Before the Hearings Commissioners

at Christchurch

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in the matter of:	a submission on the proposed Hurunui and Waiau River Regional Plan and Plan Change 3 to the Natural Resources Regional Plan under the Resource Management Act 1991
to:	**Environment Canterbury**
submitter:	**Meridian Energy Limited**

Statement of evidence of Steven Woods

Dated: 12 October 2012

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CHAPMAN TRIPP

1. QUALIFICATIONS AND EXPERIENCE

1.1 My Name is Steven Woods. I am employed as a Civil Engineer in the Christchurch office of MWH New Zealand Limited, and have been engaged by Meridian Energy Limited ("Meridian") to provide Hydrology and Engineering evidence. I have approximately fourteen years of experience. I am a Chartered Professional Engineer in the Geotechnical and Civil practice areas, a Member of the Institute of Professional Engineers New Zealand and a Category A Recognised (Dam Safety) Engineer.

1.2 The evidence I will present today is within my area of expertise, except where I state that I am relying on information provided by another party. My expertise in hydrology includes assessment of available abstractions for irrigation and hydropower purposes on the Waiau, Hurunui, Rangitata and Rakaia Rivers, modelling of minewater management by routing of recorded flows through storage reservoirs and supervision of hydrological assessments of available flow and flood flows for dam design projects.

1.3 My involvement in the Amuri Hydro Project has been to supervise a description of the baseline hydrologic characteristics of the Waiau River, provide conceptual advice on the engineering of a potential hydro scheme (the Amuri Hydro Project) and supervise an assessment of the water available for abstraction for hydropower purposes and therefore the remaining water in the river. This evidence summarises the results of the MWH letter report titled Amuri Hydro Project – Hydrology Summary and dated 2 November 2011.

1.4 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2011. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted material facts known to me that might alter or detract from the opinions expressed.

2. SCOPE OF EVIDENCE

2.1 I have been asked by Meridian to prepare evidence in relation to:

- The natural hydrology of the Waiau catchment and the impact of current takes for irrigation.
- The methodology adopted to estimate the impact that the Amuri Hydro Project (AHP) would have on the Waiau River flows.
- The effects of the AHP on the Waiau River flow regime (from the scheme inlet to its outlet).
- To infer from this the effects of implementing the proposed environmental flow and allocation regime for the Waiau River.

2.2 As modelled the AHP complies with the Environmental Flow and Allocation Regime in the Proposed Hurunui Waiau River Regional Plan ("the Proposed Plan") for the Waiau River, except for the 2 m^3/s "gap" proposed between the "A" and "B" allocation blocks which has not been provided for in the modelling. The effect of not modelling the 2 m^3/s gap is to slightly increase the amount of water that the AHP is modelled to abstract from the river. In my opinion the difference in the amount of water abstracted by the AHP from the river with and without the 2 m^3/s gap between the B and C blocks would be very small relative to the overall volume of water abstraction modelled. I also note that the modelled AHP is based on a maximum generation flow of 50 m^3/s and therefore does not represent the maximum scheme size that could be developed if the scheme was sized to use the full C Block allocation as well as the A and B blocks when not used for irrigation. However, I am of the opinion that a generation flow of 50 m^3/s represents the economic upper limit for hydropower development under the Proposed Plan, as the additional generation potential associated with constructing a larger scheme (that can be operated at its full capacity for a shorter period of time compared to a 50 m^3/s scheme) would not be sufficient to overcome the additional cost. Therefore, I consider the findings from the assessment of hydrological effects of operating the AHP to be equivalent to the effects of fully implementing the allocation regime in the Proposed Plan. For this reason I consider that the assessment of hydrological effects carried out for the AHP can be used to assess the effects of the flow regime (based on the provision of at least 20 million cubic metres of storage) in the Proposed Plan. I note also that the modelling undertaken takes into account all existing known abstractions, and likely future irrigation abstractions.

3. SUMMARY OF EVIDENCE

3.1 The natural characteristics of the Waiau River are for variable mean monthly flows throughout the year. The trend is for the lowest flows to occur during February, March and April with the highest flows in October and November.

3.2 Current river abstraction rules reflect the natural variability in flows by assigning variable minimum flows by month throughout the year. The river minimum monthly flows upon which abstraction is currently based on are lowest in February and March and highest between May and December.

3.3 The modelled Amuri Hydro Project (AHP) abstraction utilises flow rules that are very close to the Environmental Flow and Allocation Regime proposed by the Plan for the Waiau River. The difference is very small and models a slightly higher water abstraction than allowed for in the plan, i.e. slightly overestimates the impact of the AHP on the river flows.

3.4 The modelled AHP will affect a stretch of river 29km long before water is returned to the river.

3.5 The modelled proposal has limited effect on the lowest flows in the river compared to current irrigation abstraction but has a larger effect on mid range flows by increasing the proportion of time that the river flow is at the monthly minimum level (20 m^3/s as proposed by the Plan). This is illustrated by a reduction in the estimated median flow (i.e. flow exceeded 50% of the time) of 66 m^3/s under current irrigation abstraction to 20 m^3/s under the modelled AHP proposal.

3.6 The modelled proposal has limited effect on flood flows in the river as it has been assumed that the AHP would not operate in Waiau River flows above 200 m^3/s, as measured at the Marble Point Flow recorder. Meridian propose to shut down the scheme at a flow of about 210 m^3/s, so this reflects probable operating practise.

4. HYDROLOGY OF THE WAIAU RIVER

4.1 The Waiau catchment is bounded on the north by the Clarence and Conway catchments and on the south by the Hurunui catchment. The river flows southward from its source in the Main Divide to its confluence with the Hope River, where it turns sharply to flow in an easterly direction. It crosses the southern edge of the Hanmer Plain and then flows south through the Marble Point Gorge to emerge onto the Emu and Amuri Plains. It then generally flows east and passes through two more gorges, separated by a plain west of Parnassus, before reaching the sea.

4.2 The river is generally confined within a single channel between the Waiau River and Hope River confluence and the Hanmer Plain, and through the upper, middle and lower gorges. In contrast, where the river is adjacent to the Hanmer, Emu and Amuri Plains, and the plain immediately west of Parnassus, it is braided and runs in a series of river channels with an overall width varying between approximately 500 m and 2 km.

4.3 The Waiau River flows some 167 km from its source in the Spencer Range to the sea. The total catchment area of approximately 3,300[1] square kilometres has three distinctive regions; the steep headwaters from the Spencer Range to Hanmer (approximately 50% of the catchment area), the rolling hills downstream of Hanmer (approximately 40%), and the flat land on the Hanmer, Emu and Amuri Plains (approximately 10%).

4.4 There are a number of existing and historic water level and flow recording sites on the Waiau River. Two sites are operated and flow rated by Environment Canterbury; these provide a good basis for estimating mean river flows at potential hydropower sites on the river and assessing possible water allocation regimes. These are located at Marble Point and the river mouth. The characteristics for both sites are summarised in Table 4.1.

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[1] Catchment at river mouth as listed in “Index to Hydrological Recording Sites in New Zealand”, NIWA Technical Report 73, 2000

Table 4.1 – Characteristics of Water Level and Flow Recording Sites[2]

Site Number	Site Name	Catchment Area (km^2)	Period of Record	Mean River Flow (m^3/s)	Specific Mean Yield ($l/s/km^2$)
64602	Waiau at Marble Point	1,980	4/10/67 and ongoing	97	49.1
64609	Waiau at Mouth	3,297	30/11/73 to 17/8/95	112	33.8

4.5 Figure 4.1 presents the mean monthly variation of flow for both sites. The minimum, mean and maximum monthly mean flows are plotted. The trend is for the lowest flows to occur during February, March and April with the highest flows in October and November.

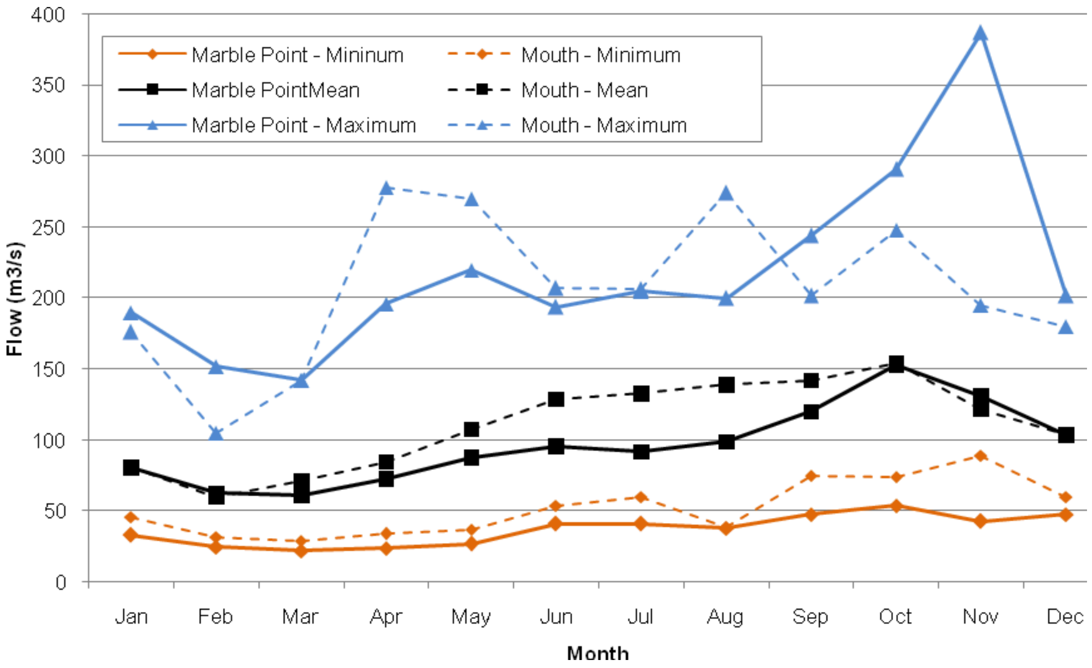

Figure 4.1 – Waiau at Marble Point & Mouth – Minimum, Maximum and Mean Monthly Mean Flows

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[2] As listed in "Index to Hydrological Recording Sites in New Zealand", NIWA Technical Report 73, 2000 (and subsequent electronic updates)

4.6 Currently abstraction on the Waiau River is administered by Environment Canterbury under the 1975 Waiau River Management and Allocation Plan. CPG New Zealand Ltd consultants[3] note that 97.9% of the existing consents utilise the minimum flow regime set out in this plan. The minimum flows specified in the plan are:

- January -20 m^3/s
- Feb, March – 15 m^3/s
- April – 20 m^3/s
- May to December – 25 m^3/s

As well as specifying minimum flows the 1975 plan also set out that in the months October to March, the flow in the Waiau River shall not be reduced by abstraction to less than 60% of the natural flow at Marble Point or to [minimum flow for relevant month], whichever is greater.

4.7 CPG New Zealand Ltd[3] investigated irrigation on the Waiau River in detail. They concluded that:

- A total of 17.1 m^3/s is allocated to irrigation, close to the 18 m^3/s total allowed for under the 1975 Waiau River Management and Allocation Plan.
- Of the total irrigation allocation 2.2 m^3/s is located below the discharge point of the Amuri Hydro Proposal. Therefore most of the allocated water is allocated along the Amuri plains reach and cannot be used for generation if required for irrigation.

Based on the study findings CPG produced a generalised irrigation profile which is summarised in the following Table 4.3. The table also shows the proportion of irrigation water that is required upstream of the proposed Amuri Hydro discharge point. A hydropower scheme could not use this water for generation, however, it could use the remainder of the water allocated to irrigation as the water would be returned to the river before being required by irrigators.

[3] CPG New Zealand Ltd, "Waiau River Flow Regime Review- Study Findings Report", November 2009.

Table 4.3 – Summary of irrigation demand

Month	Irrigation Demand (m^3/s)	Irrigation demand upstream of Amuri Hydro discharge point (m^3/s)
Jan	16.7	14.5
Feb	16.7	14.5
Mar	14.9	12.9
April	8.6	7.4
May	2.7	2.3
June	0.4	0.3
July	0.4	0.3
Aug	0.4	0.3
Sept	7.7	6.7
Oct	11.7	10.1
Nov	15.4	13.3
Dec	16.1	13.9

4.8 The Amuri (Waiau) Irrigation Company Scheme is by far the largest single user of water from the Waiau. Their main irrigation scheme takes up to 11 m^3/s of water from the true right bank downstream of Manuka Island i.e. approximately two thirds of the total current allocation of water from the Waiau River.

5. ASSESSMENT METHODOLOGY

5.1 Our hydrology model has been developed using data collected by ECan at the Marble Point monitoring site between 7 October 1967 and 7 September 2009. The location of the hydro scheme in relation to the Marble Point recorder is shown on Figure. 5.1

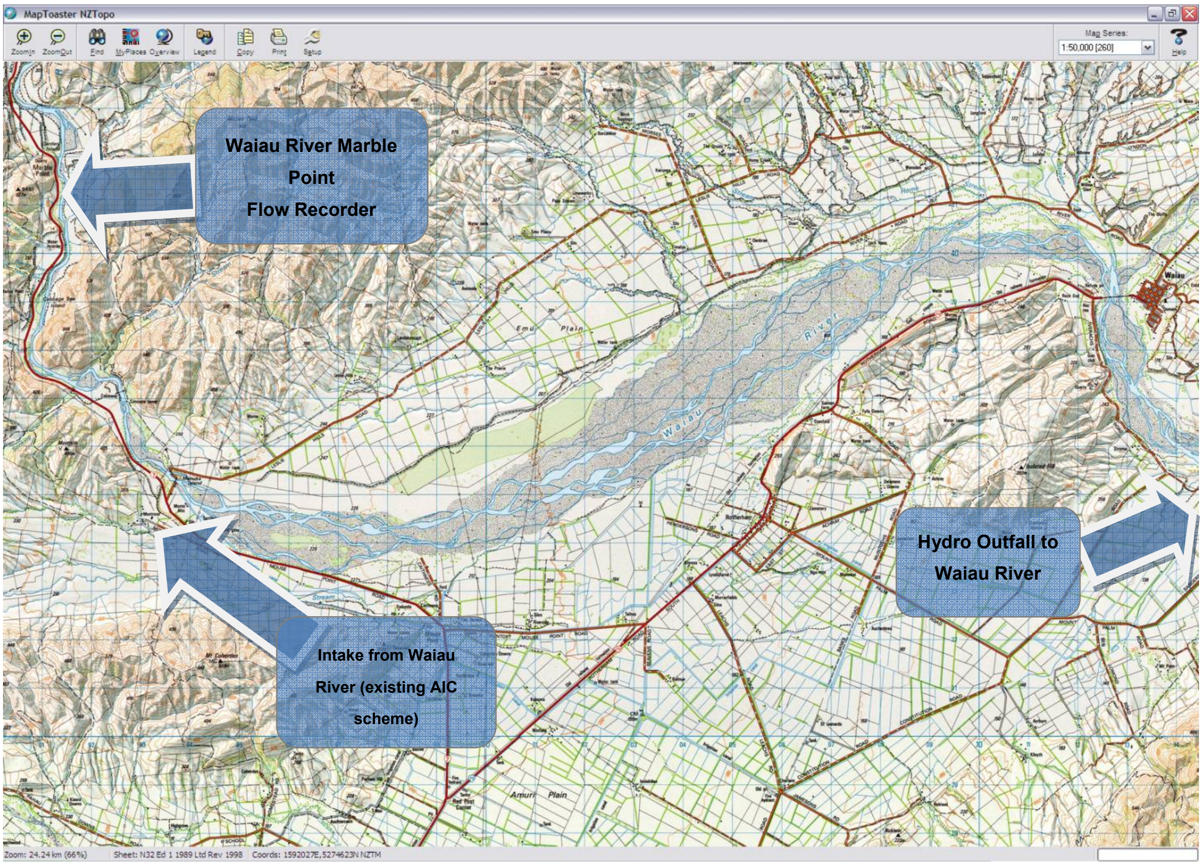

Figure 5.1 – Key Waiau River Locations for Hydrology Assessments

5.2 Key assumptions made in the model are:

- Natural river flows are those provided by the flow recorder at Marble Point (site 64602).
- The flow record is from 7 October 1967 to 7 September 2009 and is the mean daily flow in cubic metres per second (m^3/s).
- All modelled flows are calculated on a daily basis.
- The intake for the flow abstraction hydropower is at about the existing intake structure for the Amuri Irrigation Company (AIC) Waiau scheme (right bank adjacent to Manuka Island at the 'twin bridges' on Leslie Hills Road).

- The outfall back into the Waiau River for the proposed hydropower scheme is on the right bank and downstream of the Waiau Township but upstream of the Stanton River confluence. The maximum length of river that will be affected by the proposed hydropower scheme is 29km.
- No losses to groundwater have been included in the flow model within the reach.
- No tributary inflows have been included in the flow model within the reach.

5.3 The hydrology model was developed with the following assumptions regarding future water allocation on the Waiau River.

- A minimum Waiau River flow of 20 m^3/s for all months is to be applied.
- An 'A Block' of up to 18 m^3/s is essentially fully allocated to current irrigation. The 'A' Block is the highest priority water for river users.
- A maximum 'A' Block demand of 14.5 m^3/s is upstream of the hydro outfall (i.e. up to 14.5 m^3/s of the 'A' Block is abstracted for irrigation). The remainder of the 'A' Block demand is downstream of the outfall.
- A 'B Block' of up to 11 m^3/s is for future irrigation demand. B Block water is only available once the full A Block allocation is available.
- A maximum B Block demand of 6 m^3/s is assumed upstream of the hydro outfall, with 5 m^3/s downstream of the outfall.
- A 'C Block' of up to 42 m^3/s is for future hydropower. C Block water is only available once the full A and B Block flows are available. We have assumed that there is no gap between the B and C blocks.
- Up to 3.5 m^3/s of the 'A' Block and 5 m^3/s of the 'B' Block can also be abstracted for hydro (i.e. the current or assumed future irrigation demand is downstream of the hydro outfall so can be abstracted, used for hydro, and returned to the river).
- Any available water from the 'A' or 'B' Blocks which is not taken (demanded) for irrigation is assumed available to be taken for hydro, i.e. irrigation usage has priority over hydropower.
- A maximum hydro generation take of 50 m^3/s has been used.
- If the river flow is greater than 200 m^3/s, then no water is taken for hydro generation purposes.

- The assessment is on a 'run of river' basis with no in scheme storage assumed i.e. the flow into the scheme for hydropower purposes is the flow discharged by the scheme.

5.4 The model assumes a variable monthly irrigation demand upstream of the Amuri Hydro proposed outfall as shown in Figure 5.2. The 'A' Block demand series has been developed from the historical analysis by CPG New Zealand Ltd[4]. The 'B' block demand has been scaled to a maximum of 6 m³/s from the A Block demand.

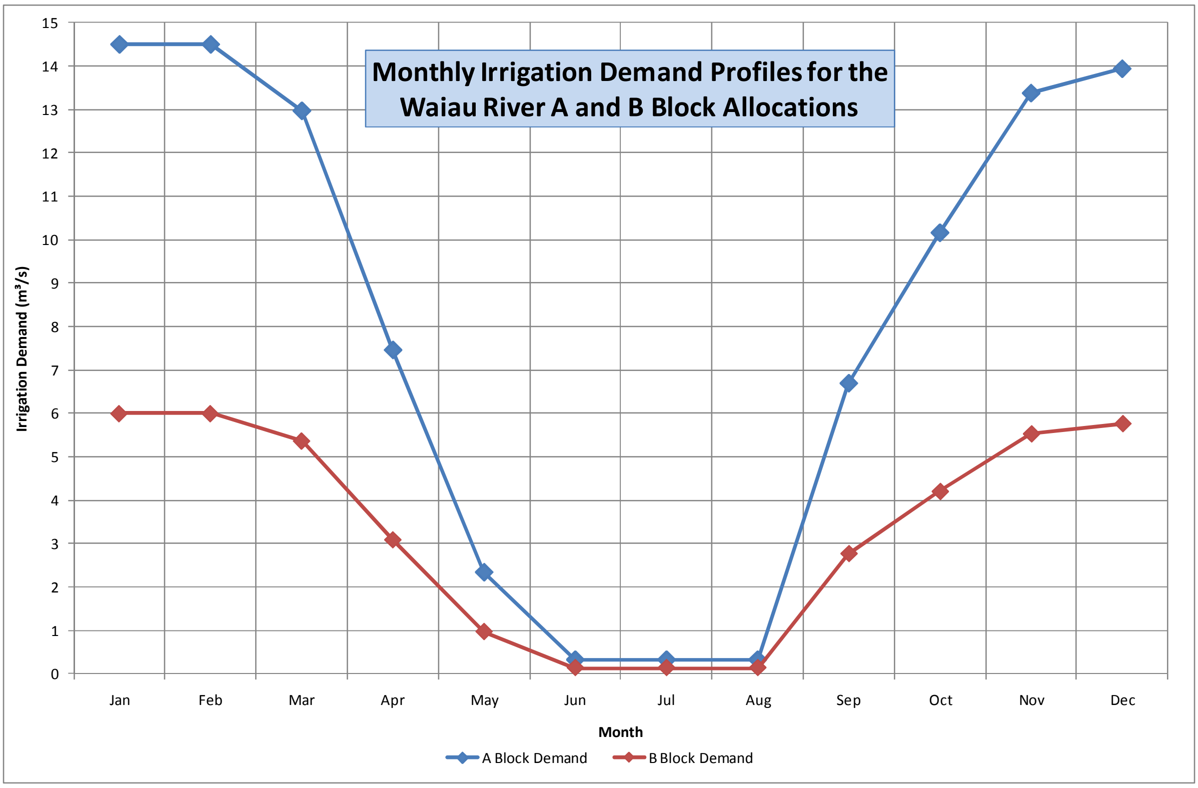

Figure 5.2 – Monthly Irrigation Demand Profiles for A and B Blocks (upstream of Amuri Hydro Outfall)

5.5 The model presents results for four different scenarios, namely:

- Natural Flow – taken as the flow at the Marble Point recorder.
- Status Quo - uses the current Waiau River minimum flow rules and the current estimated irrigation demand along the Amuri Plains Reach ('A' Block only), i.e. the blue line in Figure 5.2.

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[4] CPG New Zealand Ltd, "Waiau River Flow Regime Review- Study Findings Report", November 2009.

- Modelled Full Irrigation Development – uses the proposed 'A' and 'B' Block flow allocation rules on the Waiau River and the 'A' and 'B' Block irrigation demand profiles presented in Figure 5.2.
- Modelled Proposal – as for the modelled full irrigation development series with the additional abstraction of up to 50 m^3/s of water for hydro generation purposes (under the proposed AHP) taken from the 'C' Block, and from the 'A' & 'B' Blocks when these are not required for irrigation.

6. MODELLING SUMMARY

6.1 A summary of the results of the analysis are presented in Table 6.1. This table shows the effects of the different flow regimes on a number of widely used flow statistics. As expected the effect of increasing abstraction from the river (from left to right across the table) is to increase the percentage of time that the river is at lower flows as illustrated by the reducing mean, median, mean annual minimum, 25th and 75th percentile flows.

Table 6.1 – Summary of key river statistics from hydrology modelling (Waiau River)

STATISTIC	NATURAL FLOW	STATUS QUO	MODELLED FULL IRRIGATION DEVELOPMENT	MODELLED PROPOSAL
Minimum	20	15.0	20	20
Mean	96.8	88.9	86.0	55.1
Median	73.0	66.4	63.9	20.0
Maximum	1,132.5	1,119.2	1,113.6	1,113.6
Mean Annual Minimum (MALF)	29.6	19.8	20.8	20.0
7 Day MALF	32.2	21.7	21.4	20.0
Mean Annual Maximum	671.7	664.6	661.7	661.7
75th Exceedance Percentile	51.3	43.1	39.4	20.0
25th Exceedance Percentile	113.0	105.2	102.5	52.5

With respect to Table 6.1, I make the following comments:

- The minimum flow is an average daily figure and reflects that the natural low flow in the river over the modelled period was 20 m^3/s (rounded to the nearest m^3/s). Under the current river management plan (status quo) the river is allowed to be drawn below this natural figure to a value of 15 m^3/s in the months of February and March. Under the future modelled irrigation and hydro scenarios the minimum flow would rise above the minimum flow under the current river management plan because of the increase in the February/March minimum flow requirement from 15 to 20 m³/s.

- The mean flow in the river as expected shows a steady reduction from left to right across the table with increasing abstraction for irrigation and hydro generation purposes.

- The median flow statistics highlights that under the modelled proposal the river remains at the minimum flow for more than half of the time during the modelled period.

- The maximum flow over the modelled period is changed little by the modelled proposals, the difference between the figures being the modelled current irrigation abstraction under the status quo scenario and the additional 'B' Block irrigation abstraction in the modelled full irrigation development and modelled proposal cases. It is noted that this conservatively assumes that irrigation abstraction would continue under flood conditions, when in reality irrigation may stop due to excessive suspended sediment in the river flow. The modelled full irrigation development and the modelled proposal have the same maximum flow as it is assumed that hydro generation would shut down in flows greater than 200 m^3/s to prevent excessive accumulation of suspended sediment in the scheme intake works.

- The mean annual low flow or MALF (i.e. mean of the lowest flows in each year) reduces from the natural flow as expected under each of the abstraction scenarios. The modelled full irrigation development and modelled proposed scenarios increase the figure from the status quo because of the increase in minimum flows during February and March. The 7 day MALF is the mean of the lowest mean 7 day consecutive period in each year. It can be seen that the 1 day and 7 day MALF figures are similar. This indicates that it is not unusual under either natural or modified conditions for the river to remain at low flows for periods of up to at least a week at a time.

- The mean annual maximum (also known as the mean annual flood) is the mean of the highest flow recorded each year. As noted above there is limited abstraction assumed under flood conditions, therefore limited change to the mean annual maximum.

- The 75th and 25th percentiles give an understanding of the percentage of time that the river exceeds certain flows. For example under natural conditions the Amuri reach would have flows at or in excess of 51 m^3/s for 75% of the time. Under the modelled proposal the Amuri reach would have flows at or in excess of 20 m^3/s for 75% of the time.

6.2 As shown by the small changes in maximum river flow in Table 6.1, the modelled proposal has a more limited impact on high river flows than on mean and median flows. This is because abstraction for hydro generation purposes is assumed to cease once the river flow reaches 200 m^3/s to avoid excessive inflow of suspended sediment to the scheme. This effect is further illustrated in Table 6.2 which shows the impact on the modelled proposals on the occurrence of mean daily river flows at Marble Point in excess of 250 m^3/s. The mean number of days per annum reduces under the abstraction scenarios because of a small number of days when the natural flow would have been just over 250 m^3/s but the abstraction reduces the flow to just under 250 m^3/s. However these days were found to be part of a larger flood event such that the number of distinct events per annum (where consecutive days exceed 250 m^3/s they are included as one flood event) did not change.

Table 6.2 – Effect of Modelled Scenarios on River Flows over 250 m^3/s at Marble Point

STATISTIC	NATURAL FLOW	STATUS QUO	MODELLED FULL IRRIGATION DEVELOPMENT	MODELLED PROPOSAL
Mean number of days per annum	16	15	14	14
Mean number of distinct events per annum*	8	8	8	8
Mean number per annum absent more than 6 weeks	2	2	2	2
Maximum number of days absent	330	330	330	330

*separate flood events where 250 m^3/s is exceeded (i.e. where consecutive days exceed 250 m^3/s they are included as one flood event).

6.3 In order to visually represent the data, flow verses time, plots are presented for years considered to represent dry, average, and wet conditions. The representative years were selected by the Cawthron Institute and were based on a percentile assessment of mean annual flow. From the percentile assessment the years closest to the 10th, 50th and 90th percentile were used for the typical dry, average, and wet years respectively. Flows in the selected years were also visually checked to make sure there was a reasonably even spread of flow across the year i.e. the overall annual average was not being skewed by a small number of isolated flow events e.g. one or two large floods.

6.4 Appended Figure A1 shows the effect of the proposed flow regimes in a typical dry year. It can be seen from the blue natural flow line that the river had very limited flood or fresh activity between the start of January and the middle of April. Had the existing irrigation abstractions been in place, under the current water allocation regime the river flow is predicted to have reduced to the minimum flow of 15 m^3/s throughout almost all of February and March. The modelled proposal in green shows an increase over the status quo in February and March because of the higher monthly minimum flow with a sustained period of 3.5 months at the 20 m^3/s minimum flow. After mid April a more regular series of floods and freshes occurs introducing increased flow variability to the river under the modelled proposal scenario. The modelled proposal has little impact on the largest flow events in the year as it is assumed that the hydro scheme would no longer take water.

6.5 Compared to the flow series shown in Figure A1, Figure A2 showing a typical wet year illustrates much reduced periods of sustained low flow from the modelled proposal. The minimum flow is maintained throughout most of February and March to match with a natural period of sustained low flows. Again the modelled proposal is shown to have little effect on the frequency and size of larger flow events.

6.6 Figure A3 illustrates a typical average year. In this particular year the traditionally dry period between January and April showed greater flow variability than the other two illustrated years. Throughout the remainder of the year there is a broad pattern for the modelled proposal of the river remaining at or near minimum flow for periods of several weeks broken up with isolated higher flow events.

Steven Woods

12 October 2012

Appendix A

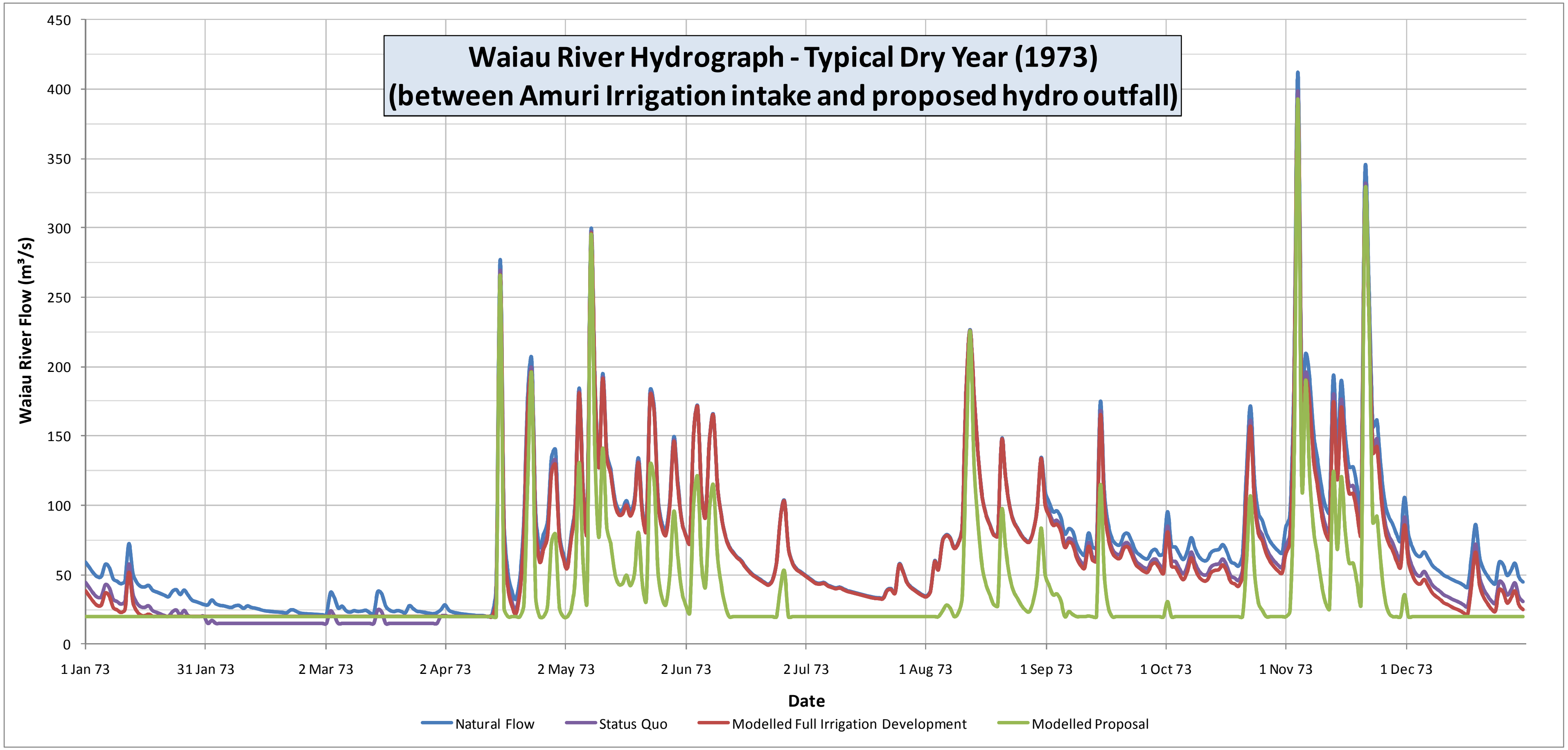

Figure A1 – Flow Series for Typical Dry Year

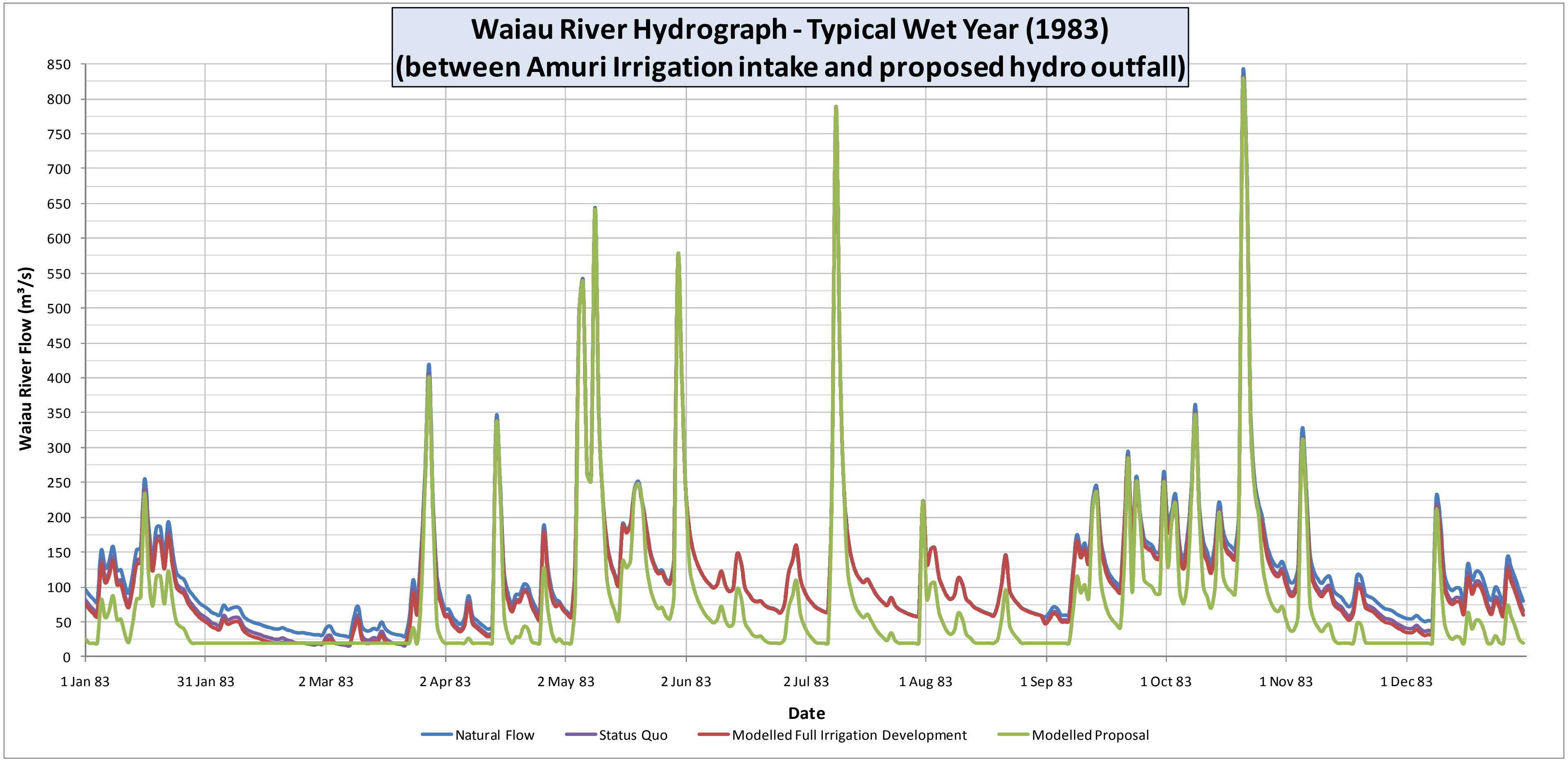

Figure A2 – Flow Series for Typical Wet Year

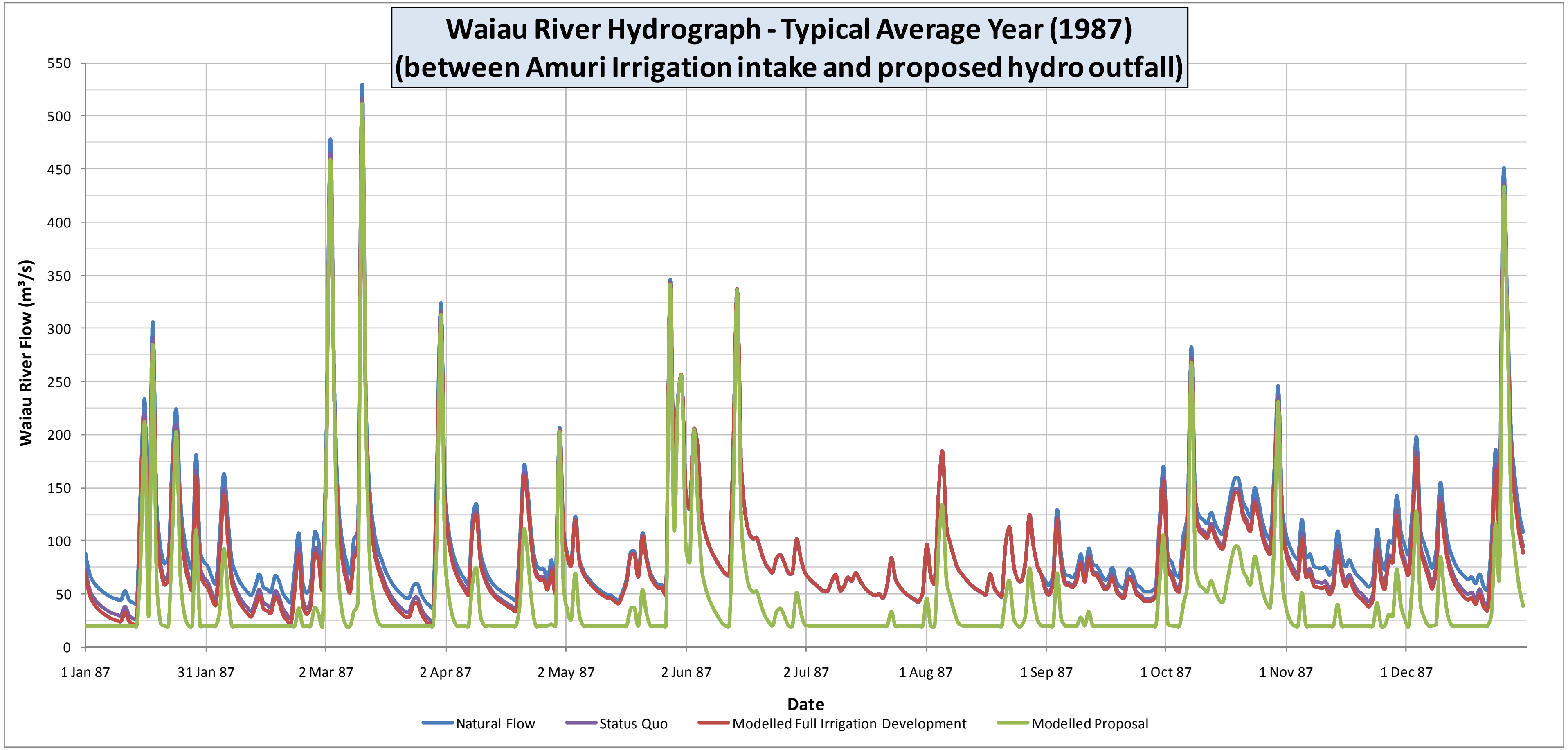

Figure A3 – Flow Series for Typical Average Year