NIWA
Taihoro Nukurangi

Addendum to: Ecological effects of Waikanae Water Treatment Plant abstraction

Prepared for Kāpiti Coast District Council

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1 Background

The Kāpiti Coast District Council (KCDC) holds a Resource Consent (WGN050024[23848]) to take water from the Waikanae River at the Waikanae Water Treatment Plant (WTP) for Waikanae-Paraparaumu-Raumati community public water supply. This was granted in July 2005 to allow run-of-river abstraction, ensuring the river did not fall below a minimum flow of 750 L s^{-1}. During periods of low river flow, supplementary water for public supply is obtained from a borefield, which came online in November 2005. Suren and Duncan (2011) reviewed hydrological and ecological information collected from the Waikanae River to determine whether extraction of water by the WTP was having a demonstrable effect on algal and invertebrate communities within the river.

They assessed differences in ecologically relevant flow indices above and below the WTP, and assessed differences in algal biomass, and invertebrate communities above and below the WTP. They found no significant differences in flow parameters above and below the WTP. While chlorophyll biomass was higher below the WTP, they found little evidence that this was a result of abstraction, but more likely to be attributed to nutrient inputs from agricultural land-use within the catchment and more sunlight exposure at the lower Waikanae River sampling site. They found no relationship between flow and chlorophyll biomass, either above or below the WTP. They also found no relationships between variation in hydrology and invertebrate communities above and below the WTP, suggesting that there was no direct link between invertebrate communities and flow regimes at either location.

This report was reviewed by the Greater Wellington Regional Council (GWRC), who raised concerns about the statistical approach in comparing flow indices above and below the WTP. In particular, one of the concerns was "the naturally high year-to-year variation in low flow management renders all results non-significant, yet there is clearly a quantifiable and predictable effect of removal of water…. I think comparative numbers for specific flow recessions would be a better representation of actual change 'per event'" (CH2M Beca Memorandum, 25 Sept 2012).

Although hydrological flow statistics can be analysed over discrete time periods (for example year-to-year, season to season, or low flow event to low flow event), there is little ecological relevance in conducting such a discreet analysis. Biological communities within a river reflect overall processes operating within a river potentially over a much longer time frame than a specific time period chosen for a hydrological analysis. Biological communities are monitored because they act as integrators of antecedent conditions within the river (Biggs 2000; Boothroyd and Stark 2000; Rosenberg and Resh 1993). Thus, the presence of a particular algal or invertebrate community within a river is a reflection of more long-term conditions rather than an arbitrarily chosen time period for hydrological analyses. The question posed in Suren and Duncan (2011) was thus "has the long-term abstraction for the WTP resulted in overall changes to algal and invertebrate communities of the river?", and not "does abstraction for the WTP during specific flow recessions affect algal and invertebrate communities?"

Flow data between 2004 and 2010 were analysed to include antecedent river flow for the ecological analyses, and initial examination of the abstraction data showed that 7% of the record contained zero values (Suren and Duncan, 2011). Although some zero values in the abstraction record were likely to be real (e.g. due to the main water treatment plant shutting down temporarily for several hours at a time, or when groundwater was used to supply water to the WTP instead of river water), the record also included zero values that did not fit these scenarios. A precautionary approach was taken and zero values that appeared artificial were replaced with the default mean abstraction rate of 161 L s^{-1} before analysis of the hydrological data (Suren and Duncan 2011). After a further review of Suren and Duncan (2011) by CH2M Beca and NIWA, following the review by GWRC, the hydrological analysis was repeated using the original abstraction record (i.e. including all zero abstraction values). The aim of this additional analysis was to investigate if ecologically relevant flow indices would be significantly different upstream and downstream of the WTP when the original unmodified abstraction record was analysed. A further aim in this addendum was to correct some minor errors within the summary flow indices table that were found during the review process.

2 Reanalysis of hydrological data

The method for reanalysis of the hydrological data follows that described in Suren and Duncan (2011). The ecologically relevant flow indices used in both analyses are shown in Table 2-1. Briefly, low flow indices were calculated as 'water years' from 1 July to 30 June, to encompass the summer and autumn when low-flows predominate. High flow indices were calculated from 1 January to 31 December, to encompass winter high flows. These statistics were calculated for both the flow above the WTP, and for the derived flow below.

Table 2-1: List of flow indices calculated from the hydrological monitoring station above the WTP. The same statistics were also derived for flows below the WTP, based on the natural flow record minus the recorded abstraction rates.

Type of flow index	Name	Abbreviation	Description
Flow	Max flow	Qmax	The maximum instantaneous flow
	Mean flow	Qmean	The mean annual flow (Jan – Dec)
	Median Flow	Q_{50}	The median annual flow (Jan – Dec)
Flood Frequency	FRE3 (floods/y)	FRE3	Number of floods > 3 × median flow per year
Low Flow Magnitude	7day MALF	MALF	The lowest mean 7-day annual low flow period
	Lower quartile	Q_{25}	Flows that are exceeded 75% of the time
	Lowest inst. flow	LowQ_Inst	The minimum instantaneous flow
Low Flow Duration	Ave duration <7d MALF	Dur_MALF	Average duration of flows less than the 7 day MALF
	Ave duration in lower quartile	Dur_{25}	Average duration of flows less than flows that are exceeded 75% of the time
	Max duration (days)	DurMALF_max	Maximum duration of a low flow event less than the 7 day MALF
	Max duration (days)	Dur_{25}_max	Maximum duration of a low flow event less than flows that are exceeded 75% of the time

Reanalysis of the hydrological data showed that the average abstraction rate after reanalysis was 161 L s^{-1} (compared with 166 L s^{-1} reported in Suren and Duncan (2011)). Otherwise, trends in monthly abstraction and percentage abstraction were similar for both analyses (Figure 2-1). Year-to-year variation and percentage of flow abstracted were also similar for the two analyses (Figure 2-2), as was the average abstraction rate (approximately 7% for both analyses).

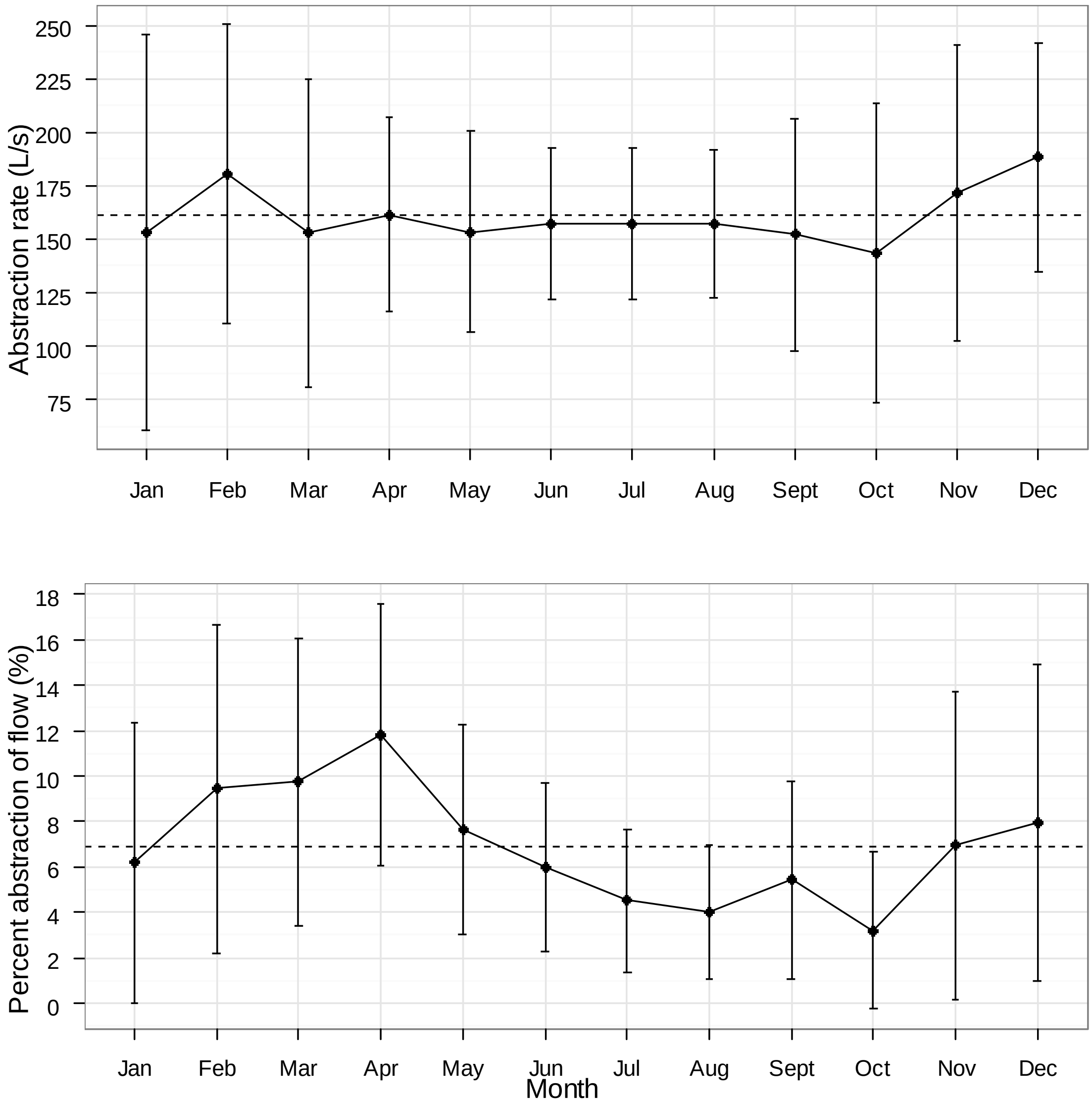

Figure 2-1: Monthly abstraction rate (L s^{-1}) and percentage abstraction of flow from the Waikanae River (mean + 1 sd). Dashed line shows average abstraction rate and percent of abstracted flow for the period between 2004 and 2010.

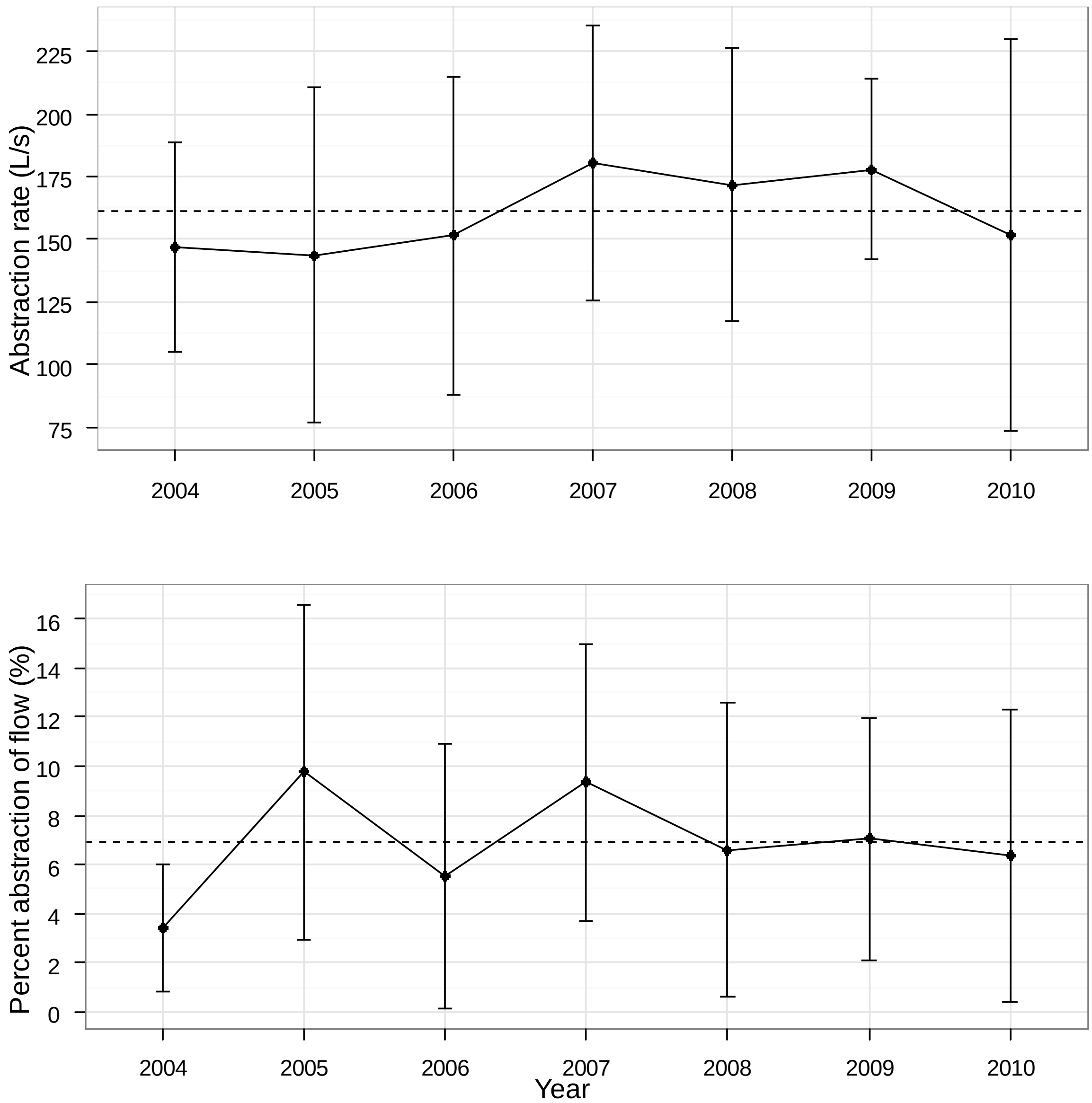

Figure 2-2: Annual abstraction rate (L s^{-1}) and percentage abstraction of flow from the Waikanae River (mean + 1 sd). Dashed line shows average abstraction rate and percent of abstracted flow for the period between 2004 and 2010.

Calculation of percentage differences above and below the WTP showed that seven of the eleven indices differed by 10% or less. The greatest difference (approx. 70%) occurred for the average duration of flows below the MALF (Dur_MALF), which was higher below the WTP. The 7d-MALF used for this comparison was 1040 L s^{-1} which was the 7d-MALF for the whole record (1975 to 2011) from the Waikanae River at Water Treatment site. This is 18% greater than the 878 L s^{-1} 7d-MALF from the same site for the period of record being compared (2004 to 2010). Thus the durations in Table 2-2 are longer than would be expected from both sites in the long term. The statistic is the average total duration per year (days) that flows are less than 1040 L s^{-1}. This duration is longer at the downstream site for two reasons:

- When the flows from both sites fall to less than 1040 L s^{-1} the downstream site is the first to fall below 1040 L s^{-1} because of the abstraction. The time of the end of the low flow period is usually the same for both sites when a fresh increases flows at both sites to above 1040 L s^{-1}.
- For some low flow periods the flows at the upstream site stay just above 1040 L s^{-1} and flows from the downstream sites are just below 1040 L s^{-1}.

These points are illustrated in Figure 2-3 that shows hydrographs upstream and downstream of the abstraction point for 2005 which had the longest duration of flows less than 1040 L s^{-1}. No statistically significant changes were observed for any of the calculated flow indices described in Table 2-1 and listed in Table 2-2.

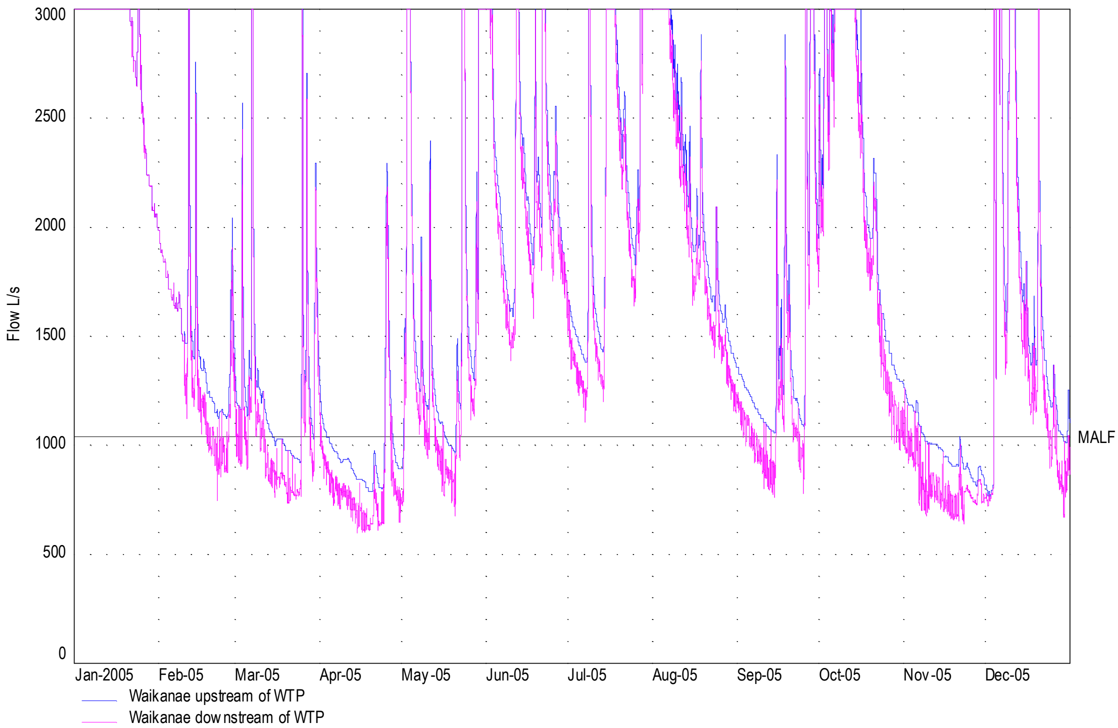

Figure 2-3: Hydrograph for the Waikanae River upstream and downstream of the WTP abstraction point. The black horizontal line is at the long term 7d-MALF of 1040 L s^{-1}.

Table 2-2: Summary of mean flow indices calculated from the 7-year flow period (2004-2010) above and below the WTP using the unmodified abstraction data. The percentage difference of calculated indices, as well as the results of t-tests (degrees of freedom = 12) between flows above and below the WTP, is also shown.

Type of flow statistic	Abbreviation	Above WTP	Below WTP	% Difference	T-test, *p*-value
Flow	Qmax (L s-1)	192,545	192,447	-0.05	t = 0.002, *p* = 0.999
	Qmean (L s-1)	5,597	5,436	-2.88	t = 0.159, *p* = 0.876
	Q50 (L s-1)	3,064	2,894	-5.56	t = 0.264, *p* = 0.796
Flood Frequency	FRE3 (no. per year)	12	11.6	-3.44	t = 0.208, *p* = 0.838
Low Flow Magnitude	MALF (L s-1)	968	842	-13.00	t = 0.949, *p* = 0.362
	Q25 (L s-1)	1,780	1,604	-9.86	t = 0.594, *p* = 0.564
	LowQ_Inst (L s-1)	923	762	-17.45	t = 1.326, *p* = 0.211
Low Flow Duration	Dur_MALF (days)	23.2	40.0	72.75	t = -1.251, *p* = 0.235
	Dur25 (days)	111.2	119	6.83	t = -0.246, *p* = 0.810
	DurMALF_max (days)	11.3	13.4	19.14	t = -0.448, *p* = 0.662
	Dur25_max (days)	23.4	24.1	3.24	t = -0.133, *p* = 0.897

A point to note is that percentage differences reported in Suren and Duncan (2011) are incorrect. The corrected figures are shown in Table 2-3.

Table 2-3: Summary of mean flow indices calculated from the 7-year flow period (2004-2010) above and below the WTP using modified abstraction data with corrected percentage difference values. Corrected table from Suren and Duncan (2011).

Type of flow statistic	Abbreviation	Above WTP	Below WTP	% Difference	T-test, *p*-value
Flow	Qmax (L s^{-1})	192,545	192,401	-0.07	t = 0.003; *p* = 0.998
	Qmean (L s^{-1})	5,597	5,424	-3.10	t = 0.171; *p* = 0.867
	Q_{50} (L s^{-1})	3,064	2,889	-5.72	t = 0.272; *p* = 0.791
Flood Frequency	FRE3 (no. per year)	12.03	11.61	-3.44	t = 0.208; *p* = 0.838
Low Flow Magnitude	MALF (L s^{-1})	968	798	-17.52	t = 1.215; *p* = 0.248
	Q_{25} (L s^{-1})	1,780	1,597	-10.26	t = 0.619; *p* = 0.548
	LowQ_Inst (L s^{-1})	923	734	-20.48	t = 1.489; *p* = 0.163
Low Flow Duration	Dur_MALF (days)	23.2	42.2	82.25	t = -1.377; *p* = 0.194
	Dur_{25} (days)	111.2	121	9.08	t = -0.325; *p* = 0.751
	DurMALF_max (days)	11.3	14.3	27.05	t = -0.622; *p* = 0.545
	Dur_{25}_max (days)	23.4	25.0	6.71	t = -0.283; *p* = 0.782

The NMDS ordination of flow indices showed similar spread and variation as described in Suren and Duncan (2011), where greater yearly variation in flow indices is observed, but smaller differences above or below the WTP (Figure 2-4). Results of the ANOSIM were also similar to that reported in Suren and Duncan (2011) with significant differences in flow indices over time (R = 0.946, *p* = 0.001), but no differences in flow indices above and below the WTP (R = -0.011, *p* = 0.907).

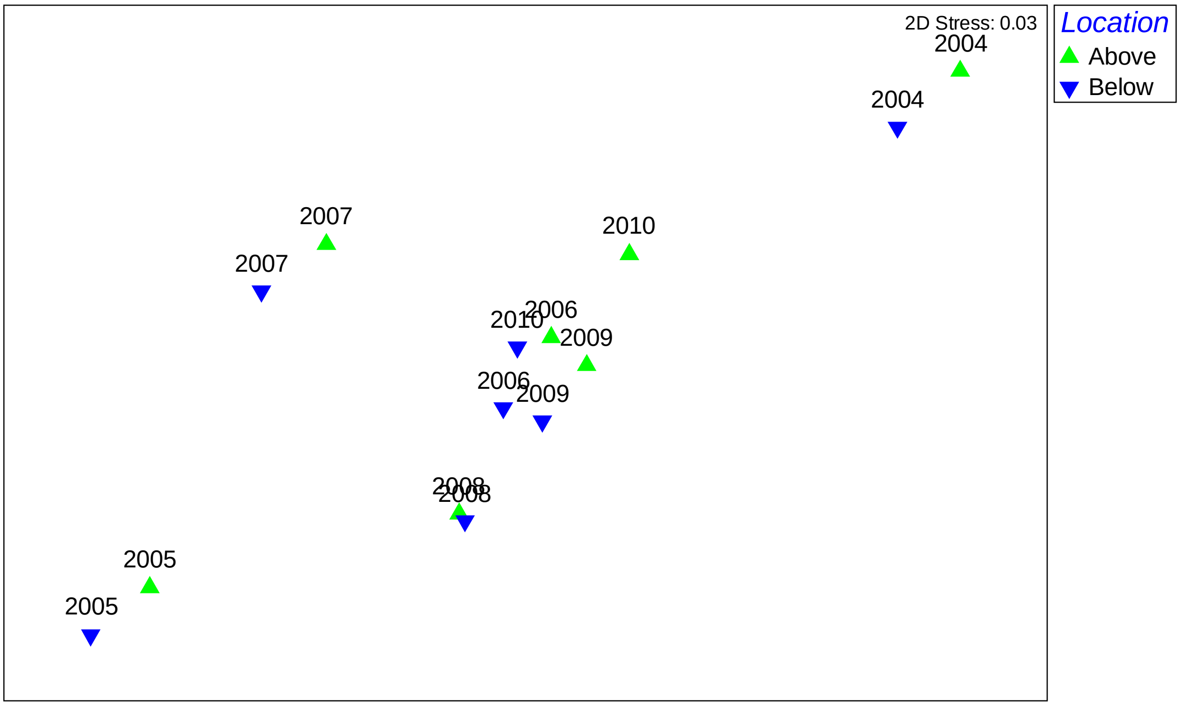

Figure 2-4: NMDS ordination of flow data from the Waikanae River above and below the WTP. Note the generally small difference between the two locations, but the large year-to-year variation.

Along with effects on flow indices, algal biomass and invertebrate communities, Suren and Duncan (2011) also discussed the possible effects of low flows on fish communities. They reported the number of days when river flow was less than 750 Ls^{-1} for a 12 hour period or more (this period thought to be long enough to exert potentially adverse effects on fish). Following the same procedure as described in the 2011 report, and using the unmodified abstraction data, the number of days fitting this criteria was the same or less than that reported in Suren and Duncan (2011) (Table 2-4).

Table 2-4: Number of days where flow was less than 750 Ls^{-1}s for a consecutive 12 hour period or more, showing comparison between modified and unmodified abstraction record. Analysis is based on the flow hydrograph from 1 January 2004 to 31 December 2010. * indicates period prior to consent for water abstraction being granted.

Year	Month	No. days flow < 750 Ls^{-1} for 12 hours or more	
		Modified abstraction record (Suren and Duncan, 2011)	Unmodified abstraction record
2005	March*	1	0
	April*	12	9
	November	6	4
	December	1	0
2006	January	5	3
2008	January	3	3
	February	6	6
	March	11	11

In conclusion, this analysis was carried out after external and further internal review comments, and where the objective was to investigate if using the unmodified abstraction record changed the findings reported in Suren and Duncan (2011) where a modified abstraction record was used. We also wanted to correct the errors found within the percentage difference data (presented in Table 2-3). We found that the monthly and yearly trends in water abstraction were similar for both the modified and unmodified abstraction data, as was the average abstraction rate. Although the flow indices above and below the WTP were also similar for both datasets, further assessment of the mean annual low flow duration (Dur_MALF) was conducted in this analysis. We show that the duration of flows below the long-term MALF (1040 L s^{-1}) is longer below the WTP than above, either because of abstraction or because of flow levels remaining just above 1040 L s^{-1} above the WTP, and just below 1040 L s^{-1} below the water abstraction point.

Minimum flows are set to provide flow conditions that maintain the biota at a particular level with the belief that any changes downstream of the abstraction will be minor. Thus the emphasis in assessing the effects of abstraction should be on the biological effects rather than the hydrological effects.

3 References

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