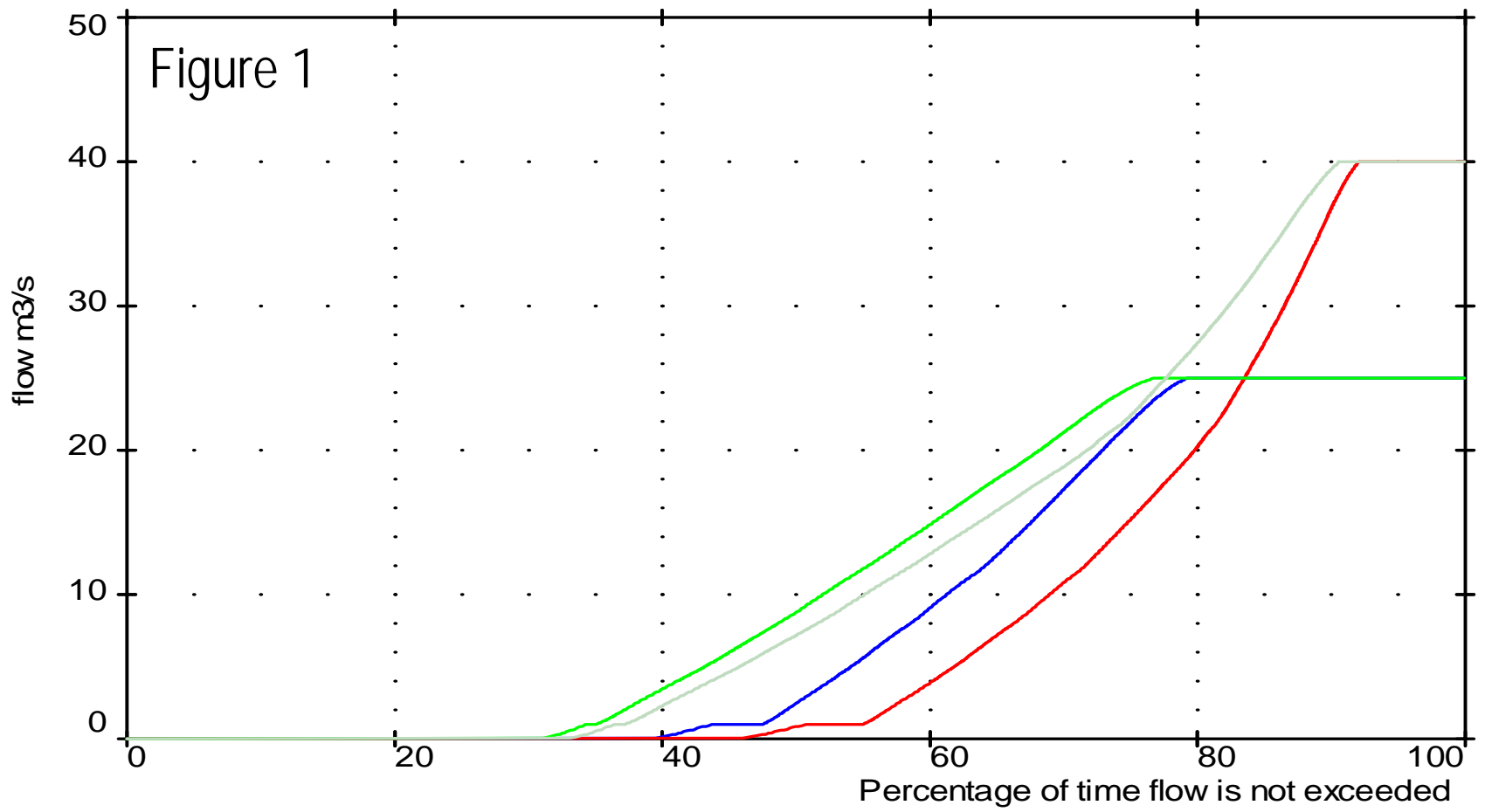
- The recommended B Block abstraction regime would allow abstraction from an unmodified flow of $80 \text{ m}^3\text{s}^{-1}$

The end

- Description of Waimakariri and Rakaia River hydrology
- An assessment of the cumulative effects of abstractions
- An assessment of the effects of bywash flows on receiving waters
- An assessment on the cumulative effects of the abstractions on bed load movement
- Comment on the 2D modelling that has been used to assess ecological effects of the scheme
- Comment on recent work on sediment movement in the Waimakariri River in relation to river flushing

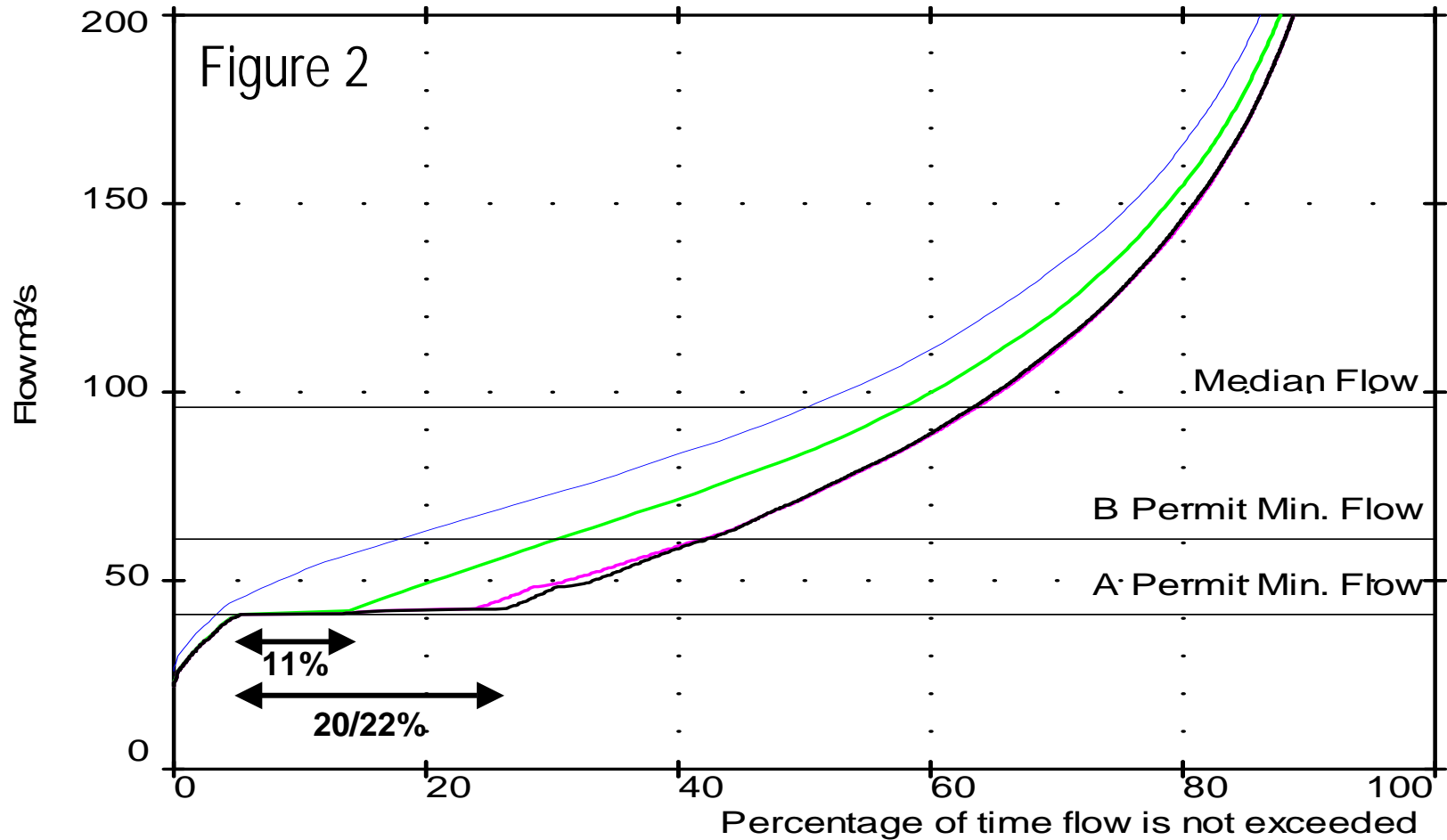
- Data sources and assumptions
 - Waimakariri: Mr R de Joux's unmodified flows
 - Rakaia: Gorge/Fighting Hill flows
 - CPW demand series: 20:25:240 & 20:40:220
 - Summer is 1 November to 30 April

1967 - 2001



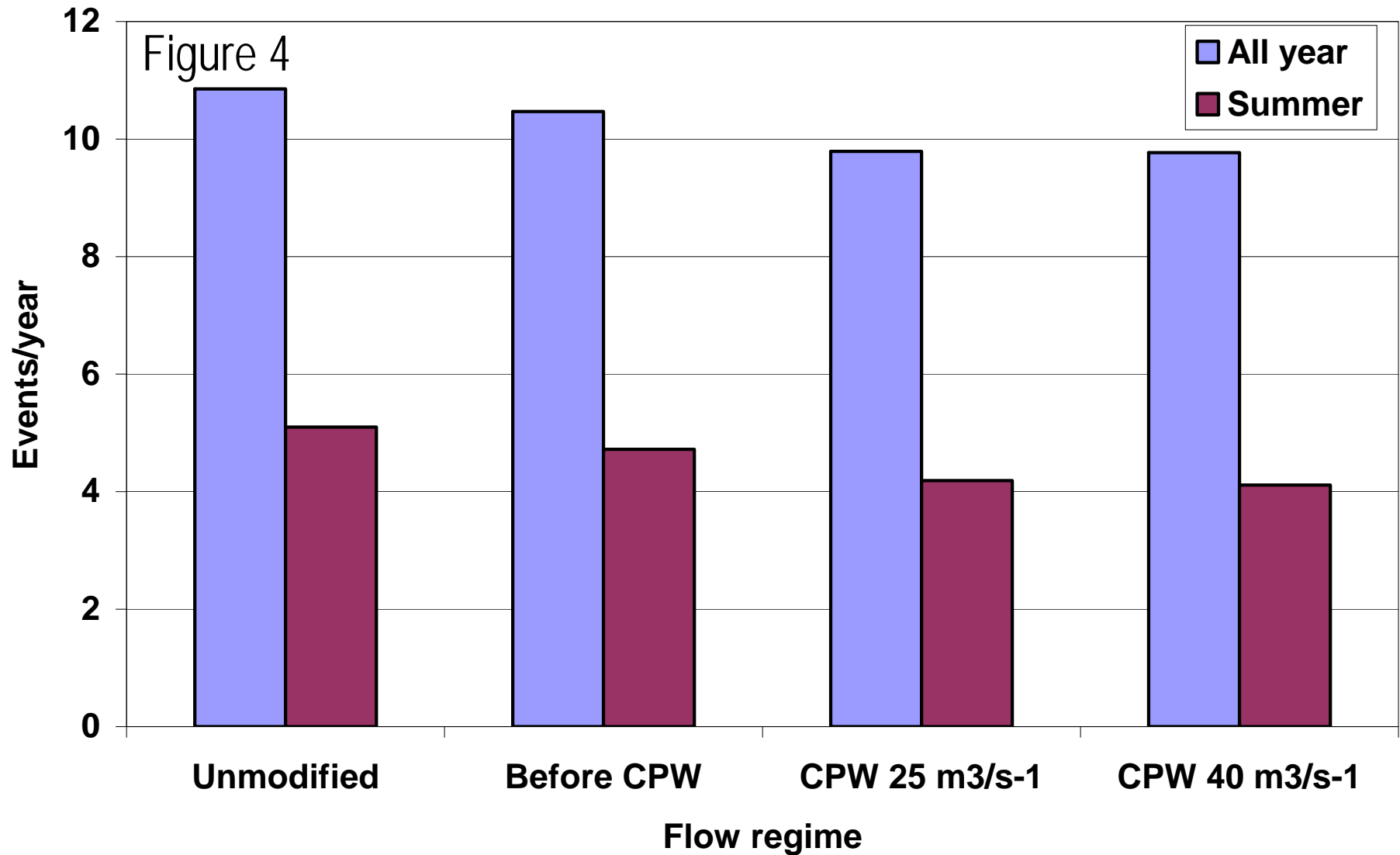
- 20 m³/s annual take
- 40 m³/s annual take
- 20 m³/s summer taken (Nov - April)
- 20 m³/s summer take (Nov - April)

Waimakariri flow duration curves-all year.

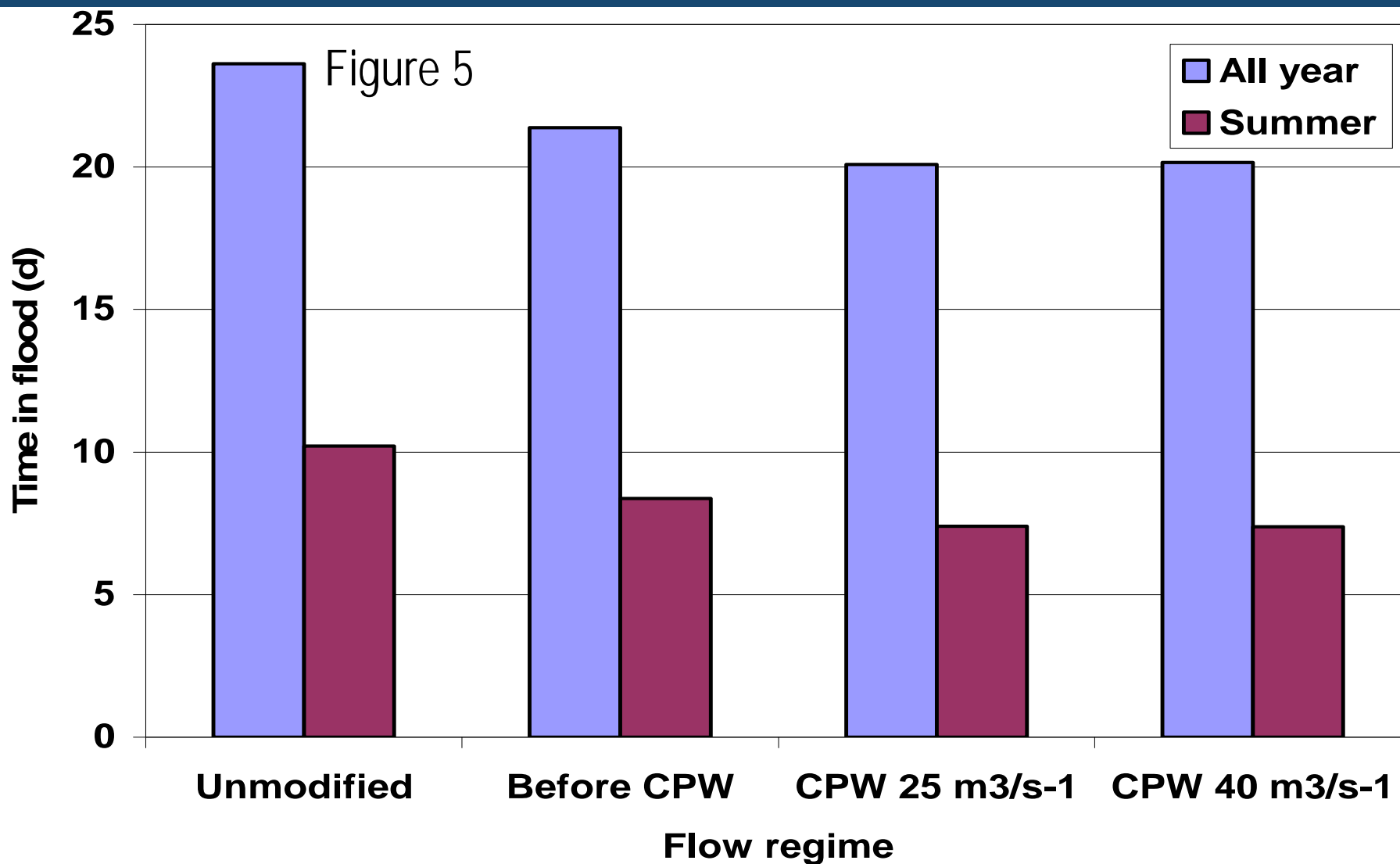


- Unmodified (no abstraction)
- With current take
- With current take and CPW 25 m³/s take
- With current take and CPW 40 m³/s take

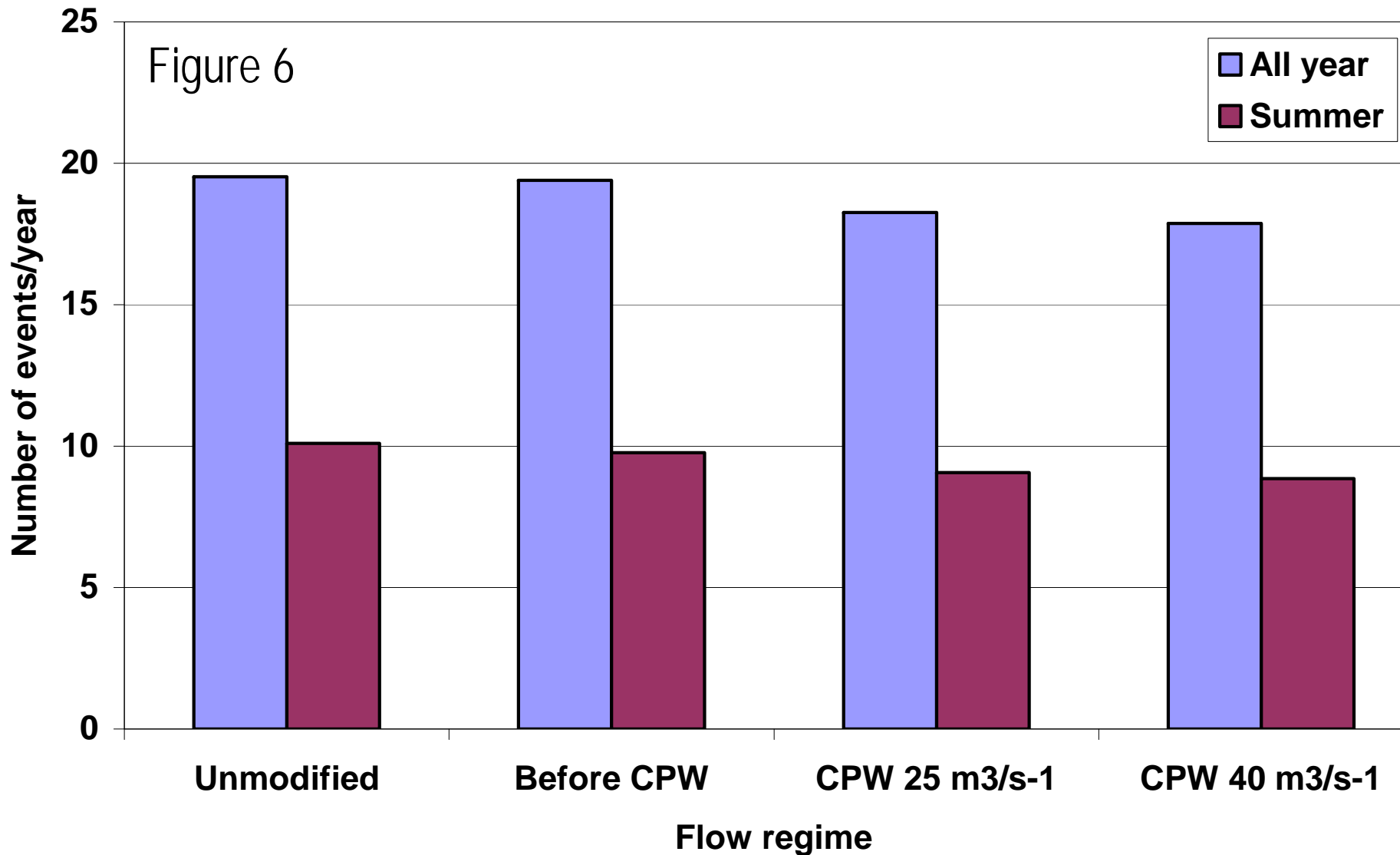
Waimakariri River: FRE3 frequency



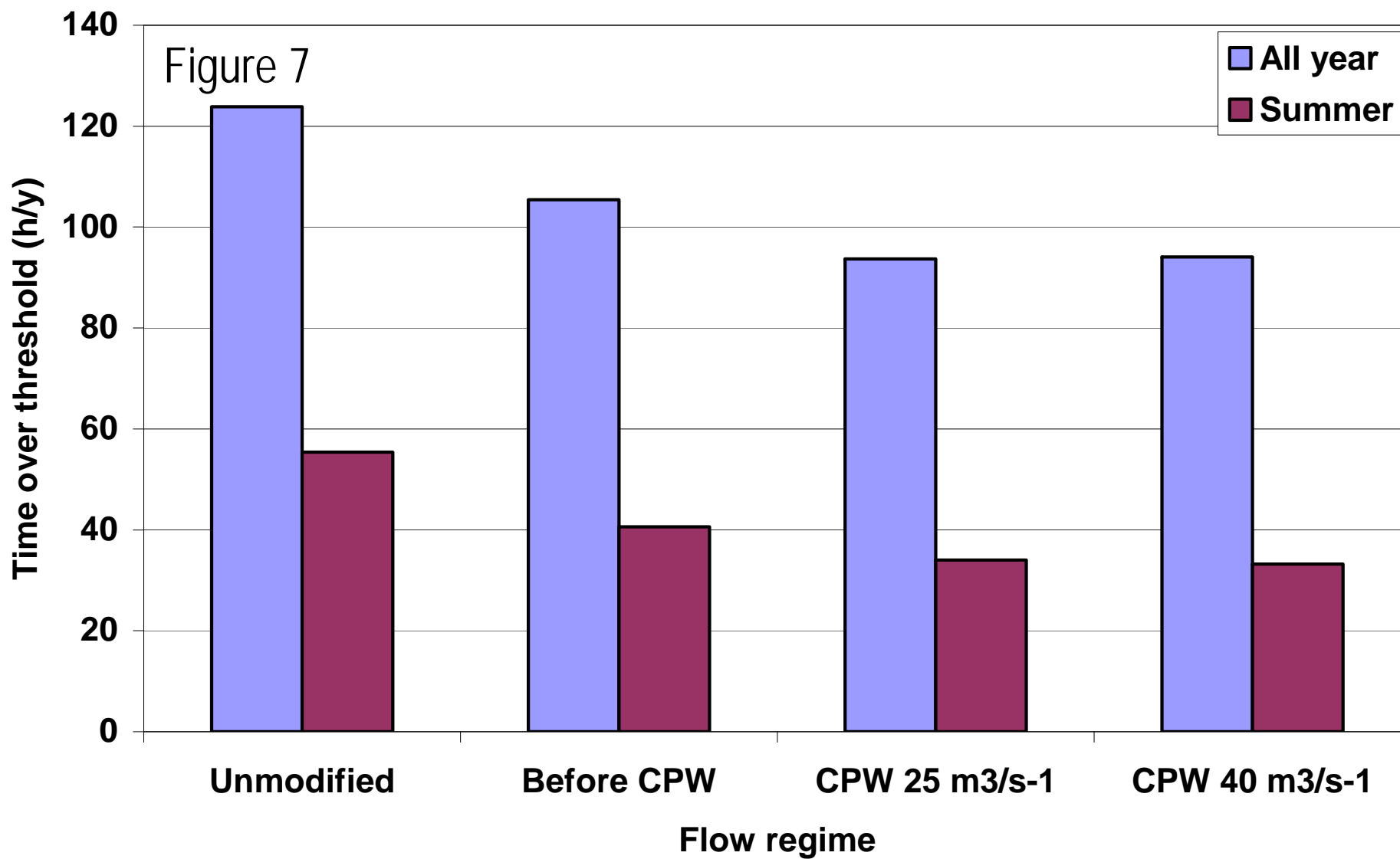
Waimakariri River: FRE3 duration



Waimakariri River: MIN3 frequency

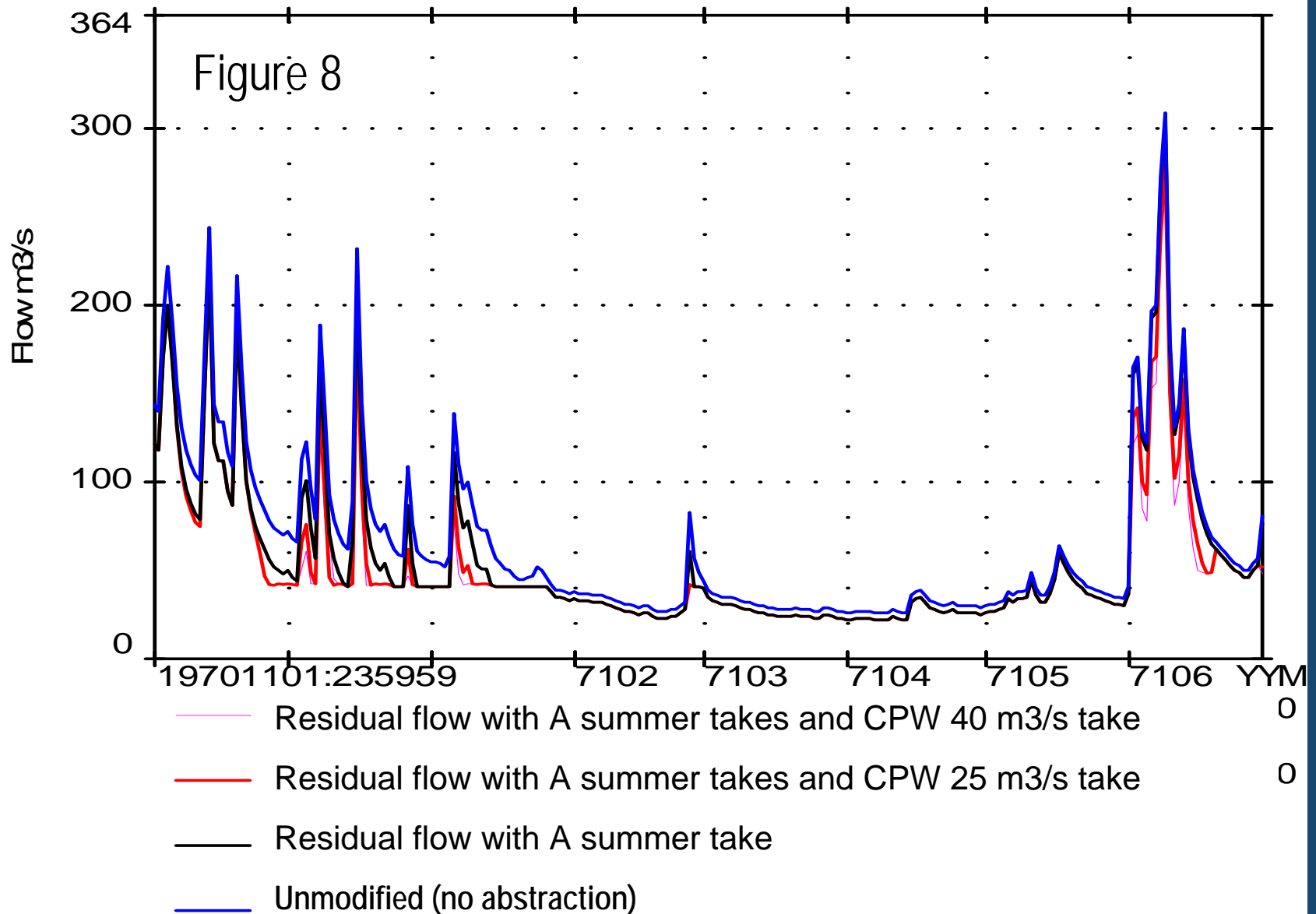


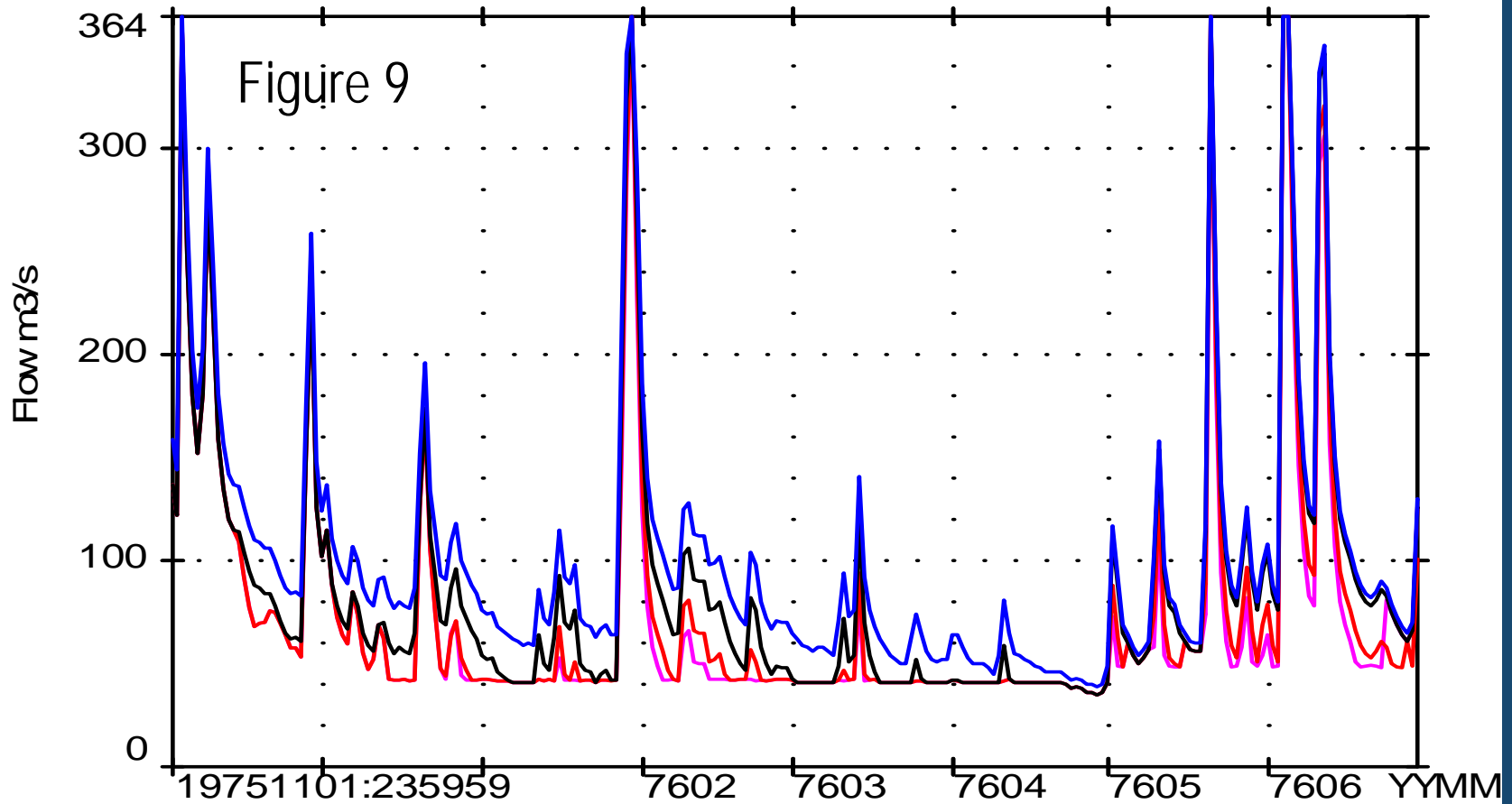
Waimakariri River: MIN3 duration



- Freshes and floods are important to river health as they remove fines and algal growths.
- CPW does reduce the number and duration of FRE3 and MIN3 freshes but the reduction is relatively small (10-13%).
- This average reduction is probably not significant, but any reduction during dry summers is important.
- Best mitigated by allowing freshes after 3 weeks of low flows to remain in the river.

Waimakariri River: dry year hydrographs





- site 6640192 MJD Residual flow 4 +A summer + CPW 2040220 Flow m³/s
- site 6640191 MJD Residual flow 4 +A summer + CPW 2025240 Flow m³/s
- site 6640123 MJD Residual flow 4 no restriction+A(Nov-Apr) Flow m³/s
- site 66401 Waimakariri unmodified flow flow m³/s

- 41 to 150 m^3s^{-1} flows most affected
- CPW causes a large increase in the total time of flatlining at 41 m^3s^{-1}
- The maximum take of 25 m^3s^{-1} will occur ~24% of the time
- Median flow reduction: 84-72 m^3s^{-1} (14%)
- Median summer flow reduction: 69-44 m^3s^{-1} (30%)
- Mean flow reduction: 116-107 m^3s^{-1} (8%)
- Mean flow summer reduction: 102-90/88 m^3s^{-1} (11/13%)

- Minimum flow duration increases from 10% time to 17/19% of the time after CPW
- Minimum flow summer duration increases from 18% of the time to 34/38% of the time after CPW
- FRE3 and MIN3 events reduced ~10%
- FRE3 and MIN3 durations reduced by 13 and 18% during the summer.

- Takes are constrained by the WCO that specifies minimum monthly flows (90-139 m^3s^{-1}) above which takes are subject to 1:1 sharing and a maximum of 70 m^3s^{-1} .
- The total take sought by CPW & ACWT of 40 m^3s^{-1} is constrained by the current allocation of 39.84 m^3s^{-1} leaving only 30.16 m^3s^{-1} for the applicant.

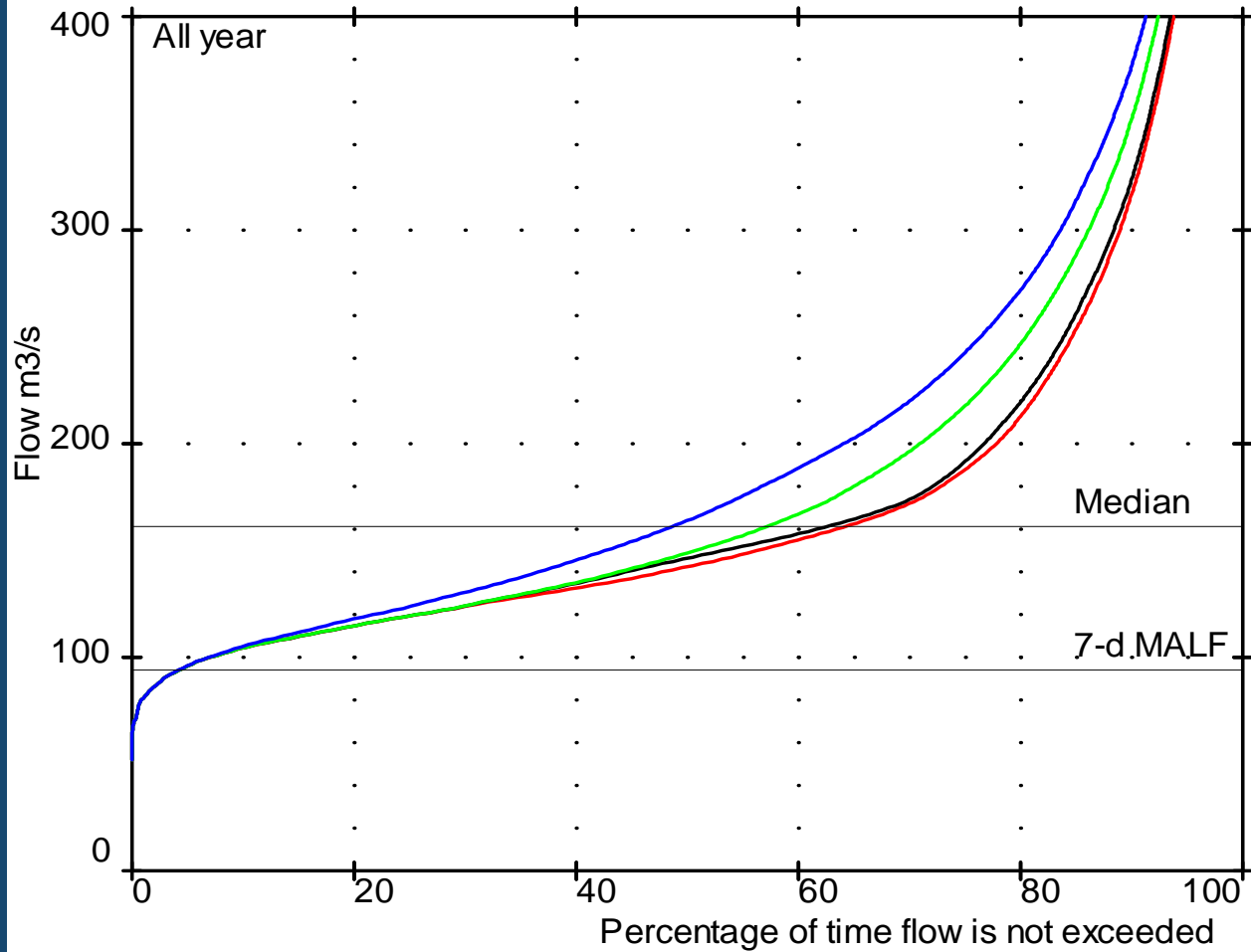
- Rakaia takes: Currently $33.84 \text{ m}^3\text{s}^{-1}$, so only $36.16 \text{ m}^3\text{s}^{-1}$ available to CPW.
- Current takes assumed to operate all year round.- This covers the option for current consent holders to store water.
- The take by ACWT is assumed lost, CPW assume this ACWT remains in the river.
- No account taken of Synlait priority. Evidence of Tipler and de Joux indicates it makes little difference to the river, though it may affect the amount of reservoir storage to maintain service.

Rakaia River: flows for the full take

	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	192	176	173	165	163	164	159	160	158	174	197	207
Bands 1-4 + CPW	232	216	215	205	203	204	199	200	198	214	237	247
Bands 1-4 + CPW + ACWT	264	248	245	237	236	236	231	232	230	246	269	279

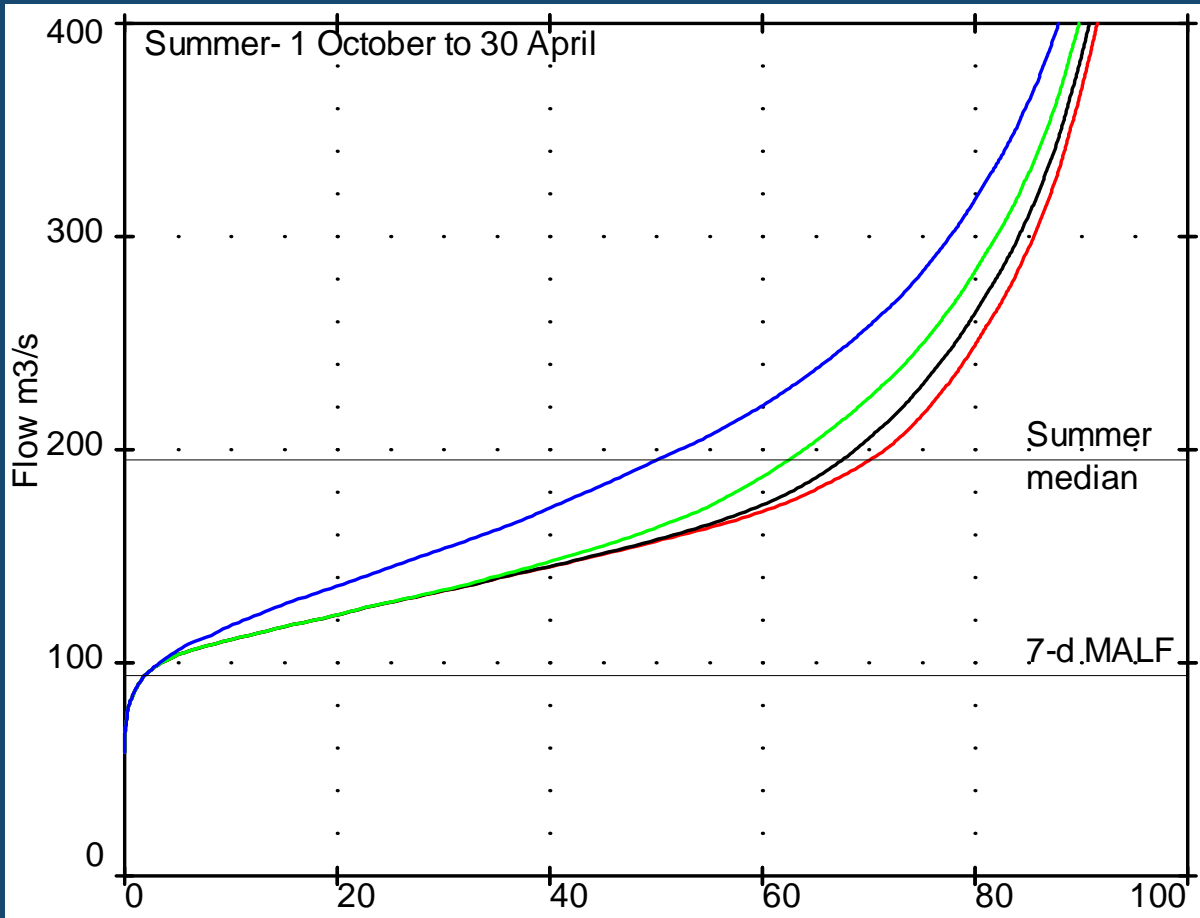
Water only available to CPW at high flows

Rakaia River: all flows duration curves



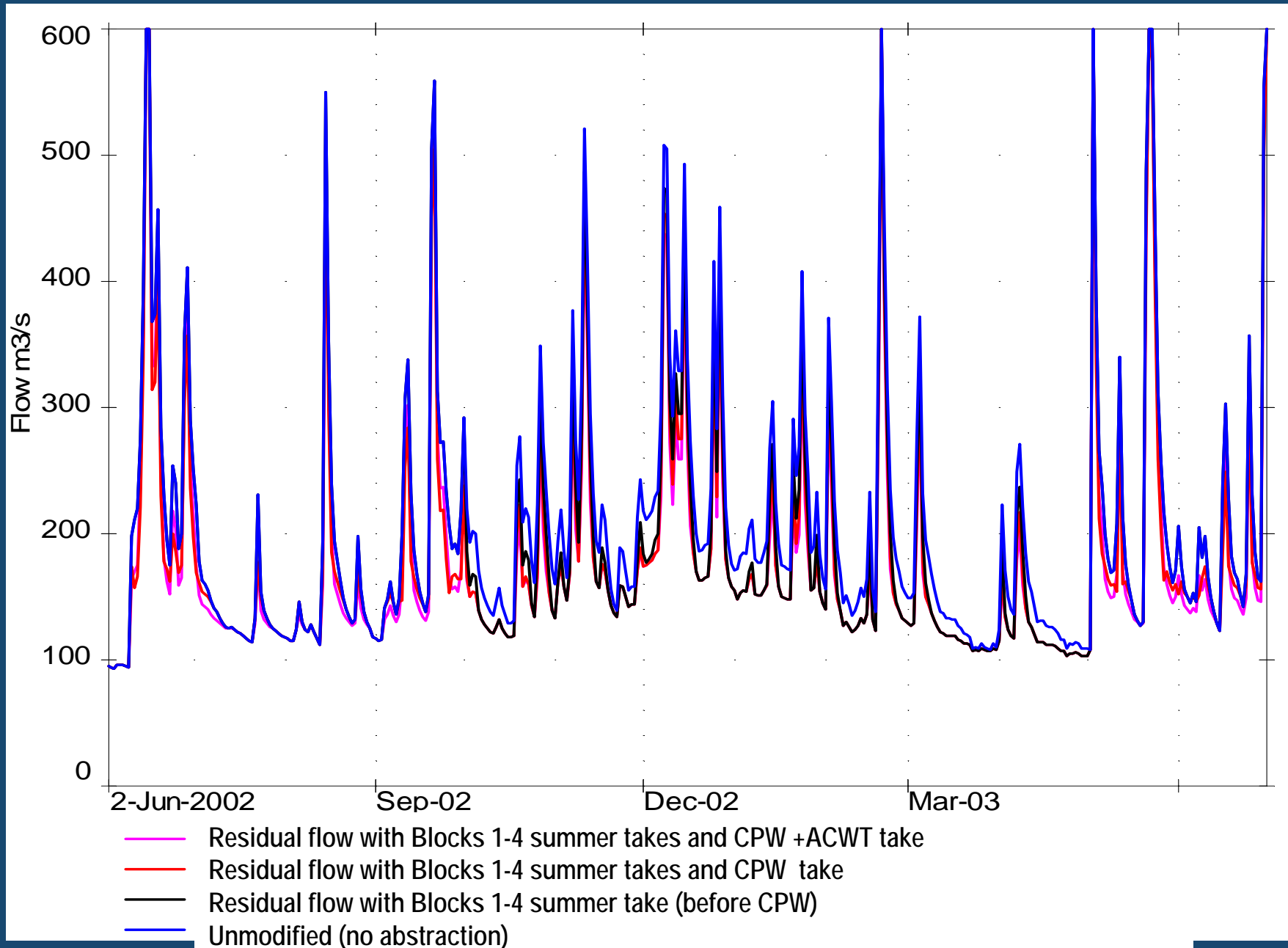
- Residual flow with Blocks 1-4 summer takes and CPW +ACWT take
- Residual flow with Blocks 1-4 summer takes and CPW take
- Residual flow with Blocks 1-4 summer take (before CPW)
- Unmodified (no abstraction)

Rakaia River: summer flows duration curves

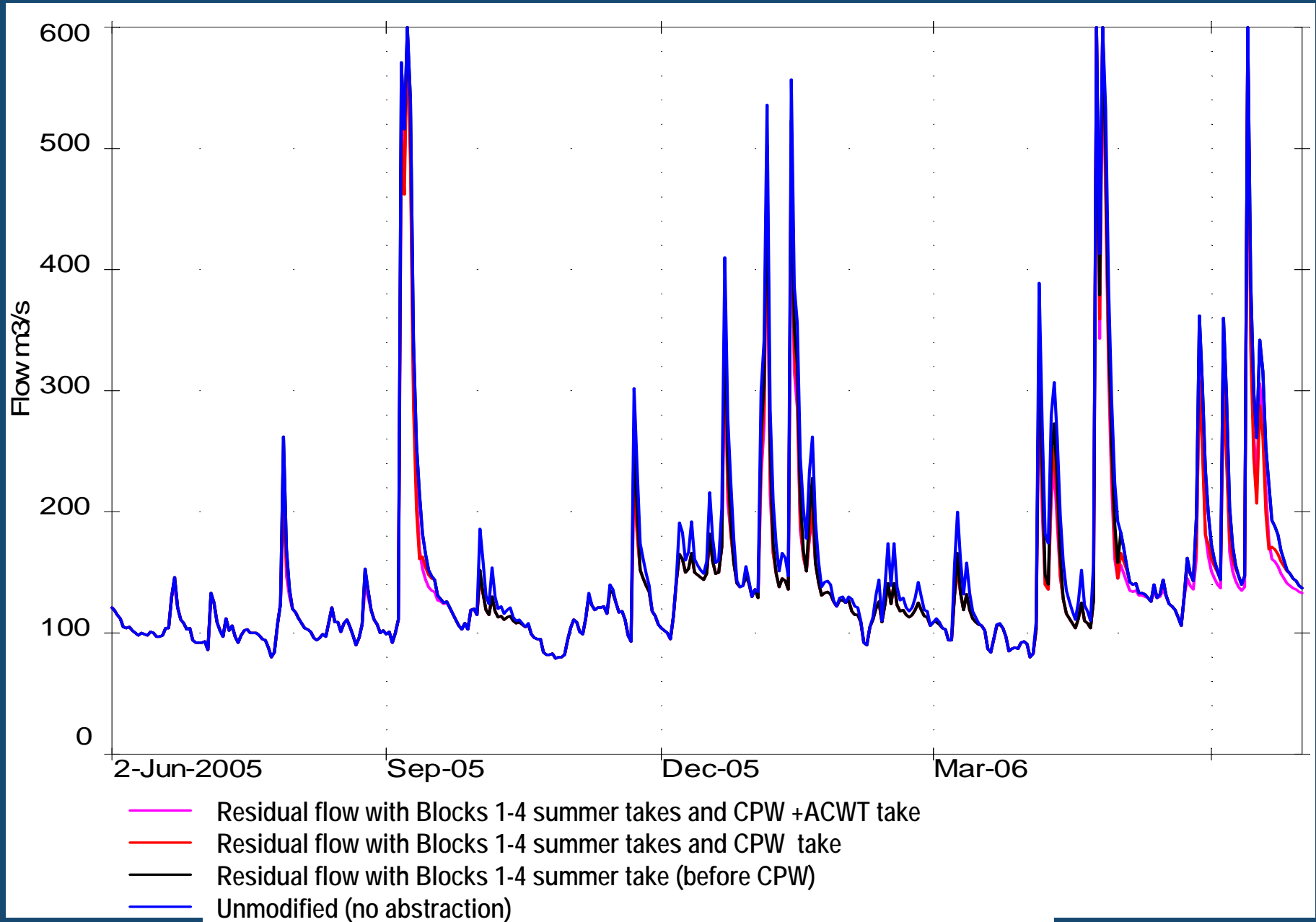


- Residual flow with Blocks 1-4 summer takes and CPW +ACWT take
- Residual flow with Blocks 1-4 summer takes and CPW take
- Residual flow with Blocks 1-4 summer take (before CPW)
- Unmodified (no abstraction)

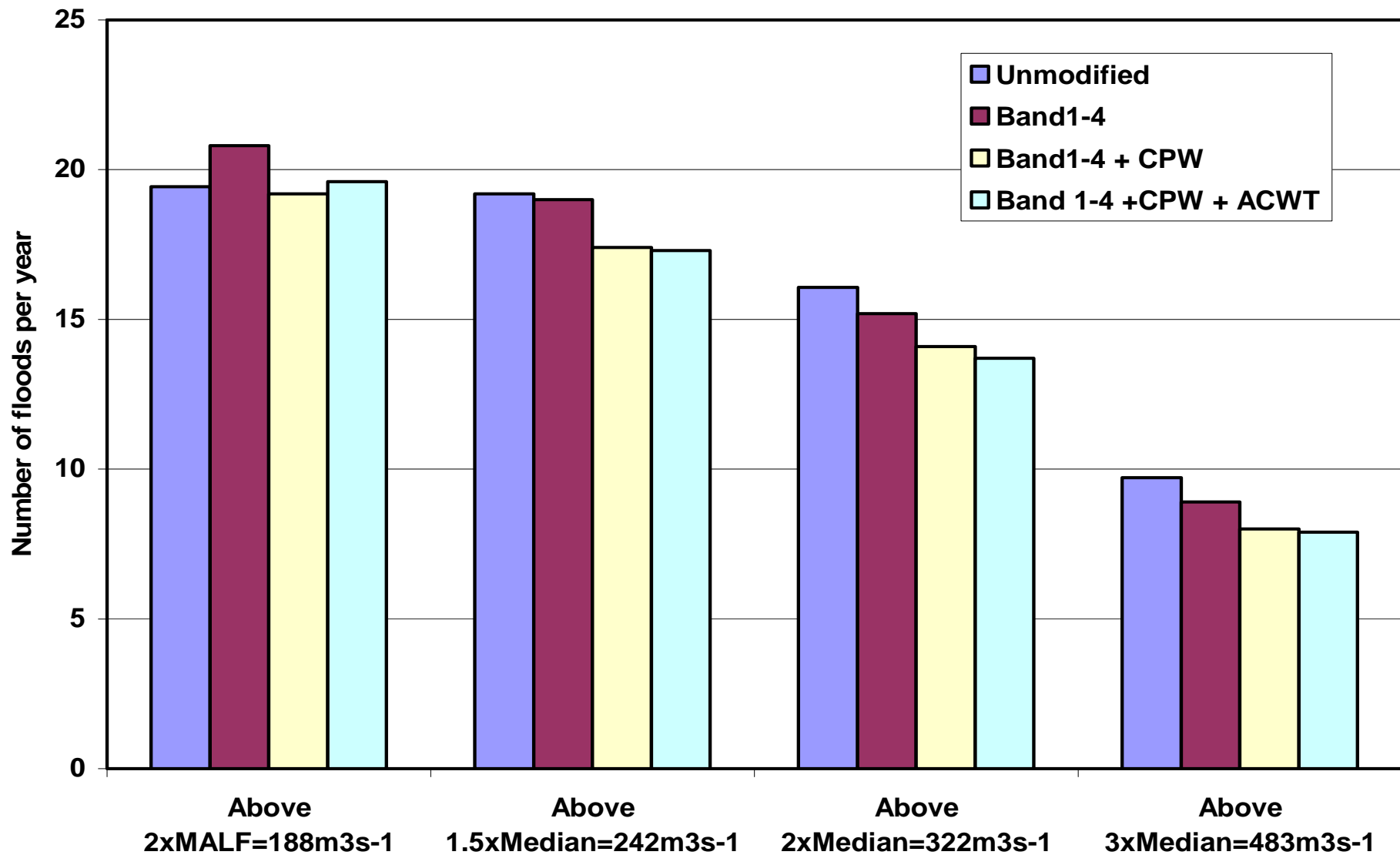
Rakaia River: flows during a typical season



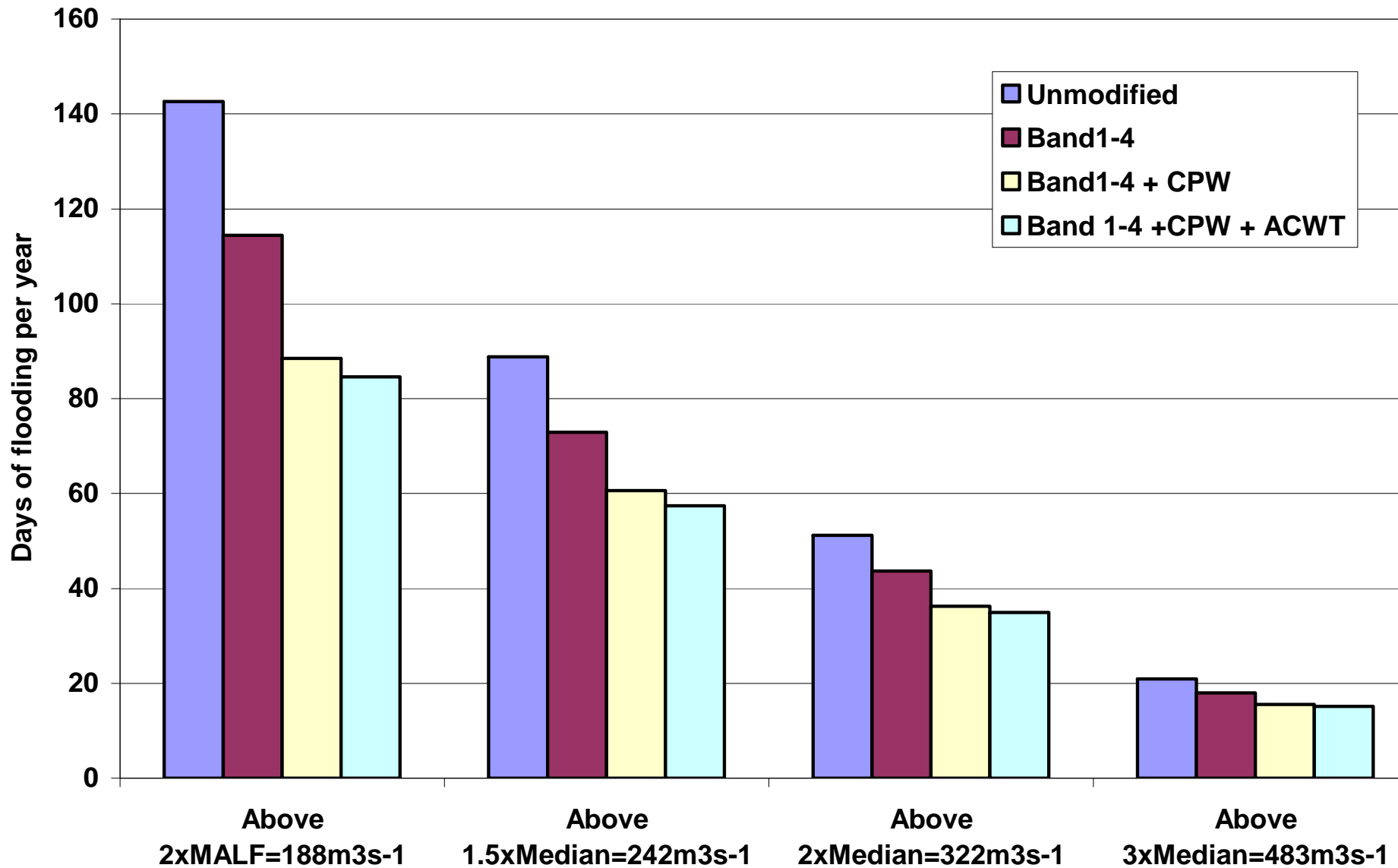
Rakaia River: flows during a dry season



Rakaia River: frequency of floods



Rakaia River: duration of floods



Rakaia River: flow statistics (Table 2)

	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 m ³ s ⁻¹ (1.5xMedian)	24	21	17	16	-24
% time > 188 m ³ s ⁻¹ (2xMALF)	38	32	26	25	-22