

**IN THE MATTER** of the Resource Management  
Act 1991

**AND**

**IN THE MATTER** of an application by Meridian  
Energy Limited for resource  
consents for the Mokihinui Hydro  
Project

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**STATEMENT OF EVIDENCE OF RODERICK DONALD HENDERSON ON  
BEHALF OF MERIDIAN ENERGY LIMITED**

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## 1. **QUALIFICATIONS AND EXPERIENCE**

1.1 My full name is Roderick Donald Henderson (Roddy).

1.2 I have the following qualifications: M.Sc. (Resource Management) (1979) and B.E. (Civil) (1977), both from Canterbury University. I am a member of the New Zealand Hydrological Society (since 1979), the New Zealand Freshwater Sciences Society (since 1980), the International Association of Hydrological Sciences (since 1999), and the Meteorological Society of New Zealand (since 2003). In 1995 and 1996 I lectured in Surface Water Hydrology to the 3rd Professional class in the School of Civil Engineering at Canterbury University.

1.3 I am acting Group Manager of the Catchment Processes and Water Resources Group at the NIWA Christchurch campus. I have been a practising hydrologist since commencing employment with the Ministry of Works and Development Hydrology Centre in 1979, with particular interest in engineering hydrology, hydrological extremes, and the hydrology of New Zealand's hydropower system. I am co-author of a recent publication on decadal climate influences on New Zealand hydrological extremes (McKerchar and Henderson 2003), and two recent publications on mapping rain and flow over New Zealand (Tait et al. 2006 and Woods et al. 2006). I am the author or co-author of numerous reports on the hydrological characteristics and simulation of regulated and unregulated hydrology of New Zealand's power schemes, including; the Tongariro Power Development, between the minimum flows hearing of 1989 and the subsequent consents hearings of 2000; the Manapouri power scheme; the Waitaki Power Scheme and lower Waitaki River hydro development; and the Clutha River power scheme. I am a contributing author to Chapter 11 of the Working Group II contribution to the IPCC Fourth Assessment Report (Hennessy et al. 2007). Since late 2007 I have been Programme Co-ordinator for the Foundation for Research Science and Technology (FRST) funded programme "Nationally Significant Database: Water Resources and Climate" a \$4.5M

programme that manages the network of rain, climate, flow, water level, water quality and soil moisture recording stations across New Zealand.

1.4 I have read the Code of Conduct for Expert Witnesses (Rule 330A, High Court Rules and Environment Court Practice Note) and I agree to comply with it. I have complied with it in the preparation of this statement of evidence.

1.5 I have been involved in the following work in relation to Meridian Energy Limited's (Meridian's) Mokihinui Hydro Proposal (MHP):

a. Mokihinui River proposed hydropower scheme: Hydrology report (NIWA 2007) (I am the principal author of that report, and in this evidence I refer to it as "my report");

and I have prepared my statement of evidence in reliance on this work.

1.6 I have also reviewed the reports and statements of evidence of other experts giving evidence on behalf of Meridian relevant to my area of expertise, including Mr Watts, Mr Jowett and Dr Goring.

## 2. **SCOPE OF EVIDENCE**

2.1 I have been asked by Meridian to prepare evidence in relation to the effects of the MHP on the hydrology of the Mokihinui River.

## 3. **EXECUTIVE SUMMARY**

3.1 The flow series available from the Mokihinui River flow recorders, between 1972 and 1994, is adequate to describe the hydrology of the river.

3.2 Mean flow for the Mokihinui River is 90.4 cumecs, median flow is 45.6 cumecs, and mean annual 7-day low flow is 16 cumecs. Mean annual flood is 1,840 cumecs, 100-year return period flood is estimated as 3,280

cumecs, and the PMF is estimated as 2.2 times the 100-year flood, or 7,200 cumecs.

- 3.3 For flood events that begin below the median flow and rise to more than 100 cumecs, maximum rates of rise over time steps from three hours to ten hours are greater than 60 cumecs/hr for 25% of events, and greater than 100 cumecs/hr for 10% of events. There are between one and two such events per month on average.
- 3.4 Analysis of all floods shows that rates of rise of 83 cumecs/hr, as proposed by Meridian for the summer time, are exceeded in between one half and one third of all events. Rates of rise of 139 cumecs/hr, as proposed by Meridian for the winter time, are exceeded in between one third and one quarter of all events.
- 3.5 There are no effects of El Niño/Southern Oscillation or other longer-term climate influences observable in the Mokihinui flow record. There is however likely to be some influence in the future, of climate change, but this cannot be assessed with precision at present.
- 3.6 Mean flow, median flow, flood flows and seasonal variation of flows are unaltered by the proposed scheme. However the time that the river flow spends above the station capacity (120 cumecs) will be reduced from 66 to 55 days per year on average.
- 3.7 Daily pattern and flow distribution are the most affected aspects of the hydrology. The river will spend 23% of the time at the maximum generation, which is higher than the mean flow and 35% of the time will be at the minimum flow of 16 cumecs. The median daily range will increase from 11 cumecs to 104 cumecs, reflecting the fact that generation will commonly be at both minimum (16 cumecs) and maximum (120 cumecs) during most days between floods.
- 3.8 The reservoir would spend 35% of the time within 0.5 m of minimum level, and about the same amount of time within 0.5 m of spill level. Less

than 2% of the time would be spent at higher levels during and after floods.

- 3.9 Tributary streams above the proposed dam would be affected by inundation of their lower reaches. This would occur permanently below the lake operating minimum, frequently up to the spill level of 100 masl, and infrequently above that.

#### **4. THE PROPOSAL**

- 4.1 I confirm my evidence is based on the project proposal as described in the Assessment of Environmental Effects, brief details of which are described in Appendix 1.

#### **5. OVERVIEW OF THE MOKIHINUI CATCHMENT**

- 5.1 The Mokihinui River is located on the north western coast of the South Island, approximately 40 km north of Westport. It flows generally westward from the Kahurangi National Park to the sea near Seddonville. It has a catchment area of approximately 680 square kilometres above the proposed dam site and is approximately 57.5 km long. In the upper catchment, two branches of the river, the north and south branches, drain a large inland basin formed by the Glasgow, Lyell, Matiri and Radiant Ranges. These two branches meet at the Mokihinui forks - some 27 km above the river mouth. Below the forks, the river flows for approximately 16 km through a narrow gorge, after which it opens out into a wide floodplain where it flows approximately 11.6 km to the sea.

#### **6. FLOW DATA AND MODEL**

##### *Flow data*

- 6.1 The 22 year flow record used in my report and this evidence, both to provide summary statistics describing the Mokihinui hydrology, and also as input to a model of the way the proposed dam operation would affect flows downstream, was derived from the Burkes Creek and Welcome

Bay recorders on the Mokihinui River. These recorders were in operation between 1972 and 1994.

- 6.2 At the recorder sites water level sensing equipment provides a record of river level (or stage). Regular flow measurements are carried out and are used to derive a relationship (rating) between stage and flow. Ratings change from time to time as floods re-arrange the river bed shape. Ratings are applied to the continuous stage record to produce a time series of river flow. The data have been audited according to the NIWA audit procedures.
- 6.3 Because the Mokihinui River flow record stopped in 1992, I carried out a comparison of the data with the flow record from the neighbouring Karamea catchment (acknowledging the difference in catchment size and rainfall), in order to make sure the Mokihinui River record would give accurate flow statistics. This comparative analysis is set out in section 2 of my report. I concluded that the 22 year record for the Mokihinui River is a suitable record to represent the river's behaviour, and from which to derive flow statistics and other information.
- 6.4 The Welcome Bay site was re-opened in May 2007 as part of the ongoing MHP investigations, to provide flow data for use in biological and physical sampling work. However the new data have not been used for my analyses because they cover a very short time period.

#### *Modelling*

- 6.5 A two step process was used to model the effect of the MHP and dam on the hydrology of the Mokihinui River. First the Mokihinui flow record was used as input to Meridian's PLEXOS model to model the optimal use of water given a market demand weekly profile. The PLEXOS model is described in more detail in section 4.1 of my technical report. The basic parameters were the reservoir volume-area-level curve, spillway crest of 100masl (metres above sea level), minimum flow of 16 cumecs, two turbines with a total flow capacity of 120 cumecs and a smaller turbine to pass the minimum flow when that is all the water being released.

- 6.6 There were two main limitations with the PLEXOS model. One was that in the PLEXOS model, while the reservoir was considered to spill when the crest level was reached, the actual reservoir levels whilst spilling were not modelled. The second was that extra constraints on generation during the whitebaiting season (see the evidence of Mr Jowett) could not be incorporated.
- 6.7 To overcome these limitations and as the second step of the process I used a simulation model to provide a model of reservoir level behaviour, and to model the effect of 'run-of-river' operation during the whitebaiting season.
- 6.8 In the whitebaiting season Meridian intends to operate the MHP as a 'run of river' operation meaning that outflows from the combination of generation and spill should match or be equal to inflows to the reservoir as often as possible. This is modelled by keeping the reservoir level at a target level of 99.75 masl, and adjusting generation flow each hour to bring the reservoir towards that level smoothly. This is to avoid sudden unnatural changes in flow during the whitebaiting season that might affect whitebait behaviour. The high reservoir level means that the time between normal operation and spilling will be minimised. Thus spill will lead to a flood in the river at almost the same time the river would have naturally risen downstream of the dam site.
- 6.9 The combination of the Meridian PLEXOS model and NIWA's reservoir and 'whitebaiting rule' simulation makes it possible to look at the 22 years of hydrological record for the Mokihinui and see what it would look like if the MHP were operating on the river, according to the flow regime recommended. Outputs of the modelling are shown in full in Appendices 1 and 2 of my report.
- 6.10 Limitations of the simulation model are:
- a. It assumed that the small (16 cumecs) minimum flow turbine would not be used during spill events, but only to provide minimum flows and this is incorrect. The two larger turbines can

also run at a higher flow when the lake level is above the spillway crest. These two factors mean that generation at times of spill will actually be up to approximately 150 cumecs rather than 120 cumecs. Thus the rate of drawdown of the reservoir after a flood is slightly under-estimated, as is the river flow whilst spilling.

- b. It assumed that any required flow could be passed by the generating plant. In fact the current turbine configuration cannot generate between 20 and 30 cumecs.
- c. It was not able to model the effect of the need to bid into the electricity market each half hour with a two hour lead time.
- d. It was run with hourly average flow data, and is thus not able to model short term effects of flow alteration, including the way in which generation is changed between the minimum flow and full station capacity.

6.11 The limitations are minor and I do not expect that they will have any effect on the conclusions drawn below or in other impact assessment reports.

## **7. EXISTING HYDROLOGY**

### *Mean and median flows*

7.1 The mean and median flow statistics calculated from the 22 year record are 90.4 cumecs and 45.6 cumecs respectively.

### *Low flows*

7.2 The primary statistic for low flows is the mean annual 7-day low flow (MALF). This is calculated as the average of the lowest 7-day mean flow in each year of record. The MALF for the 22 year Mokihinui record is 16 cumecs.

### *Flood flows and Probable Maximum Flood*

7.3 I carried out a frequency analysis of the Mokihinui River annual flood series (the largest flood each calendar year) in order to determine flood flows. Table 1 presents a summary of design flood estimates for the Mokihinui River, together with estimates of the 95% confidence range. I also considered whether El Niño/Southern Oscillation patterns would

have an effect on these flood estimates, given the relatively short flow record. However by looking at the longer Karamea record, I concluded that there was no evidence of shifts in the Karamea flood data between El Nino and La Nina periods. I had previously found a similar result in the Buller River flow record (McKerchar and Henderson 2003). The Buller catchment lies to the south and west of the Mokihinui catchment and the proximity and similarity of the two rivers in terms of rainfall and drainage patterns means I expect a similar finding to apply for the Mokihinui.

- 7.4 Probable Maximum Flood (PMF) is an engineering hydrology concept that is used to allow dams to be engineered so that they are able to safely deal with the greatest conceivable flow of water. The conventional procedure is to develop and calibrate a rainfall-runoff model, estimate probable maximum precipitation (PMP), and route this through the calibrated rainfall-runoff model to estimate PMF. Given the virtual absence of rainfall data for the Mokihinui catchment, application of this methodology is problematic. In this situation, the appropriate conservative approach for a hydrologist is to calculate a preliminary estimate of PMF based on flood estimates from the recorded data multiplied by a factor.
- 7.5 In my analysis I used three sources of this multiplier. The first is from Tomlinson and Thompson (1992), the second is from McKerchar (1991), and the third is from the Hydrology Centre (1988). PMF estimates from applying these multipliers are summarised in Table 2.
- 7.6 There is a considerable divergence between the estimates in Table 2. The Thompson and Tomlinson (1992) ratios are derived from a wide distribution of rain stations and are reasonably close to the ratio of 2.2 used by McKerchar (1991) for the flood estimates on the Otaki River. Although the Otaki catchment is in the North Island and is somewhat smaller than the Mokihinui catchment, it has generally similar hydrological features. It also is a steep mountainous catchment at similar latitude and experiences floods in similar north-westerly storm conditions. The Otaki-based ratio of 2.2 giving an estimate of 7,200 cumecs is recommended as a preliminary PMF estimate. This estimate

should be revisited during the detailed dam design phase if PMF is a critical parameter for dam safety.

#### *Rates of rise*

- 7.7 Mr Watts will present a suggested ramping regime, based upon consideration of water level changes and recreational use and safety. The summer rate of change from 16 to 120 cumecs is proposed to take 75 minutes. This is equivalent to a rate of rise of 83 cumecs/hr. The winter rate of change from 16 to 120 cumecs is proposed to take 45 minutes. This is equivalent to a rate of rise of 139 cumecs/hr.
- 7.8 I have analysed the naturally occurring frequency, magnitude and timing of flow changes (termed rates of rise) in the river. I considered all rising river periods, and extracted the maximum rate of rise for each flood. A single parameter was the required time between events, specified as one, two or three days. The river spends 10% of the time in rising mode. Table 3 summarises the results, and Figure 1 shows the distribution of percentage of events with a maximum rise in an hour greater than the rise on the vertical axis. The result is not particularly sensitive to the event time separation parameter.
- 7.9 Both the summer and winter rate of rise scenarios from the evidence of Mr Watts are indicated on Figure 1. For the summer rate (equivalent to 83 cumecs/hr), and depending on the choice of event separation, this rate of rise is exceeded in 35%, 42% or 48% of events. That is, one third to one half of events in the river have rates of rise larger than the proposed summer rate. For the winter rate (equivalent to 139 cumecs/hr), and depending on the choice of event separation, this rate of rise is exceeded in 25%, 30% or 35% of events. That is, one quarter to one third of events in the river have rates of rise larger than the proposed winter rate.

#### *Flow variability*

- 7.10 River flows are inherently variable. Over time-frames from a few days to a few weeks they fluctuate according to the weather systems that pass over New Zealand. Over time-frames of a season to a year or two they react to larger or smaller amounts of rain than usual caused by a variety of climatic influences. Over decades they may react to longer-term climatic fluctuations or climate change influences. Flows in the Mokihinui

catchment are not influenced markedly by long-term climate signals, unlike rivers further to the south-west (McKerchar and Henderson 2003). Nor are they particularly affected by the state of the El Niño/Southern Oscillation. The dominant feature of Mokihinui flows is their response to the frequent passage of weather systems from the Tasman Sea, with a weekly to fortnightly period.

- 7.11 Climate change could affect all the flow statistics I have discussed above. There is no visible signal attributable to climate change in the instrumental record of river flow in New Zealand. The potential exists for change within this century but only a limited amount of work has been done to quantify these potential effects in New Zealand. In my opinion, more work will need to be done at the next stage of dam design to assess potential climate change impacts on dam design floods. I understand that the need to confirm spillway capacity has also been identified in the Damwatch engineering report.

#### *Tributaries*

- 7.12 Between the Mokihinui River mouth and Mokihinui Forks, there are 43 tributary inflows as defined by the digital stream network of the River Environment Classification (REC). 40% of these are named streams or creeks, and of the unnamed tributaries, only one is not a first order stream. I have summarised basic properties of the named tributaries, derived from application of mean flow and low flow models, and using the REC digital network for areas, elevations and stream order and length. These are shown in Table 4.
- 7.13 In Table 4, stream order is one for small streams with no tributaries, two if order one streams join, three when order two streams join, etc. The Mokihinui main stem from the Forks to the sea is order six, as the North and South Mokihinui are each order five. Distance to sea is from the junction between the tributary and the main river measured along the digital stream network. Tributary catchment areas, mean flows and low flow figures are generally the difference in these statistics between the adjacent main stem stream segments, and thus include an allowance for direct drainage to the main stem segment in each case. Exceptions are for Chasm and Page Streams, where the tributary only values are used as they are very close together when they join the main stem. Mean

flows should be within  $\pm 20\%$ , and low flows within  $\pm 50\%$ , as both sets have been adjusted according to the fit of their respective models at the Mokihinui flow recorder. Uncertainties are still large however because there are no available flow or rain data in the catchment upstream of the Welcome Creek gauge with which to calibrate these estimates. Estimates of elevation (reservoir depth) have been taken from the underlying 30m DEM of the REC, and have a standard error of at least  $\pm 10\text{m}$ .

## 8. ACTUAL AND POTENTIAL EFFECTS OF MHP ON HYDROLOGY

- 8.1 There will be two immediate effects of MHP on the hydrology of the Mokihinui River, the creation of a reservoir and then the creation of a new flow regime downstream of the dam. A dam and power station operated to match electricity demand in a market with diurnal consumption signals will alter the flow regime of the river downstream. Determining factors are: the relative size of the generation plant versus mean river flow; the amount of storage in the operating range of the reservoir versus the mean inflow and flood flows; and the minimum flow that is set below the dam. Above the upstream extent of the impoundment area the MHP will not affect the hydrology of the river.
- 8.2 Flow duration curves are a condensation of all flow hydrographs in a time series into a single curve that describes the amount or fraction of time that the river has spent above or below each flow in the range. Figure 2 shows flow duration curves for inflows to the reservoir (blue) and for the river downstream of the proposed dam (green). This is effectively a graph to summarise Mokihinui hydrology before and after MHP.

### *Mean, median and low flows*

- 8.3 A comparison of the current hydrology versus the hydrology with the MHP shows that mean flow (marked by a diamond on Figure 2) is preserved, as coincidentally is the median. The steps in the down river duration curve between minimum and maximum generation flow highlight the effect of the power scheme. At the extreme right is a small amount of time spent below the minimum flow of 16 cumecs. This is

because the river naturally goes below that flow for about 3% of the time, and the reservoir is not large enough to buffer these occurrences. A river inflow this low happens on average approximately one year in two. At these times the power station would be operated to keep the lake level at the minimum level of 97 masl, and thus generation flows would equal the low river inflow.

- 8.4 Nearly 35% of the time would be spent at the minimum flow, compared with 3% of the time at or below this flow naturally. Smaller steps at 30, 60, and 90 cumecs are a function of different combinations of the three turbines. Limitations in the simulation mentioned at 6.10b above would make some minor changes to this distribution curve, and in particular some flow ranges would not occur. These ranges would appear as vertical steps in the flow duration curve. Approximately 23% of the time would be at maximum generation of 120 cumecs, and 15% of the time would have some spill flow. This represents a reduction in time above 120 cumecs from 66 days/year (now) to 55 days/year (with MHP), a 15% reduction.

#### *Flood flows*

- 8.5 I have also considered the effects of MHP on the flood hydrology of the Mokihinui River. The reservoir volume and area are small compared to the flood inflows that occur regularly. If the reservoir was at the minimum level of 97 masl and generation at the maximum of 120 cumecs, then the mean annual flood would fill the reservoir to 100 masl in 1.6 hours, and the 100-yr flood would take 53 minutes. Thus the reservoir has limited ability to alter the flood magnitude or frequency.
- 8.6 Figure 3 shows a flood frequency analysis of both the inflows to the reservoir, and the flows in the river downstream of the proposed dam. As expected the effect of the reservoir is more evident for smaller floods, where size is reduced by up to 150 cumecs (approximately 10%). For floods larger than the 10% aep (annual exceedance probability) flood (10-year return period) the effect is small.

#### *Flow variability including daily pattern*

- 8.7 I have carried out analysis to see whether the MHP would have any effects on flow variability. In terms of seasonal variability, I have

concluded that because of the small size of the reservoir, there are no significant changes in seasonal variation of flows.

- 8.8 The operation of the MHP scheme will introduce a significant change to daily flow behaviour. This is because where inflows and storage capacity allow, flows are retained in the reservoir for generation at times of higher demand for electricity, and during times of lower demand, flows will be at the minimum flow. The desired generation pattern has one or two daily peaks at which the flow will be at maximum generation, and between which the flow will be less. At night flow will tend to be at the minimum flow. This pattern is clearly seen in Figure 4.
- 8.9 Figure 4 also shows a difference between daily pattern with and without the 'whitebaiting' rule in operation. When the whitebaiting season, with its modelled 'run-of-river' hydrology, is removed from the analysis the daily pattern of flows is more definite, and approaches minimum flow in the middle of the day as well as at night. There is none-the-less considerable variability in this daily pattern. When the river is in flood, generation can be at maximum while the reservoir is full. Once the flood is past, and the reservoir level recedes below the spill level of 100 masl, generation is expected to follow the demand signal fairly closely, with maximum generation once or twice each day, lower flows between the peak periods, and minimum flows at night. As river flows continue to reduce, there is then insufficient water in storage to allow the demand signal to be followed exactly. The duration of periods with peak generation reduce from several hours to only one hour, and inter-peak flows also approach the minimum flow. As the river recedes further, one or other of the two daily peak generation cycles disappear, and if the recession continues for long enough, both disappear and the generation will be at minimum flow until the next flood event. In every second year on average, inflows will decline below the minimum (set at the MALF of 16 cumecs) and generation will decline with them below the minimum flow.
- 8.10 In summary, it can be seen that flow changes from minimum flow (16 cumecs) to full generation flow (120 cumecs) will occur once or twice per day between floods when the amount of water in the reservoir allows.

*Tributaries*

- 8.11 The proposed dam and power station operations will have no effect on the hydrology of the tributaries. Mean flows and other flow statistics will be unchanged.
- 8.12 Upstream of the proposed dam (from Welcome Creek to the Forks) there will be hydraulic effects of the reservoir, which will inundate the lower reaches of tributary streams that enter the river. This effect will vary with reservoir level (as I discuss in the section on reservoir level frequency analysis and reservoir level duration below) and distance upstream from the dam.
- 8.13 Downstream of the dam, tributary levels and flows near their confluence with the Mokihinui, will be affected by transitory hydraulic effects of the generation flow from the power station, as this is proposed to be varied on a daily and hourly basis. Changes in stage height of the river below the dam will be discussed in more detail in the evidence of Dr Goring.

*Reservoir levels*

- 8.14 The reservoir created by the proposed dam will have a spill level of 100 masl, and a minimum operating level of 97 masl. The reservoir has a short residence time at mean flow of 12.6 days, and under a mean annual flood this reduces to 15 hours. The reservoir can fill from minimum level to spill level under a mean annual flood flow in 1.6 hours, and with a 100-year flood flow this reduces to less than an hour. During the whitebaiting season, Meridian proposes that the reservoir level will be maintained close to the crest to reduce the interval between full generation and spilling. For example at a lake level of 99.75 masl the mean annual flood flow will fill the reservoir to spill level in just over 8 minutes.
- 8.15 Mean reservoir level is 98.6 masl over the period modelled (1972 to 1994). The reservoir spends 35% of the time within 0.5 m of minimum level, and about the same amount of time within 0.5 m of spill level. Less than 2% of the time is spent at higher levels during and after floods. Generally the reservoir declines in level under the normal generation pattern, as flows recede. When the reservoir is at its minimum, generation is gradually limited by receding inflows, so that less time can

be spent at maximum generation. This effect continues with the reservoir close to minimum until the next flood.

- 8.16 The reservoir will spend 85% of the time below the spillway level, and only 2% of the time more than 0.5m above spillway level (100 masl) when flood events cause large rises in the reservoir level for short periods. I have carried out an analysis of the infrequent excursions above 100.5 masl, and the probabilities of exceedance per annum are given in Table 5. The results are given for instantaneous reservoir levels, and also reservoir levels averaged over 1, 3 and 7 days. These averaging intervals are chosen to give information that may be of more relevance in assessing environmental impacts of high reservoir levels than the instantaneous values. Table 5 shows that extreme reservoir levels are modified at averaging intervals of one day or more. For example, instantaneous reservoir level exceeds 105.5 masl with a 2% annual probability (on average once every 50 years) but the equivalent one day average reservoir level is only 103.7 masl.
- 8.17 A combination of spill and generation draws the reservoir down to below 100 masl after the inflow flood has receded.

*Summary of effects*

- 8.18 In summary, the modelling shows that mean flow in the Mokihinui River is unaltered by the proposed scheme, as is the median flow. Seasonal variation of flows is unaffected as the reservoir has limited storage capability. Flood flows are little affected for the same reason. However the time that the river flow spends above the station capacity (120 cumecs) will be reduced from 66 to 55 days per year on average
- 8.19 Daily pattern and flow distribution are the most affected aspects of the hydrology. The river will spend 23% of the time at the maximum generation, which is higher than the mean flow. 35% of the time will be at the minimum flow of 16 cumecs. The median daily range will increase from 11 cumecs to 104 cumecs, reflecting the fact that generation will commonly be at both minimum (16 cumecs) and maximum (120 cumecs) during most days between floods. Tributaries to the Mokihinui will not have altered flow statistics, but those lower tributaries above the

proposed dam will be inundated permanently below the lake operating minimum, frequently up to the spill level of 100 masl, and infrequently above that. The reservoir will spend 35% of the time within 0.5 m of minimum level, and about the same amount of time within 0.5 m of spill level. Less than 2% of the time is spent at higher levels during and after floods.

## 9. CONCLUSION

- 9.1 I conclude that the flow series available from the Mokihinui River flow recorders, between 1972 and 1994, is adequate to describe the hydrology of the river. A longer record, until the present day, could be synthesized from the flow record on the Karamea River to the north, but would not significantly alter any of the statistics.
- 9.2 Mean flow for the Mokihinui River is 90.4 cumecs, median flow is 45.6 cumecs, and mean annual 7-day low flow is 16 cumecs. Mean annual flood is 1,840 cumecs, 100-year return period flood is estimated as 3,280 cumecs, and the PMF is estimated as 2.2 times the 100-year flood, or 7,200 cumecs.
- 9.3 For flood events that begin below the median flow and rise to more than 100 cumecs, maximum rates of rise over time steps from three hours to ten hours are greater than 60 cumecs/hr for 25% of events, and greater than 100 cumecs/hr for 10% of events. There are between one and two such events per month on average.
- 9.4 Analysis of all floods shows that rates of rise of 83 cumecs/hr, as proposed by Meridian for the summer time, are exceeded in between one half and one third of all events. Rates of rise of 139 cumecs/hr, as proposed by Meridian for the winter time, are exceeded in between one third and one quarter of all events.
- 9.5 There are no effects of El Niño/Southern Oscillation or other longer-term climate influences observable in the Mokihinui flow record. There is

however likely to be some influence in the future, of climate change. The significance of climate change for the Mokihinui River and the design of a scheme such as the MHP cannot be assessed with precision, as only a limited amount of work has been done to quantify these potential effects in New Zealand.

- 9.6 For modelling the effect of the MHP on the hydrology of the Mokihinui River a two-step process was used. First Meridian's PLEXOS model was used to model the optimal use of water given a market demand weekly profile. Then a simulation model was used to provide a model of reservoir level behaviour, and to model the effect of 'run-of-river' operation during the whitebaiting season.
- 9.7 Results of this modelling show that mean flow in the Mokihinui River is unaltered by the proposed scheme, as are median flows. Flood flows are little affected as the reservoir has limited storage capability. Seasonal variation of flows is unaffected for the same reason. However the time that the river flow spends above the station capacity (120 cumecs) will be reduced from 66 to 55 days per year on average, a 15% reduction.
- 9.8 Daily pattern and flow distribution are the most affected aspects of the hydrology. The river will spend 23% of the time at the maximum generation, which is higher than the mean flow. 35% of the time will be at the minimum flow of 16 cumecs. The median daily range will increase from 11 cumecs to 104 cumecs, reflecting the fact that generation will commonly be at both minimum (16 cumecs) and maximum (120 cumecs) during most days between floods.
- 9.9 The reservoir would spend 35% of the time within 0.5 m of minimum level, and about the same amount of time within 0.5 m of spill level. Less than 2% of the time would be spent at higher levels during and after floods.
- 9.10 Tributary streams above the proposed dam would be affected by inundation of their lower reaches. This would occur permanently below

the lake operating minimum, frequently up to the spill level of 100 masl, and infrequently above that.

**TABLES**

Table 1 - Summary of Mokihinui flood frequency estimates.

<b>Annual exceedance probability</b>	<b>Peak flow (cumecs)</b>	<b>95% confidence range (±%)</b>
1 in 2 (median annual flood)	1840	9
1 in 2.33 (average annual flood)	1840	9
1 in 5	2170	11
1 in 20	2700	15
1 in 50	3030	17
1 in 100	3280	19
1 in 200	3530	21

Table 2 - PMF estimates for the Mokihinui River

<b>Item</b>	<b>Value (cumecs)</b>	<b>Multiplier</b>	<b>Source of data to derive multiplier</b>	<b>PMF estimate (cumecs)</b>
1/100 AEP flood (Q <sub>100</sub> )	3,280	2.0	Tomlinson and Thompson (1992)	6,560
1/100 AEP flood (Q <sub>100</sub> )	3,280	2.2	McKerchar (1991)	7,200
Mean annual flood	1,840	7.0	Hydrology Centre (1988)	12,900
Largest flood	3,505	3.0	Hydrology Centre (1988)	10,500
Recommended (see text)		2.2		7,200

Table 3 – Flow rises in one hour, for three different event separation times, and with a number of exceedance probabilities.

Event time separation (days)	No. of events	Rise in one hour (cumecs)				
		95% exceed:	75% exceed:	50% (median)	25% exceed:	5% exceed:
1	1403	2	10	46	135	297
2	969	2	15	61	155	327
3	731	3	23	77	177	349

Table 4 - Mokihinui tributaries between the coast and the Forks, and some basic statistics. Hodge Creek is a tributary of Rough and Tumble Creek, and the reservoir surface would extend above the confluence of the two. Depth at tributary junctions is based on a reservoir full to 100m.

Tributary name	Stream order	Distance to sea (km)	Tributary catchment area (km <sup>2</sup> )	Tributary mean flow (L/s)	Tributary 7-day MALF (L/s)	Depth of proposed reservoir at trib. junction (m)	Length of tributary inundated at 100 masl (m)
Brewery Stream	1	0.8	2.71	172	10		
Marris Stream	1	2.2	2.53	145	22		
Sawyer Creek	1	3.2	2.06	116	16		
Stillwater Creek	3	3.4	19.41	1154	167		
Chasm Stream	4	5.6	22.33	2768	383		
Page Stream	2	5.6	3.29	223	10		
Coal Creek	3	7.1	12.36	1245	142		
Burke Creek	2	10.1	5.73	626	115		
Podge Creek	3	10.1	4.26	297	47		
Proposed Dam		12.1					
Welcome Creek	2	12.3	3.83	370	73	62.6	600
Johnny Cake Creek	2	14.5	3.68	333	64	58.5	350
Rough and Tumble Creek	4	16.5	30.46	2351	426	46.7	2300
Hodge Creek u/s of confluence	3						490
Anderson Creek	3	18.8	5.17	465	87	40.8	320
Jones Creek	2	22.0	2.36	201	39	38.3	170
Maori Creek	3	22.1	17.49	1443	260	28.7	900
Specimen Creek	3	26.3	16.48	1625	321	<2	400
Pakihi Creek	2	26.4	2.40	199	33	<2	60

Table 5 - Reservoir level frequency values (reservoir level exceeded with a given annual exceedance probability) for four averaging intervals and a range of exceedance probabilities

Annual Exceedance Probability	Return Period (years)	Instantaneous reservoir level (masl)	1-day average reservoir level	3-day average reservoir level	7-day average reservoir level
50%	2	103.0	101.7	100.8	100.4
20%	5	103.8	102.4	101.1	100.5
10%	10	104.3	102.8	101.3	100.6
5%	20	104.8	103.2	101.5	100.7
2%	50	105.5	103.7	101.7	100.8
1%	100	106.0	104.1	101.9	100.9

**FIGURES**

Figure 1 – Distribution of percentage of events with a maximum rise in an hour greater than the rise on the vertical axis. Three different event separation values are used, but do not significantly affect the distribution. The rates of rise proposed in Mr Watts’ evidence are marked.

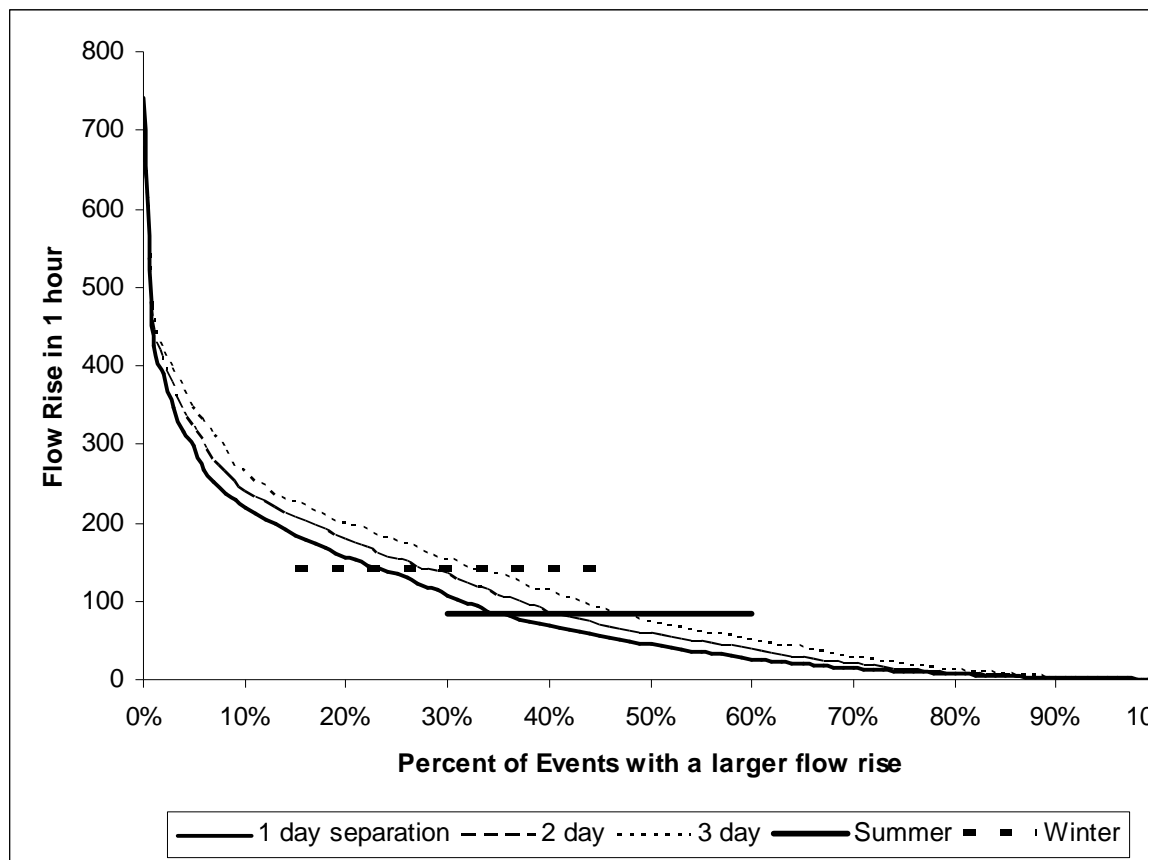


Figure 2 – Flow duration curves for inflows to the reservoir (blue) and for the river downstream of the proposed dam (green).

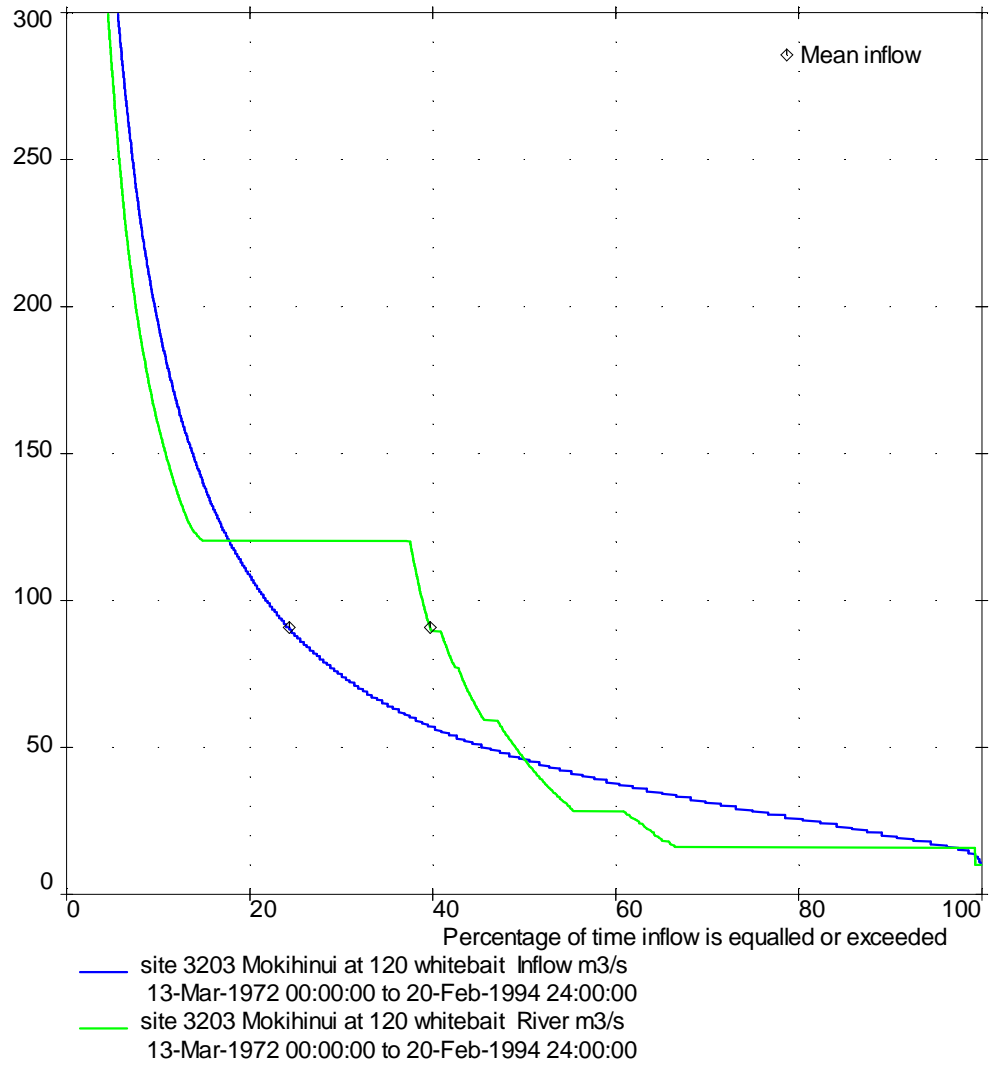


Figure 3 – Flood frequency curve of hourly average inflows (blue) and hourly average downstream river flows (red). Vertical axis shows flood size (cumecs). Horizontal axis shows annual exceedance probability (aep = 1/return period) on a log scale.

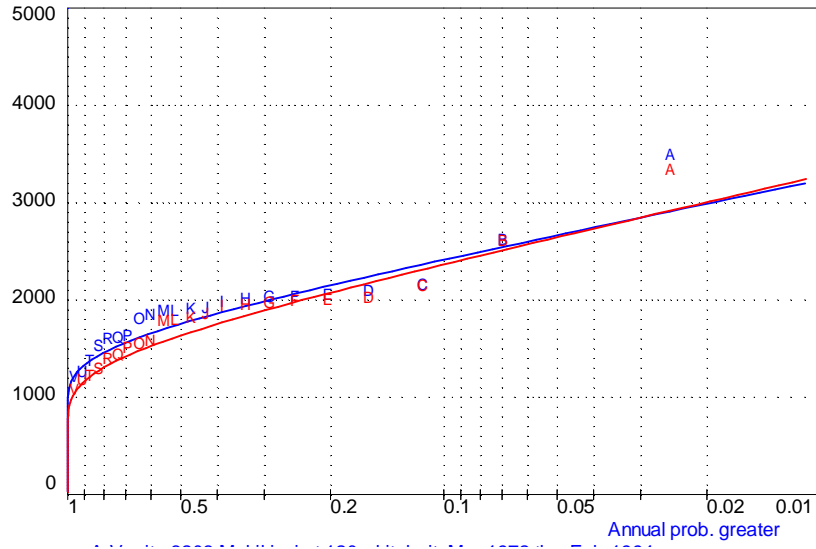
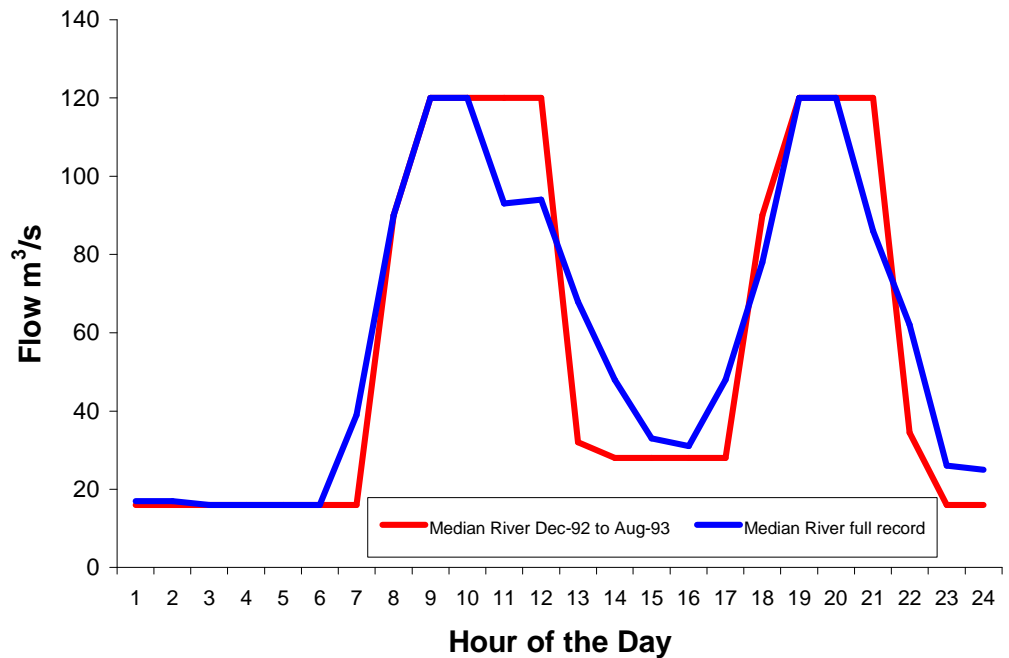


Figure 4 – Daily pattern of flows showing the simulated median river flow for the full record (blue), and median river flow for a year outside the whitebait season (red) for each hour of the day from the simulated scheme operation.



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