Before Environment Canterbury Regional Council

In the matter of	of the Resource Management Act 1991
And	
In the matter of	the Rangitata Diversion Race Consents

Statement of evidence of Alasdair Keane for Central South Island Fish and Game Council

11 April 2018

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Qualifications and experience

1 My full name is Alasdair John Keane.

2 I completed a Master of Science Degree (Honours) in Earth Sciences from the University of Waikato in 1985 and in addition completed the Graduate Course in Hydrology at the University of New South Wales in 1989. I have been a member of the Geological Society of New Zealand since 1979, a member of the New Zealand Hydrological Society since 1986 and a member of the New Zealand Society of Large Dams since 2001.

3 I have worked in the area of hydrology for 33 years, on matters including water resource assessment for hydropower, irrigation and other end uses, the quality assurance of stream flow and rainfall data in New Zealand and overseas. This has included modelling abstraction/diversion of river flows to storage and assessing residual river flows.

4 Following graduation in 1986, I was employed as a field hydrologist at the Ministry of Works and Development (**MWD**) in Hamilton and a year later I joined the Power Division of MWD in Wellington (later to become Works Consultancy Services). For about 11 years I was responsible for maintaining water level and flow data for New Zealand's major hydro storage lakes and power stations.

5 In 1997 I joined Designpower Ltd (later PB Power) and was seconded for 15 months as hydrology specialist in the Technical Specialist Group of the Electricity Corporation of New Zealand (**ECNZ**). My responsibilities included providing strategic hydrology advice and support to ECNZ business groups and had the role of hydrology advisor to the Matahina Dam Strengthening Project in 1997/98.

6 Upon returning to PB Power in 1998 I participated in preparation of technical documentation for the sale of Highbank, Matahina and Cobb power stations.

7 In 2000 I formed Keane Associates Ltd and have been the principal in this consultancy for 17 years. During this time I have undertaken a wide range of activities including

(a) Rainfall and river flow data collection;

(b) Quality assurance and auditing of hydrological data;

(c) Auditing data collection systems and contracted hydrological services;

(d) Development or improvement of quality assurance for hydrological information systems;

(e) Review of hydrological information for comprehensive dam safety reviews and for bank lending institutions and corporate investors considering investment in hydropower and irrigation schemes;

(f) Water balance modelling for rehabilitation of existing water assets and for proposed new water projects, including hydropower and small scale irrigation; and

(g) Studies relating to the feasibility of proposed new hydro-electric and irrigation schemes.

8 I have visited the Rangitata River and Rangitata Diversion Race on several occasions in relation to studies undertaken. This included visits to various points along the Rangitata Diversion Race (the intake and sandtrap, canal and irrigation scheme flow monitoring locations in 1997 and 2001. Most recently I visited the RDR intake area, the river mouth and points in between in April 2017 with staff from Central South Island Fish & Game (**CSIFG**).

9 In 2000 I completed a modelling study to assess the impact of increasing the seasonal minimum flow in the Rangitata River on RDR intake flows and the seasonal utilisation of the diverted flow on irrigation schemes and generation assets. In 2001 I undertook an operational performance evaluation of the Rangitata Diversion Race for RDRML following completion of an upgrade to hydrometric monitoring systems.

10 In preparing this evidence I have taken into consideration:

(a) Klondyke Storage Proposal - Hydrology Assessment (July 2016) & subsequently updated data tables;

(b) Rangitata Diversion Race Fish Screen Hydrology Assessment (Nov 2017)

(c) Ryder memo dated 11 August 2017 “Relocation and re-design of the proposed fish screen on the Rangitata Diversion Race”, Ryder Consultants;

(d) Canterbury Land and Water Regional Plan - Volume 1 (December 2016);

(e) Water Conservation (Rangitata River) Order 2016 (2006/401);

(f) Rangitata Water Conservation Order Appeal – Final Decision, Environment Court Decision No C135/2005;

(g) Rangitata Water Conservation Order Application, Report by the Special Tribunal October 2002;

(h) Mosley M P (2001), Rangitata River Natural Character, Amenity Values and Flow Regime (revised edition), Report U01/23 Environment Canterbury;

(i) Rangitata River Management Plan 1986-1996 (March 1986);

(j) Written evidence of Mr Veendrick

(k) S42 report by Mr Meredith

11 I have read the Code of Conduct for Expert Witnesses (Schedule 4, High Court Rules 2016)[1] and agree to comply with it. I have complied with the Code in the preparation of this statement of evidence.

Executive summary

12 The flow regime of the Rangitata River is afforded protection through a WCO for flows below a natural flow 110m3/s with no cap on extraction above this this flow.

13 RDRML have applied to take and store an additional 10m3/s above a natural flow of 132.5m3/s.

14 The proposed take further decreases the FRE statistics for flows below the RDR take. FRE statistics provide a basis for assessing the effect of the proposed take on aquatic biology.

15 The proposed take extends periods of flat line flow downstream of the last take, in aggregate by an additional 2% of the time or 7.3 days per year on average.

16 CSIFG requested examination of the effects of alternative high flow extraction rules to the additional block take proposed by RDRML.

17 Alternative 1:1 flow share and Recession & 1:1 flow share extraction rules were modelled using daily natural flows (Klondyke) from July 1971 to June 2015 and compared to the proposed take.

18 Alternative 1:1 flow share and Recession & 1:1 flow share rules result in half the incremental additional duration of flat line flows.

19 Recession & 1:1 flow share rule preserves the existing FRE statistics.

Scope of evidence

20 I have been asked by the CSIFG to provide evidence to this hearing relating to the effects of the proposed RDRML take on the flow in the Rangitata River below the RDR intake and to examine alternative abstraction rules for the proposed additional 10 m^3/s bulk take. Therefore, my evidence here includes:

(a) An overview of my understanding of the RDRML proposal and comments on the effect on the hydrology of the river;

(b) An overview of the modelling I have undertaken of the existing and proposed extraction from the Rangitata River, including some alternative extraction rules for the proposed additional extraction;

[1] Code of Conduct for Expert Witnesses (Schedule 4 , High Court Rules 2016 http://www.legislation.govt.nz/regulation/public/2016/0225/latest/versions.aspx (accessed 28 April 2017)

(c) A comparison between the proposed extraction and alternative extraction rules on the existing hydrology of the river, including;

i. Key flow statistics;

ii. Changes to the flow regime in the directly affected reach, flow duration and variability;

21 The emphasis of evidence is for flows in excess of 110m^3/s as no changes are proposed to the flow regime below 110m^3/s.

Overview of Rangitata River hydrology

22 The catchment of the Rangitata River at the gorge has an area of about 1461km2. The hydrology regime reflects a river with glaciated headwaters at the main divide of the Southern Alps.

23 The river has a mean flow of 94.9 m^3/s (July1971 to June 2015) and the annual mean flow varies between 69.6 m^3/s (1977) and 124.9m^3/s (1983). The median flow is 75 m^3/s.

24 The absolute maximum and minimum flows recorded are 2979m^3/s in January 1994 and 31m^3/s in July 1992. The 7-day MALF is 38.7m^3/s

25 The lowest mean monthly flows occur in July and the highest during the snow melt season in early summer. Floods are less common during June to September when precipitation typically falls as snow in the upper catchment.

26 The natural character, amenity values and flow regime of the catchment are afforded protection under the terms of the Rangitata WCO (2006). The WCO sets a flow management regime for the river below the gorge covering surface water abstraction and hydraulically connected groundwater sources.

27 Minimum flows are set for 15 May to 14 Sept (15m^3/s) and 15 Sep to 14 May (20m^3/s). Up to 33m^3/s is available for abstraction when flows are between the seasonal minimum and 110m^3/s and there is no cap above110m^3/s

28 Allocation below 110m^3/s is fully allocated and 22.6m^3/s is allocated above 110m^3/s totalling 55.6m^3/s or 58.6% of the mean flow.

29 When flow gaugings have been carried out at intervals between the Gorge and the coast a minor nett gain in flow is measured but this is within the margin of gauging error.

Klondyke storage proposal

30 RDRML have proposed construction of a 53Mm^3 off-river Klondyke Storage Pond (**KSP**) on the left bank of the river downstream of the sandtrap and are applying for an additional bulk

consumptive take of up to 10m^3/s at their existing intake on the Rangitata River when the flow in the river is more than 132.6m^3/s measured upstream at the Klondyke recorder.

31 In addition to the consumptive takes, a non-consumptive 3 - 5m^3/s for operation of the rotary screen fish bypass is proposed to be taken at the existing intake and discharged back to the river approximately 1,400m downstream of the intake.

32 The construction of the KSP appears to enable RDRML to more fully exercise the existing resource consents and the proposed high flow take in most years.

33 Mr Veendrick in his evidence describes the proposed additional take through the existing intake to the RDR and for the new fish pass arrangement. He describes the effects of the additional abstraction on the river flow below the intake and at the last point of take based on the daily mean flow series from 1 July 1971 to 31 May 2015. This period was selected because it includes significant irrigation drought events in the 1970s and endeavours to use the longest available flow record to capture the maximum variability in river flow.

34 When considering high flow allocations, the impact of each successive take may seem limited when assessed in isolation. The taking of high flows has no effect on the minimum flow in the river because they occur infrequently and as such will have a small effect on mean flow. However high flow takes do have an effect on freshes and floods in the river. This is demonstrated by the change in the FRE statistics between the natural river and modified river flows in Table 2. The FRE statistics describes the average number of freshes and flood events that occur annually over a threshold flow. Typically, this threshold is a multiple of the median flow. The FRE_3 statistic describes the occurrence of flows greater than 3x median flow. This statistic is typically used to describe the frequency of flows high enough to disturb the riverbed sufficiently to discourage the development of nuisance periphyton on the stream by which I understand limits fish feeding opportunity. $FRE_{1.5}$ and FRE_2 describe the occurrence of smaller freshes. These statistics are referred to as relevant by Dr Meredith in his memorandum, and other experts will be better qualified than me to describe the importance of these statistics to the aquatic biology in the river.

Downstream of RDR Take	(flow m^3/s)		
	Natural	Existing	Proposed
Mean	94.9	66.7	65.2
Median	75.0	44.4	44.4
Minimum	32.1	16.1	16.1
7 Day MALF	38.7	18.5	18.5
Lower Quartile	53.2	27.6	27.6
Upper Quartile	109.1	78.4	78.2
$FRE_{1.5}$	11.3	10.2	9.5
FRE_2	9.9	8.0	7.6
FRE_3	5.9	5.0	4.8

Downstream of all takes	(flow m^3/s)		
	Natural	Existing	Proposed
Mean	94.9	61.5	60.0
Median	75.0	42.6	42.6
Minimum	32.1	15.3	15.3
7 Day MALF	38.7	17.6	17.6
Lower Quartile	53.2	26.4	26.4
Upper Quartile	109.1	75.1	74.8
$FRE_{1.5}$	11.3	9.1	8.4
FRE_2	9.9	6.9	6.6
FRE_3	5.9	4.3	4.0

Table 2 Comparison between natural flows and modelled existing and proposed flow statistics downstream of the RDR take and downstream of all takes.

35 The net effect is that flows above 142.6m^3/s at Klondyke reduce by 10m^3/s below the intake. Referring to Table 2 and the effects that I have modelled, the effect of the proposed 10m^3/s abstraction is to reduce the mean flow downstream of the RDR take by 1.5m^3/s or 2.4% from 61.5 to 60 m^3/s, and in the river downstream of the last take by 2.2% from 61.5 to 60 m^3/s.

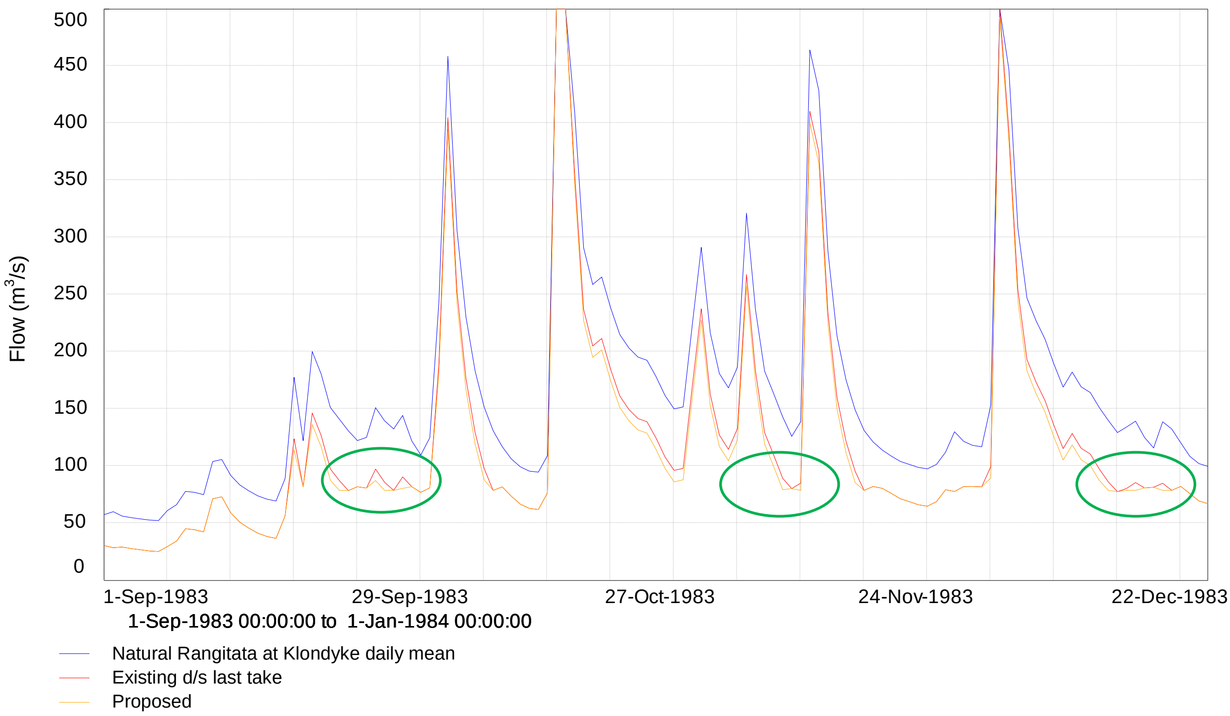
36 In comparison to the existing situation, the FRE_3 statistic downstream of all takes reduces by 7% from 4.3 to 4.0. The FRE_2 statistic reduces by 4% from 6.9 to 6.6. The $FRE_{1.5}$ reduces by 7.6% from 9.1 to 8.4.

37 The statistics for flows below 132.6m^3/s (minimum, 7-day MALF, lower quartile and upper quartile) are unchanged.

38 Under the existing flow regime the river maintains periods of steady flow with some intermittent small variation in flow. This pattern is created by the removal of a block of flow under the existing practice of allocating blocks of flow for abstraction and occurs when the

residual river flow is around 80 m^3/s. The effect of the proposed additional block take is to flatten off such freshes up $10m^3/s$ in amplitude that might otherwise occur when the residual flow is around 80 m^3/s. Thus the effect is to lengthen existing periods of flat flow or creating periods of flat flow in the troughs between peaks or across small freshes. I have illustrated some examples of this in Figure 1 showing hydrographs for Sep-1983 to Jan-1984, Oct-1990 to Jan-1991 and Sept-2011 to Jan-2012. Examples of these incremental changes to flat flow features are circled in green.

39 So an effect of the additional block takes from the river is an incremental increase in the duration of flat lined flow periods in the river and this is more apparent in the assessment of flow downstream of all takes. The same effect can be seen in the flow duration curves (Figure 9) at around 80 m^3/s. Overall the river flows are held steady at about 80 m^3/s for an additional 2% of the time or on average about 7.3 days per year.



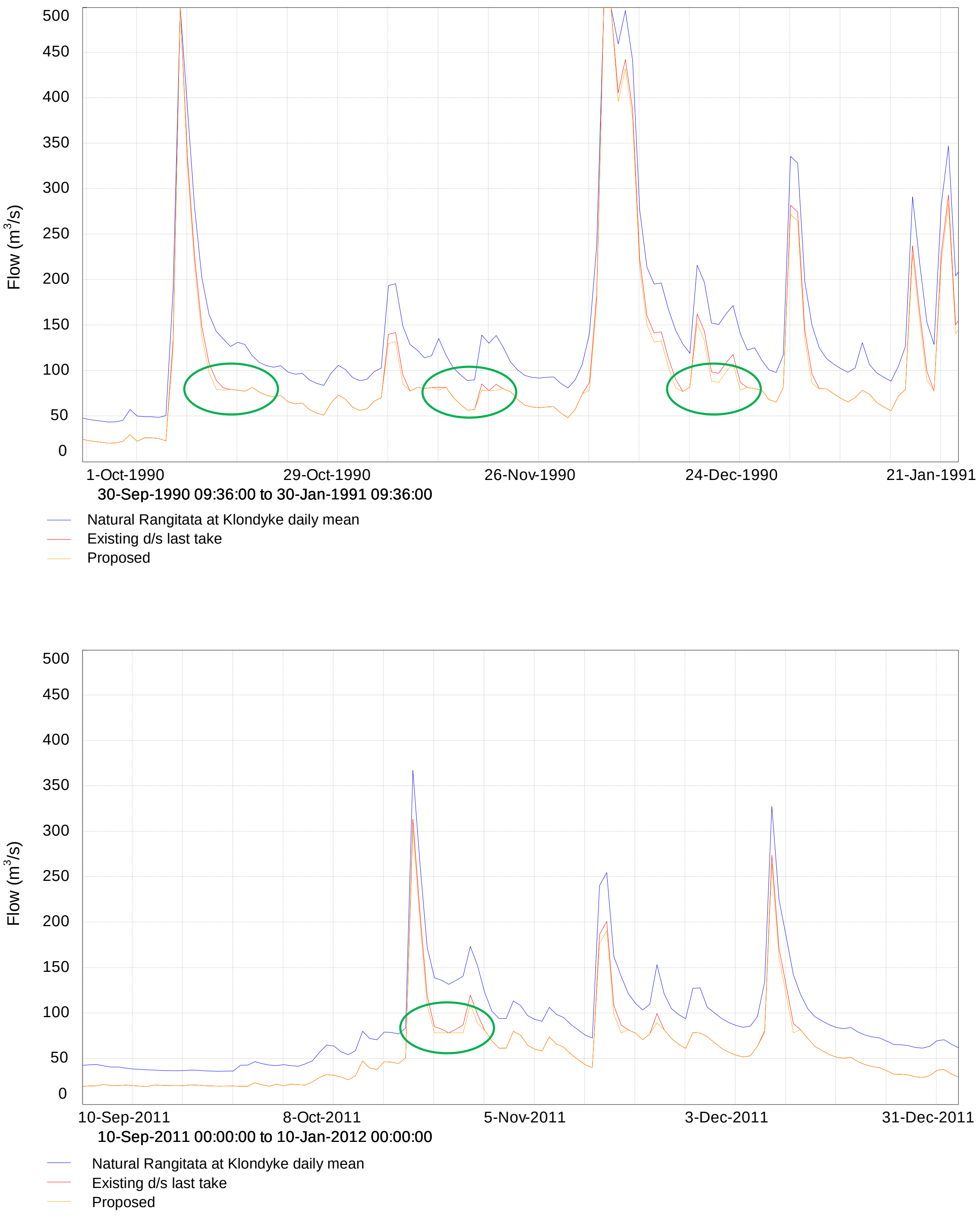


Figure 1 Examples of incremental addition to flat lining effect (river flows downstream of all intakes)

Alternatives to proposed bulk flow extraction

40 While the current CLWRP contains no specific cap or limit on high flow allocation in the Rangitata River below the Gorge, the previous River Management Plan (Waugh and Scarf 1986) and the Special Tribunal Decision both promoted a cap and flow sharing regime in the high flow range.

41 For this reason, CSIFG have asked me to model alternative extraction rules to illustrate a comparison between the proposed 10m^3/s bulk take and these alternatives.

42 I have undertaken modelling of the existing and proposed flow regime following a similar process to Mr Veendrick, with the exception that I have not included the temporary diversion of the fish screen bypass flows. My modelling produces similar flow statistics for the existing and proposed flow regimes as was modelled by Mr Veendrick. While there are small differences these are attributed to slightly different hydrology datasets and the use of different modelling software (in my case Hilltop VSIM). The purpose of this initial modelling was to establish a basis on which to undertake additional modelling of alternative abstraction regimes.

43 RDRML have not presented an assessment or comparison of alternative flow extraction rules and whether such alternatives might provide a similar reliable flow volume and therefore minimise the impact of abstracting additional flow on the shape and nature of the flow hydrographs downstream of the intake. For this reason, CSIFG have sought to model alternative extraction rules.

44 The following scenarios were modelled;

Baseline – existing takes,

Scenario 1 – Baseline plus RDRML proposed bulk 10m^3/s take (132.6 to 142.6m^3/s),

Scenario 2 – Baseline plus 10m^3/s & 1:1 share between 132.6 to 152.6m^3/s, (**1:1 flow share**)

Scenario 3 – Baseline minus 10m^3/s on river recession & 1:1 from 132.6 to 152.6m^3/s. (**Recession and 1:1 flow share**)

Recession and 1:1 flow share alternative was suggested by CSIFG and assumes taking water only on a falling river flow and a 1:1 flow sharing arrangement when the flow at Klondyke is between 132.6 and 152.6m^3/s.

45 River flow changes have been modelled to assess flow changes immediately below the RDR take and downstream of all takes. The key assumptions in modelling both locations are set out in Appendix 1.

46 Modelling results are at two locations on the river, immediately below the RDR intake (representing the non-braided reach between the Gorge and Arundel Bridge) and below the

most downstream consented take representing the flow regime in the braided reach downstream of the Arundel Bridge to the River mouth.

47 The existing take regime, the RDRML proposal and two alternative abstraction rules have been modelled using the daily flow dataset (Jul-1971 to Jun-2015), to allow ready comparison with Mr Veendrick's assessment of effects.

Comparing the proposed and alternative extraction rules

48 To illustrate the differences between the modelled flow regimes, plots of time series hydrographs for modelled flows in average, wet and dry years are presented in Figures 2 to 4 for flows downstream of the RDR take and Figures 5 to 7 modelled flows downstream of all takes.

49 At downstream of the RDR intake and downstream of all takes when the alternative flow regimes labelled "1:1 flow share" and the "Recession & 1:1 flow share" scenarios are compared to the RDRML proposal,

(d) the transition in flow from zero to full take, when flow is above the minimum flow of 132.6 m^3/s at Klondyke, is smoother and there is not a step introduced to the flow hydrograph on the rising and falling flow limbs.

(e) The difference between the 1:1 flow share and Recession & 1:1 flow share regime is essentially that no flow is taken on the rising flow in the latter case.

(f) In both of these scenarios less flow volume is available to be taken than in the RDML proposal.

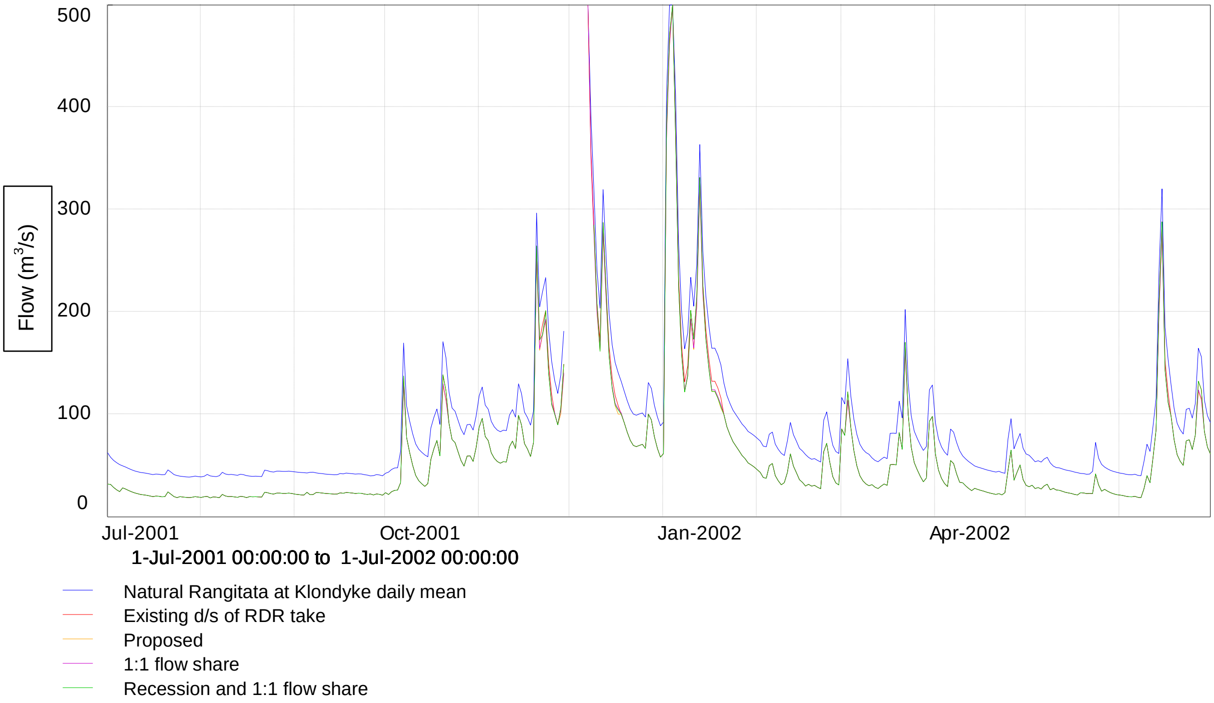


Figure 2 Rangitata downstream RDR take - comparison between proposed RDRML and alternative rules in an average year (1 Jul 2001 - 30 June 2002)

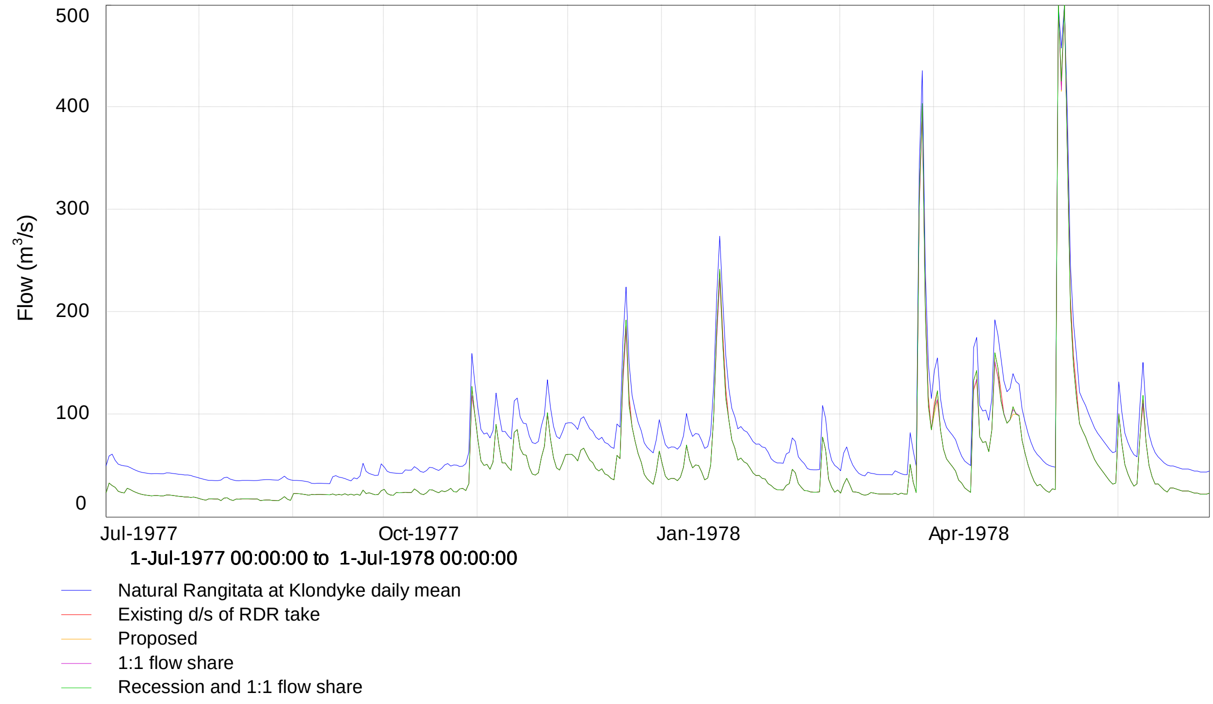


Figure 3 Rangitata downstream of RDR take - comparison between proposed RDRML and alternative rules in a dry year (1 Jul 1977 - 30 June 1978)

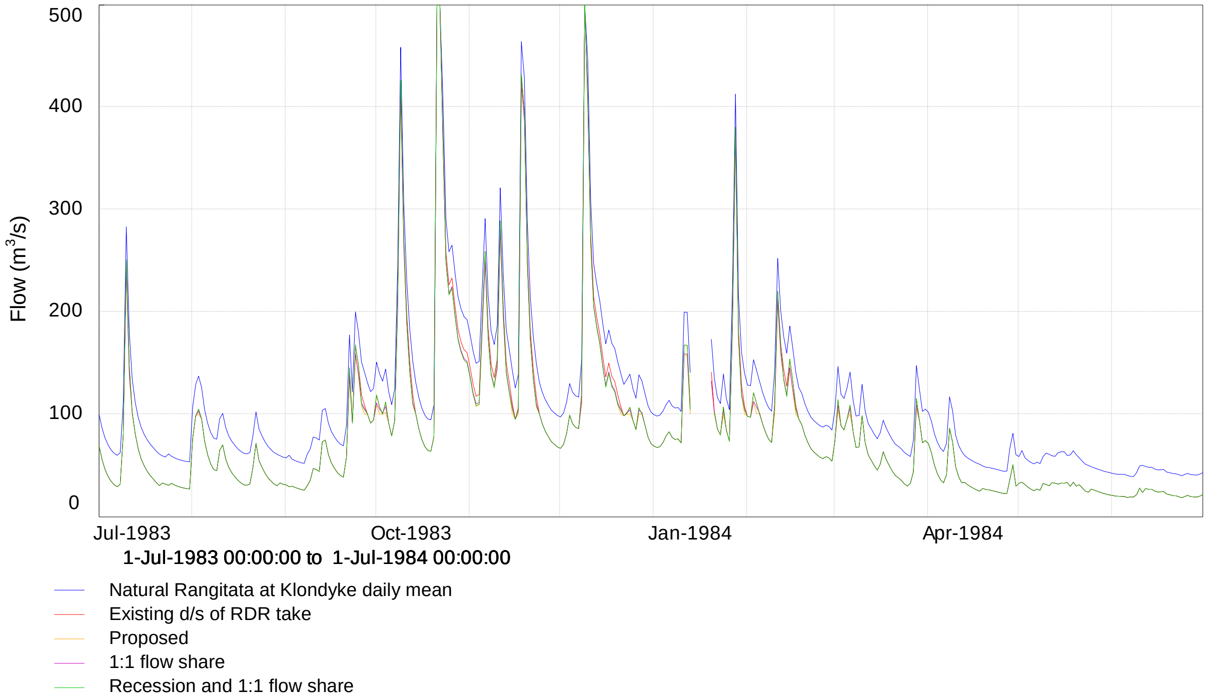


Figure 4 Rangitata downstream of RDR take - comparison between proposed RDRML and alternative rules in a wet year (1 Jul 1983 - 30 June 1984)

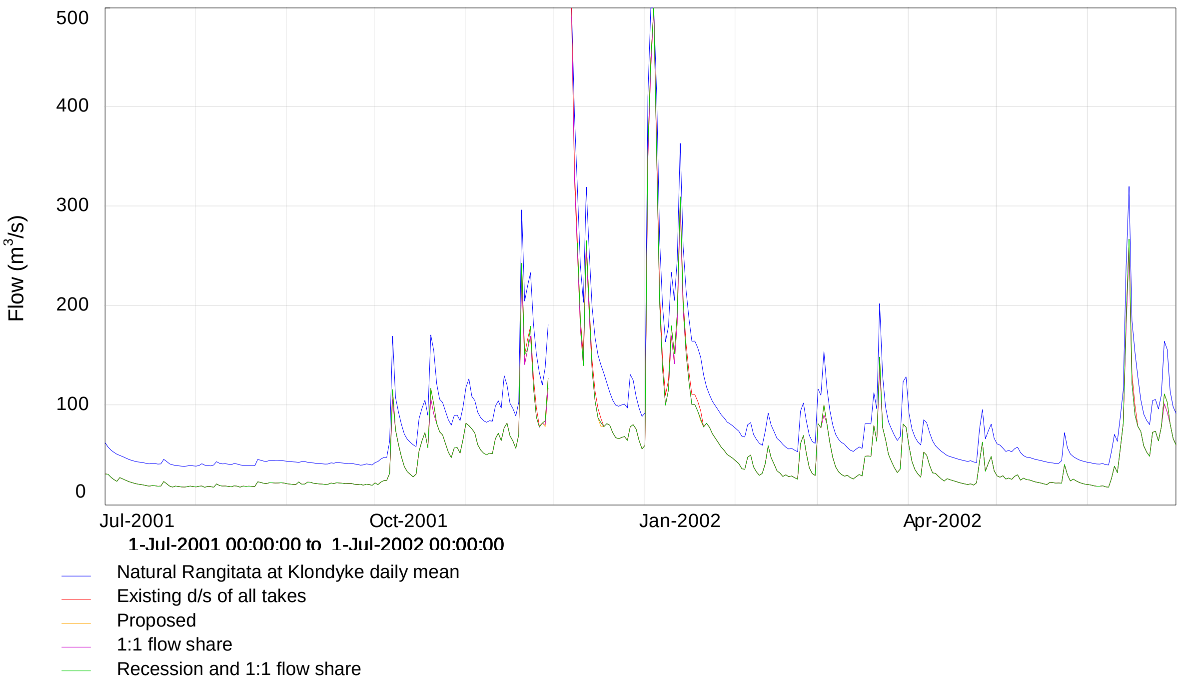


Figure 5 Rangitata River downstream of all takes - comparison between RDRML and alternative rules in an average year (1 Jul 2001 - 30 June 2002)

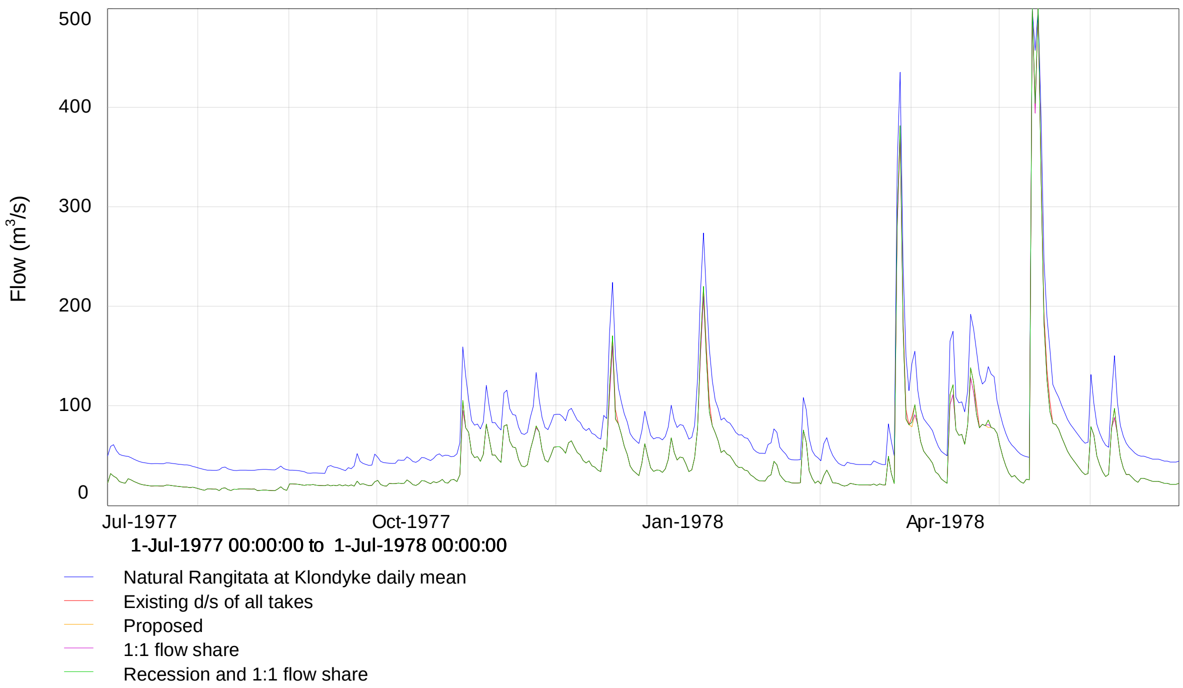


Figure 6 Rangitata River downstream of all takes - comparison between RDRML and alternative rules in a dry year (1 Jul 1977 - 30 June 1978)

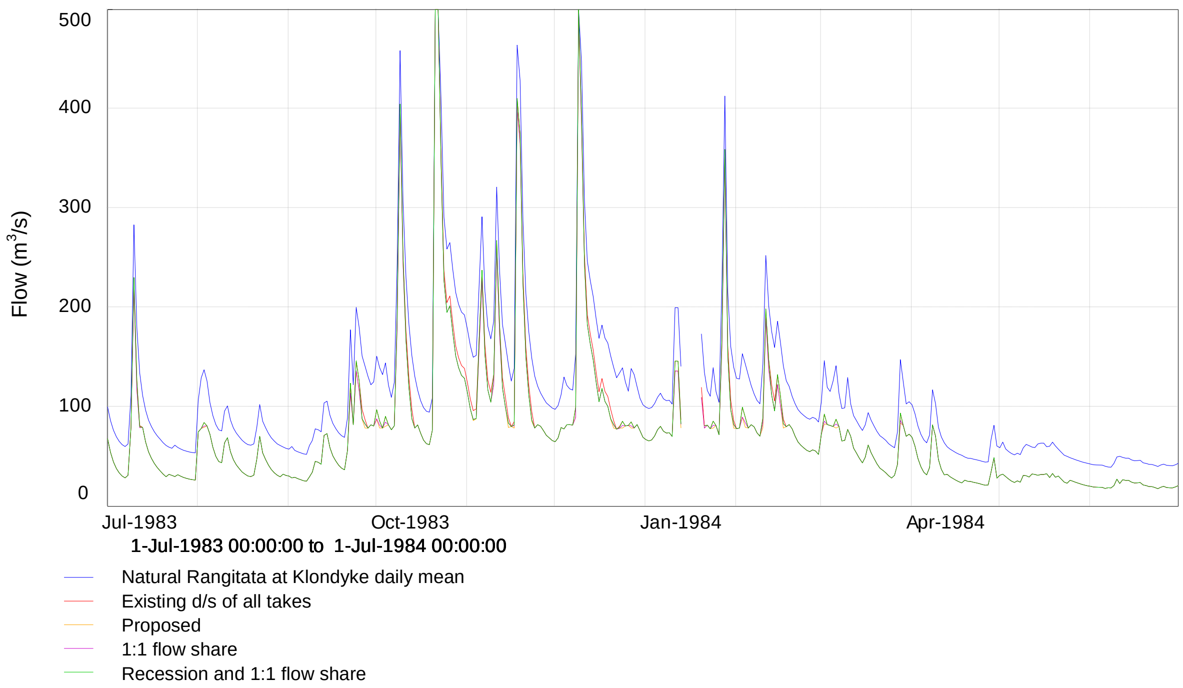


Figure 7 Rangitata River downstream of all takes intake - comparison between proposed RDRML and alternative rules in a wet year (1 Jul 1983 - 30 June 1984)

50 Flow duration curves for each modelled flow regime is compared in Figures 8 and 9. The flow duration curves are presented over the flow range 0 to 150 m^3/s to illustrate the effects described above for the flow hydrographs that are also apparent in the flow duration curves.

51 At downstream RDR take (Figure 8) a small shoulder occurs in the flow duration curve for the RDRML proposal at a flow above 100m^3/s flow. This represents the onset of periods of more stable flows, perhaps not yet so steady as to apparent as flat lining, but this effect is not apparent in the flow duration curve for the existing flow regime.

52 At downstream of all takes (Figure 9) the flat line step already exists in the flow duration curve for the existing flow regime when flows are about 80 m^3/s as shown in Figure 9. This occurs for 5% of the time, between the flow exceedance of 17 to 22% and is an effect of the existing abstraction regime. The proposed abstraction regime lengthens this period by 2%. The 1:1 flow share and Recession & 1:1 flow share regimes lengthens this period by 1% of the time. The flow statistics downstream of RDR intake and downstream of all takes for the existing and alternative flow regimes are summarised below in Table 3 and Table 4. More detailed tabulations including a flow duration table, annual flood, FRE_3, FRE_2, $FRE_{1.5}$ and 7-day low flow statistics are included in Appendix 2.

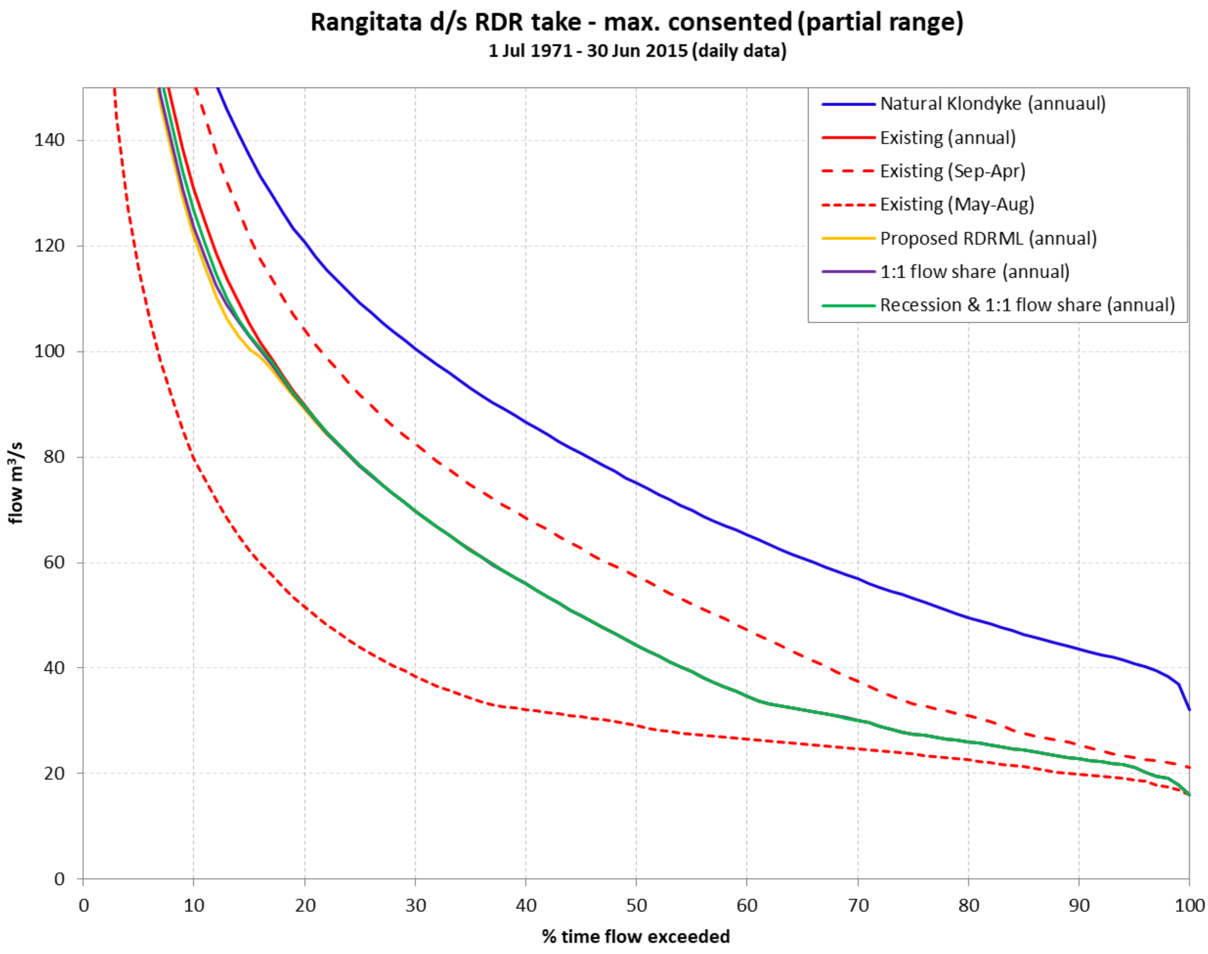


Figure 8 Flow duration curves for various flow regimes downstream RDR take

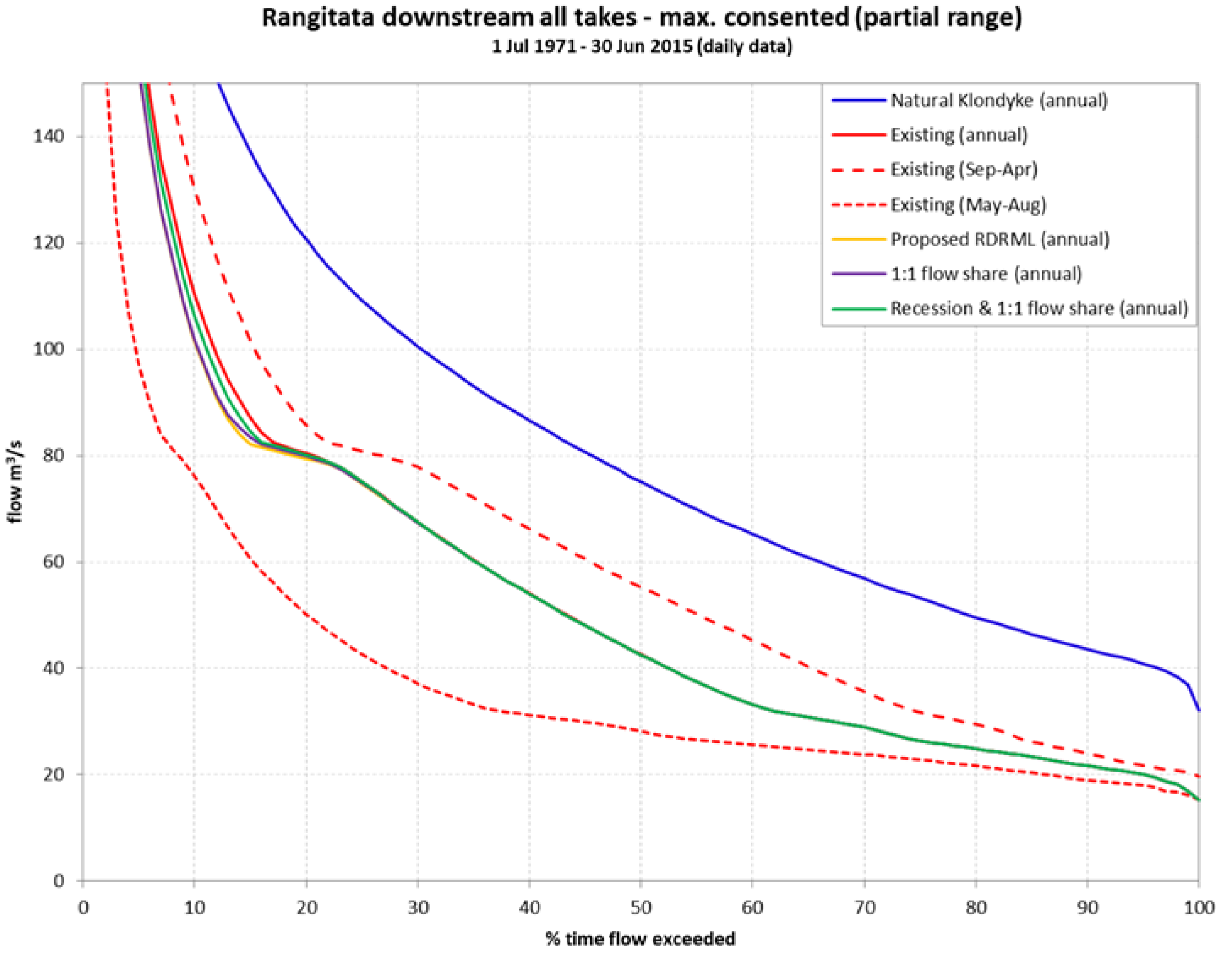


Figure 9 Flow duration curves for various flow regimes downstream all takes

Downstream of RDR Take	(flow m^3/s)				
	Natural	Existing	Proposed	1:1 flow share	Recession and 1:1 flow share
Mean	94.9	66.7	65.2	65.5	65.4
Median	75.0	44.4	44.4	44.4	44.4
Minimum	32.1	16.1	16.1	16.1	16.1
7 Day MALF	38.7	18.5	18.5	18.5	18.5
Lower Quartile	53.2	27.6	27.6	27.6	27.6
Upper Quartile	109.1	78.4	78.2	78.3	78.4
$FRE_{1.5}$	11.3	10.2	9.5	9.6	10.4
FRE_2	9.9	8.0	7.6	7.7	8.2
FRE_3	5.9	5.0	4.8	4.8	5.0

Table 3 Summary of flow statistics downstream RDR take for existing and alternative take rules.

Downstream of all takes	(flow m^3/s)				
	Natural	Existing	Proposed	1:1 flow share	Recession and 1:1 flow share
Mean	94.9	61.5	60.0	60.1	60.9
Median	75.0	42.6	42.6	42.6	42.6
Minimum	32.1	15.3	15.3	15.3	15.3
7 Day MALF	38.7	17.6	17.6	17.6	17.6
Lower Quartile	53.2	26.4	26.4	26.4	26.4
Upper Quartile	109.1	75.1	74.8	74.8	75.1
$FRE_{1.5}$	11.3	9.1	8.4	8.4	9.2
FRE_2	9.9	6.9	6.6	6.6	7.0
FRE_3	5.9	4.3	4.0	4.0	4.3

Table 4 Summary of flow statistics downstream all takes for existing and alternative take rules

53 The flow statistics are for all regimes are the same below the upper quartile flow because the high flow abstraction occurs above this flow.

54 The main difference is observed in the FRE statistics that represents the average annual frequency of freshes and floods. The FRE statistics for the 1:1 flow share regime result in a similar reduction to the proposed regime at both downstream of the RDR take and downstream of all takes. The main benefit of the Recession & 1:1 flow share regime is that it preserves the existing FRE statistics because the peaks of floods and freshes are allowed to pass before the proposed abstraction occurs on the recession of each event.

Alasdair Keane

11 April 2018

Appendix 1 – Modelling assumptions

1 Hilltop VSIM was used to model the rules for each consented abstraction rule and to subtract the individual modelled abstractions form the flow measured at Klondyke. The scenarios were modelled first using a daily flow data 1 July 1971 to 30 June 2015.

2 Several longitudinal flow gauging exercises have been undertaken on the Rangitata River as reported in Scarf & Waugh 1986 and Wilson 2013. The conclusion from these studies is that there is not a significant natural net gain or loss in flow between the Gorge (Klondyke) and the river mouth or that if there is a small increase in flow that it is less than the flow gauging error and therefore not significant.

3 Existing takes down the river were modelled in a similar way to the RDRML proposal. The RDR take is modelled in accordance with the consent conditions. Non-RDR surface water and stream depleting groundwater takes with minimum flow of less than or equal to 66m3/s are assumed during the irrigation season only (September to April inclusive) and amount to 1.11m3/s in accordance with the Rangitata WCO maximum of 1.12m3/s., non-RDR surface water takes with a minimum flow restriction greater than or equal to 110m3/s are assumed to operate all year round when flow is available and amount to 22.6m3/s. This is in accordance with the WCO flow regime.

4 The effect of stream depleting groundwater takes on river flow was modelled assuming the stream depletion flow values provided by ECan that are summarised in Appendix D of the RDRML Hydrology Report.

5 Total abstracted flows include direct surface water takes, and consented takes include derived river depletion flows from hydraulically connected groundwater takes. Consented flow restrictions relating to the Rangitata at Klondyke recorder were modelled but not restrictions on take relating to flow in tributaries which in the overall assessment is considered minor.

6 Modelling has not taken account of abstraction from the South Ashburton River but has focussed on the flow available to abstract from the Rangitata River on the basis that future increase in the minimum flow at the South Ashburton River intake and the availability of the new Klondyke Storage is likely to mean that the existing and future RDR consents are likely to be fully exercised.

7 The irrigation season is assumed to be September to April inclusive.

Appendix 2 – Flow statistics

Natural - Rangitata River at Klondyke

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
94.9	75.0	32.1	38.7	53.2	109.1	1094	11.3	9.9	5.9

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1418.3	378.2	300.6	262.4	235.5	215.3	200.7	188.7	179.1	170.4
10	163.0	156.4	150.7	145.8	141.2	137.1	133.3	129.7	126.5	123.3
20	120.6	118.0	115.5	113.3	111.2	109.1	107.3	105.5	103.8	102.1
30	100.5	99.0	97.5	96.0	94.5	93.1	91.6	90.3	89.1	87.9
40	86.7	85.4	84.2	82.9	81.8	80.6	79.5	78.4	77.2	76.1
50	75.0	73.9	72.9	71.9	70.8	69.9	68.9	67.9	67.0	66.1
60	65.2	64.3	63.4	62.5	61.7	60.8	60.0	59.2	58.4	57.7
70	56.9	56.1	55.3	54.6	53.9	53.2	52.5	51.7	51.0	50.3
80	49.6	49.0	48.4	47.8	47.1	46.5	45.9	45.3	44.7	44.2
90	43.6	43.0	42.6	42.1	41.5	40.9	40.2	39.5	38.4	37.0
100	32.1									

Daily Flood Flows(m^3/s)

Mean Annual	701
1:5	940
1:10	1130
1:20	1320
1:50	1550
1:100	1730
1:200	1910
1:500	2140
1:1000	2320

7 Day Low Flow (m^3/s)

Annual	38.7
1:5	36.6
1:10	35.6

Ratio of instantaneous to daily flood peaks 1979-2015: 1.561

Rangitata d/s RDR intake - Existing

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
66.7	44.4	16.1	18.5	27.6	78.4	1044	10.2	8.0	5.0

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1386.1	346.0	268.4	230.2	203.3	183.2	168.6	156.6	147.0	138.3
10	130.9	124.4	118.7	113.8	109.4	105.4	101.7	98.6	95.5	92.4
20	89.8	87.2	84.7	82.6	80.5	78.4	76.6	74.8	73.1	71.4
30	69.8	68.3	66.8	65.3	63.8	62.4	61.0	59.7	58.4	57.2
40	56.0	54.7	53.5	52.3	51.1	50.0	48.9	47.7	46.6	45.5
50	44.4	43.3	42.2	41.3	40.2	39.3	38.3	37.3	36.4	35.6
60	34.7	33.9	33.3	32.8	32.4	32.1	31.7	31.4	31.0	30.6
70	30.2	29.7	29.0	28.4	27.9	27.6	27.2	26.9	26.7	26.4
80	26.1	25.8	25.5	25.1	24.8	24.5	24.1	23.8	23.4	23.1
90	22.9	22.6	22.3	22.0	21.7	21.2	20.3	19.6	19.1	17.9
100	16.1									

Daily Flood Flows(m^3/s)	
Mean Annual	669
1:5	910
1:10	1100
1:20	1280
1:50	1520
1:100	1700
1:200	1880
1:500	2110
1:1000	2290

7 Day Low Flow (m^3/s)	
Annual	18.5
1:5	17.2
1:10	16.4

Ratio of instantaneous to daily flood peaks 1979-2015: 1.561

Rangitata d/s RDR intake - Proposed

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
65.2	44.4	16.1	18.5	27.6	78.2	1028	9.5	7.6	4.8

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1376.1	336.2	258.6	220.5	193.6	173.5	159.0	147.1	137.5	129.1
10	121.9	115.8	110.4	106.2	102.8	100.5	98.9	96.6	94.0	91.5
20	89.1	86.7	84.4	82.3	80.2	78.2	76.4	74.6	73.0	71.3
30	69.7	68.2	66.7	65.2	63.8	62.4	60.9	59.6	58.4	57.2
40	56.0	54.7	53.5	52.2	51.1	50.0	48.9	47.7	46.6	45.5
50	44.4	43.3	42.2	41.3	40.2	39.3	38.3	37.3	36.4	35.6
60	34.7	33.9	33.3	32.8	32.4	32.1	31.7	31.4	31.0	30.6
70	30.2	29.7	29.0	28.4	27.9	27.6	27.2	26.9	26.7	26.4
80	26.1	25.8	25.5	25.1	24.8	24.5	24.1	23.8	23.4	23.1
90	22.9	22.6	22.3	22.0	21.7	21.2	20.3	19.6	19.1	17.9
100	16.1									

Daily Flood Flows(m^3/s)	
Mean Annual	659
1:5	900
1:10	1090
1:20	1270
1:50	1510
1:100	1690
1:200	1870
1:500	2100
1:1000	2280

7 Day Low Flow (m^3/s)	
Annual	18.5
1:5	17.2
1:10	16.4

Ratio of instantaneous to daily flood peaks 1979-2015: 1.561

Rangitata d/s RDR intake - 1:1 flow share

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
65.5	44.4	16.1	18.5	27.6	78.3	1031	9.6	7.7	4.8

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1377.6	337.7	260.1	222.0	195.1	175.0	160.5	148.6	139.1	130.7
10	123.6	117.6	112.4	108.8	105.7	102.9	100.3	97.6	94.7	91.9
20	89.4	86.9	84.5	82.4	80.3	78.3	76.5	74.7	73.0	71.4
30	69.8	68.3	66.8	65.3	63.8	62.4	60.9	59.6	58.4	57.2
40	56.0	54.7	53.5	52.3	51.1	50.0	48.9	47.7	46.6	45.5
50	44.4	43.3	42.2	41.3	40.2	39.3	38.3	37.3	36.4	35.6
60	34.7	33.9	33.3	32.8	32.4	32.1	31.7	31.4	31.0	30.6
70	30.2	29.7	29.0	28.4	27.9	27.6	27.2	26.9	26.7	26.4
80	26.1	25.8	25.5	25.1	24.8	24.5	24.1	23.8	23.4	23.1
90	22.9	22.6	22.3	22.0	21.7	21.2	20.3	19.6	19.1	17.9
100	16.1									

Daily Flood Flows(m^3/s)		**7 Day Low Flow (m^3/s)**	
Mean Annual	661	Annual	18.5
1:5	900	1:5	17.2
1:10	1090	1:10	16.4
1:20	1280		
1:50	1510		
1:100	1690		
1:200	1870		
1:500	2100		
1:1000	2280		

Ratio of instantaneous to daily flood peaks 1979-2015: 1.561

Rangitata d/s RDR intake - Recession & 1:1 flow share

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
66.1	44.4	16.1	18.5	27.6	78.4	1044	10.4	8.2	5.0

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1386.1	343.1	265.0	226.7	199.5	179.4	164.2	152.6	142.7	134.0
10	126.8	120.5	115.0	110.4	106.6	103.6	100.9	98.1	95.2	92.3
20	89.6	87.1	84.7	82.5	80.4	78.4	76.5	74.7	73.1	71.4
30	69.8	68.3	66.8	65.3	63.8	62.4	61.0	59.6	58.4	57.2
40	56.0	54.7	53.5	52.3	51.1	50.0	48.9	47.7	46.6	45.5
50	44.4	43.3	42.2	41.3	40.2	39.3	38.3	37.3	36.4	35.6
60	34.7	33.9	33.3	32.8	32.4	32.1	31.7	31.3	31.0	30.6
70	30.1	29.6	29.0	28.4	27.9	27.6	27.2	26.9	26.7	26.4
80	26.1	25.8	25.5	25.1	24.8	24.5	24.1	23.8	23.4	23.1
90	22.9	22.6	22.3	22.0	21.7	21.2	20.3	19.6	19.1	17.9
100	16.1									

Daily Flood Flows(m^3/s)		**7 Day Low Flow (m^3/s)**	
Mean Annual	669	Annual	18.5
1:5	910	1:5	17.2
1:10	1100	1:10	16.4
1:20	1280		
1:50	1520		
1:100	1700		
1:200	1880		
1:500	2110		
1:1000	2290		

Ratio of instantaneous to daily flood peaks 1979-2015: 1.561

Rangitata downstream of all takes - Existing

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
61.5	42.6	15.3	17.6	26.4	75.1	1011	9.1	6.9	4.3

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1364.5	324.8	247.3	209.1	182.3	162.2	147.7	135.7	126.2	117.7
10	110.5	104.2	98.7	94.3	90.5	87.1	84.4	82.4	81.8	81.1
20	80.4	79.7	78.9	77.9	76.5	75.1	73.6	72.1	70.5	69.0
30	67.5	66.1	64.6	63.2	61.8	60.4	59.0	57.7	56.5	55.3
40	54.1	52.8	51.6	50.4	49.3	48.1	47.0	45.9	44.8	43.7
50	42.6	41.5	40.5	39.5	38.5	37.6	36.6	35.7	34.8	34.0
60	33.3	32.5	32.0	31.6	31.2	30.8	30.5	30.1	29.8	29.4
70	28.9	28.4	27.8	27.2	26.8	26.4	26.1	25.8	25.5	25.2
80	24.9	24.6	24.3	24.0	23.7	23.4	23.0	22.6	22.3	22.0
90	21.7	21.4	21.1	20.8	20.5	20.1	19.5	18.8	18.2	17.0
100	15.3									

Daily Flood Flows(m^3/s)		**7 Day Low Flow (m^3/s)**	
Mean Annual	648	Annual	17.6
1:5	890	1:5	16.3
1:10	1080	1:10	15.6
1:20	1260		
1:50	1500		
1:100	1680		
1:200	1860		
1:500	2090		
1:1000	2270		

Ratio of instantaneous to daily flood peaks 1979-2015: 1.561

Rangitata downstream of all takes - Proposed

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
60.0	42.6	15.3	17.6	26.4	74.8	995	8.4	6.6	4.0

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1354.5	315.0	237.5	199.4	172.6	152.5	138.1	126.3	116.9	108.7
10	101.6	95.8	90.7	87.0	84.0	82.2	81.6	81.1	80.5	79.9
20	79.4	78.9	78.4	77.5	76.2	74.8	73.3	71.8	70.3	68.8
30	67.4	66.0	64.5	63.1	61.7	60.3	58.9	57.6	56.4	55.2
40	54.0	52.8	51.6	50.4	49.2	48.1	47.0	45.9	44.8	43.7
50	42.6	41.5	40.5	39.5	38.5	37.5	36.6	35.7	34.8	34.0
60	33.3	32.5	32.0	31.6	31.2	30.8	30.5	30.1	29.8	29.4
70	28.9	28.4	27.8	27.2	26.8	26.4	26.1	25.8	25.5	25.2
80	24.9	24.6	24.3	24.0	23.7	23.4	23.0	22.6	22.3	22.0
90	21.7	21.4	21.1	20.8	20.5	20.1	19.5	18.8	18.2	17.0
100	15.3									

Daily Flood Flows(m^3/s)	
Mean Annual	638
1:5	880
1:10	1070
1:20	1250
1:50	1490
1:100	1670
1:200	1850
1:500	2080
1:1000	2260

7 Day Low Flow (m^3/s)	
Annual	17.6
1:5	16.3
1:10	15.6

Ratio of instantaneous to daily flood peaks 1979-2015: 1.561

Rangitata downstream of all takes - 1:1 flow share

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
60.1	42.6	15.3	17.6	26.4	74.8	995	8.4	6.6	4.0

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1354.5	315.0	237.5	199.4	172.6	152.6	138.2	126.4	117.0	108.9
10	101.9	96.2	91.3	87.7	85.3	83.4	82.2	81.6	81.1	80.5
20	79.9	79.2	78.5	77.6	76.3	74.8	73.4	71.9	70.4	68.8
30	67.4	66.0	64.5	63.1	61.7	60.3	58.9	57.6	56.4	55.2
40	54.0	52.8	51.6	50.4	49.2	48.1	47.0	45.9	44.8	43.7
50	42.6	41.5	40.5	39.5	38.5	37.5	36.6	35.7	34.8	34.0
60	33.3	32.5	32.0	31.6	31.2	30.8	30.5	30.1	29.8	29.4
70	28.9	28.4	27.8	27.2	26.8	26.4	26.1	25.8	25.5	25.2
80	24.9	24.6	24.3	24.0	23.7	23.4	23.0	22.6	22.3	22.0
90	21.7	21.4	21.1	20.8	20.5	20.1	19.5	18.8	18.2	17.0
100	15.3									

Daily Flood Flows(m^3/s)

Mean Annual	638
1:5	880
1:10	1070
1:20	1250
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1:100	1670
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1:1000	2260

7 Day Low Flow (m^3/s)

Annual	17.6
1:5	16.3
1:10	15.6

Ratio of instantaneous to daily flood peaks 1979-2015: 1.561

Rangitata downstream of all takes - Recession & 1:1 flow share

Flow statistics

flow (m^3/s)									
Mean	Median	Minimum	7 Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood **	FRE1.5	FRE2	FRE3
60.9	42.6	15.3	17.6	26.4	75.1	1011	9.2	7.0	4.3

** Instantaneous flood

Flow Duration

% time flow (m^3/s) exceeded

	0	1	2	3	4	5	6	7	8	9
0	1364.5	321.9	243.8	205.6	178.5	158.5	143.4	131.8	122.1	113.5
10	106.5	100.5	95.4	91.1	87.7	85.0	83.0	82.1	81.5	80.9
20	80.3	79.5	78.8	77.8	76.5	75.1	73.5	72.0	70.5	69.0
30	67.5	66.1	64.6	63.2	61.8	60.4	59.0	57.7	56.5	55.3
40	54.1	52.8	51.6	50.4	49.3	48.1	47.0	45.9	44.8	43.7
50	42.6	41.5	40.5	39.5	38.5	37.5	36.6	35.7	34.8	34.0
60	33.2	32.5	32.0	31.6	31.2	30.8	30.5	30.1	29.8	29.4
70	28.9	28.4	27.8	27.2	26.8	26.4	26.1	25.8	25.5	25.2
80	24.9	24.6	24.3	24.0	23.7	23.4	23.0	22.6	22.3	22.0
90	21.7	21.4	21.1	20.8	20.5	20.1	19.5	18.8	18.2	17.0
100	15.3									

Daily Flood Flows(m^3/s)

Mean Annual	648
1:5	890
1:10	1080
1:20	1260
1:50	1500
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7 Day Low Flow (m^3/s)

Annual	17.6
1:5	16.3
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Ratio of instantaneous to daily flood peaks 1979-2015: 1.561