

# Assessment of Environmental Effects for Stage 1: HWP Waitohi Irrigation and Hydro Scheme

∴ Prepared for:  
Hurunui Water Project (HWP)

∴ September 2011



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## Quality Control Sheet

TITLE **Assessment of Environmental Effects for Stage 1: HWP Waitohi  
Irrigation and Hydro Scheme**

CLIENT Hurunui Water Project

VERSION Final

DATE September 2011

JOB REFERENCE C02031406

SOURCE FILE(S) C020310406\_R001\_Stage 1\_Final.doc

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### Limitations:

This report has been prepared on the basis of information on potential future land use assumed by the Hurunui Water Project Ltd and environmental conditions determined by other parties.

The report describes a numerical modelling simulation of a natural hydrological regime. Due to the variability of natural processes, the modelling output cannot be guaranteed.

The report has been prepared for Hurunui Water Project, according to their instructions, for the particular objectives described in the report. The information contained in the report should not be used by anyone else or for any other purposes.

## Executive Summary

In this report the effects of operating a storage scheme in the Waitohi River to meet irrigation demand for a 6,900 hectare area close to the Waitohi River are assessed.

It is proposed that two storage reservoirs along the Waitohi River are constructed, with a combined total live storage volume of 11.2 million m<sup>3</sup>. The main storage reservoir is Seven Hills with an active storage capacity of 7.3 million m<sup>3</sup>. The Inches Road storage reservoir will have an active storage capacity of 3.9 million m<sup>3</sup>. Both reservoirs have a proposed operating range of 20 metres.

An intake in the Hurunui River will abstract water to meet irrigation demand with the shortfall in supply being drawn from storage. The natural channel of the Waitohi River will be used to convey water from storage to the intake site on the Waitohi River further downstream.

The effects of the scheme were simulated over a 39 year period (1972-2011) using a model from which irrigation demand, Hurunui run-of-river water availability (subject to the pre-storage flow regime as described in the Proposed Hurunui and Waiau River Regional Plan) and water availability within the storage reservoirs are estimated. Seven Hills reservoir is assumed to be the primary storage with Inches Road reservoir providing supplementary irrigation supply when the live storage in Seven Hills Reservoir is completely used. Water is harvested into storage from the Waitohi River catchment subject to an environmental flow at the outlet of the Inches Road Reservoir.

The model is driven by a combination of inputs, primarily flows in the Hurunui River, inflows into the storage sites, evapotranspiration and rainfall data. Modified flows were compared with natural/existing flows and reservoir levels were estimated to assess the effects of the scheme.

The intake on the Hurunui River mainly affects the flows within the irrigation season with the largest relative reduction in flows in the flow range between 22 m<sup>3</sup>/s and 40 m<sup>3</sup>/s. The proposed scheme does not affect the flows below the minimum A-block flow as specified by the flow regime in the "Proposed Hurunui and Waiau River Regional Plan".

Effects on river flows are likely when irrigation abstraction is either ramped up or down. Investigation of the changes in water level associated with these changes in flow are required to enable environmental, ecological, aesthetic and other effects to be assessed. The water level changes in response to flow ramping have been simulated using a hydraulic model, and the results indicate that water levels in downstream reaches may vary by up to half a metre in the Waitohi River. Water levels in the Hurunui may vary by up to 100 mm. This fits well within the range of naturally occurring water levels in the relevant reaches.

The water levels in the proposed storage reservoirs are highly variable over the 39 year simulation period. In wet years the storage is hardly used whereas in dry years the live storage may be used completely. The estimated mean lake level for Seven Hills Reservoir

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is 394.5 m RL, 5.5 m below the maximum storage level. The estimated mean lake level for Inches Road Reservoir is 366.4 m RL, 3.6 m below its maximum operating level. Seasonally the lowest reservoir levels occur in the second half of the irrigation season.

The main effects on the Waitohi River immediately downstream of Inches Road reservoir are related to the periods when river flows are harvested into storage and/or when water is released to meet irrigation demand. When water is harvested into storage river flows at the outlet of the reservoir are stable at 250 L/s and when water is released to meet irrigation demand (typically in the second half of the irrigation season) flows are increased by up to 4.15 m<sup>3</sup>/s. Natural flows are unchanged during period when the reservoir is full and when there is no irrigation demand.

The reliability of the scheme described in this report is assessed based on a supply/demand ratio of 93% as required to maintain a particular modelled Soil Moisture Index (SMI). The simulation suggests that for the vast majority of years (30 in 39 years) the scheme has enough water for a complete irrigation season and is therefore reasonably reliable. In dry years the SMI tends to drop off in the last 2 months of the irrigation season (i.e. from March onwards).

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## 1.0 Introduction

Pattle Delamore Partners Ltd (PDP) has been engaged by the Hurunui Water Project (HWP) to assess the hydrological effects from the development of an irrigation scheme in the Hurunui, Waipara and Kowai catchments. This report considers the initial irrigable area of 6,900 ha for stage 1 located north and south of the Waitohi River.

It has been determined through scoping and feasibility studies that the project will involve the taking of water from the Hurunui River and will deliver water through a system of water races. With storage in place the proposed system will be able to irrigate an area of 6,900 ha.

The key elements of the project as shown in Figures A1 and A2 include:

- 1) Intakes (points at which it is proposed that flow be taken/abstracted from each relevant river system)
  - ✦ An intake on the Hurunui River at 305 m RL or 280 m RL to supply run-of river water to the distribution system (Intake no. 1).
  - ✦ An intake on the Waitohi River at 305 m RL or 280m RL to supply water to the main distribution canal north and south of the Waitohi River (Intake no. 2).
- 2) Dams
  - ✦ A dam and consequent reservoir in the Waitohi River at Seven Hills to supply water for irrigation.
  - ✦ A dam and consequent reservoir in the Waitohi River at Inches Road to supply water for irrigation.

A distribution network of water races across the plains will provide water to all shareholder properties in the scheme.

The operation will involve delivering water to the supply area from run-of-river water via a race system when water is available in the rivers, with the shortfall in demand being drawn from storage. Water from the Waitohi River will be harvested into the Seven Hills and Inches Road Reservoir to store water for irrigation, whilst maintaining a minimum environmental flow release at the outlet of the storage reservoir.

This assessment of Environmental Effects report deals with hydrology and irrigation demand and has been produced to technically support the HWP resource consent application. The activities to which this report relates are:

- ✦ The storage for irrigation purposes of up to 7.3 million m<sup>3</sup> of water in Seven Hills and up to 3.9 million m<sup>3</sup> of water in Inches Road reservoir.
- ✦ Use of water to irrigate 6,900 hectares within a command area of 8,600 hectares.

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In this report the effects of the activities are assessed, and explanations of what changes may arise in the hydrology of the Hurunui and Waitohi Rivers as a result of these activities are given. The scale and significance of these effects are reflected in the level of detail provided within each section of the report. Measures to avoid, remedy or mitigate any potentially adverse effects of the project operation are also indicated.

## 2.0 Description of the Irrigation Scheme

### 2.1 Physical Description

The scheme area is defined as the area that will be serviced by water from the irrigation supply network. The total area covered (gross irrigable area) is approximately 8,600 ha as shown in Appendix A, Figure A1. Some of the farmland in this area will not be irrigated as the gross irrigable area will be larger than the net irrigable area.

Table 1 provides a summary of the irrigable areas as identified by a Project Team that was set up for the project. The gross and net irrigable areas reported in Table 1 are based on the District Scoping Report (Tonkin & Taylor, June 2004). In this report it was assumed that 20% of the gross area would not be irrigated to account for hardstand areas, shelter belts and other non-irrigable areas. Taking these considerations into account the net irrigable area will be 6,900 ha, and demands have been developed accordingly.

<b>Irrigation Area</b>	<b>Gross Irrigable Area (ha)</b>	<b>Net Irrigable Area (ha)</b>
Hawarden north of Waitohi River	3,955	3,160
Hawarden south of Waitohi River	4,670	3,740
<b>Total area</b>	<b>8,625</b>	<b>6,900</b>

For the purpose of this assessment it has been assumed that spray irrigation will be adopted throughout.

For this project it has been assumed that the area will be used for dairy farming, with demands calculated accordingly. This assumption is conservative and maintains the capacity to irrigate almost any other crop in the future.

### 2.2 Storage Reservoirs

As explained above storage for irrigation will be provided by two storage reservoirs in the Waitohi River. Table 2 provides details of the proposed dam sites.

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Dam	Crest RL (m)	Top Water RL (m)	Dam Height (m)	Draw- down (m)	Live Storage Volume (MCM)	Peak Outflow (m <sup>3</sup> /s)
Seven Hills	405	400	46	20	7.3	3.9
Inches Road	375	370	31	20	3.9	3.9
<b>Total</b>					<b>11.2</b>	

The main storage reservoir will be Seven Hills with an operating level in the range of 380-400 m RL, and a live storage of 7.3 million m<sup>3</sup>. The operating range of the Inches Road storage reservoir will be 20 m which will provide a live storage of 3.9 million m<sup>3</sup>.

### 2.3 Water Take for Proposed Scheme

The water requirements for on-farm use are based on a peak daily water application rate of 0.45 L/s/ha. An allowance has been made in this assessment for 20% loss of flow to account for losses from the races and other on-farm losses. For 6,900 hectares of spray irrigation the total maximum demand is 3.9 m<sup>3</sup>/s.

The actual requirements for irrigation will depend upon the environmental conditions prevalent at the time and will vary between zero and the maximum value above of 3.9 m<sup>3</sup>/s. In Table 3 details of the proposed intakes are summarised.

Intake	Intake No.	Intake RL (m)	Max. Flow (m <sup>3</sup> /s)	Comment
Hurunui River (at Mandamus) <sup>(1)</sup>	1	305.0 or 280.0	3.9	To supply run-of-river water to the distribution system.
Waitohi River <sup>(2)</sup>	2	305.0 or 280.0	3.9	To supply the distribution system from Waitohi Storage.
<p>(1) This may also be a point of discharge from Waitohi Storage to supply irrigation to the north of Hurunui River.</p> <p>(2) Up to 3.9 m<sup>3</sup>/s may be left in the river here to augment the main drying reach of the Waitohi River</p>				

The intake on the Hurunui River (Intake 1) will supply Hurunui run-of-river water to the irrigable area as shown in Appendix A, Figure A1. A flow of up to 3.9 m<sup>3</sup>/s may be left in the river to provide a variable flow in the Waitohi River from this point. This water will be

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taken out further downstream to provide the lower end of the irrigable area with irrigation water. At this stage the distribution network is unknown and further detail on the effects of the Waitohi River downstream of the Waitohi River intake (Intake 2) will be provided when HWP is applying for the consents associated with the distribution network.

The Waitohi River Intake (Intake 2) will also supply stored Waitohi water to the irrigable area at the maximum flow rate shown in Table 3.

A more detailed description of the operation of the scheme is provided in Section 3.0.

## 2.4 Availability of Water

### 2.4.1 Hurunui River

The rate at which run-of-river water can be abstracted is subject to the Hurunui River flow allocation rules. Currently there are three flow regimes (sets of rules) operative for the Hurunui River: the 1980 Plan Water Allocation regime (1980 Plan), the Balmoral Irrigation Scheme regime and the modified Mosley Regime (Familton, July 2007). It is recognised by Environment Canterbury (ECan) that having three different flow regimes is not desirable and a new Hurunui River Flow Regime was notified by ECan (Variation 8) in 2008. Variation 8 was withdrawn and recently a draft of the proposed Hurunui and Waiau River Regional Plan (August 2011) was released which proposes a new flow regime for the Hurunui River. This plan has a proposed pre- and post-storage flow regime. The pre-storage flow regime is applicable when the storage capacity is less than 20 million m<sup>3</sup> and the post-storage flow regime applies when the storage capacity exceeds 20 million m<sup>3</sup>. The proposed pre-storage flow regime is the relevant flow regime for stage 1 of this project since the proposed storage has a total capacity of less than 20 million m<sup>3</sup>. Table 4 shows the minimum flows for each of the existing flow regimes (A-block) together with the "Proposed Regional Plan pre storage flow regime".

Table 4: Minimum Flow for the 1980 Plan, Balmoral Irrigation Scheme, Modified Mosley and Regional Plan Pre-Storage Flow Regimes.												
Flow Regime	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b>1980 Plan</b>	10	10	10	10	10	10	10	11	13	17	16	11.5
<b>Balmoral Irrigation Scheme</b>	12	12	12	12	12	12	12	13	15	19	18	13.5
<b>Modified Mosley</b>	15	12	15	15	15	15	15	15	20	20	20	20
<b>Regional Plan Pre Storage</b>	15	12	12	12	12	12	12	13	15	15	15	15

In addition to these minimum flows the 1980 Plan Water Allocation regime has a 1:1 flow sharing provision which limits the proportion of the available flow that can be abstracted

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at flows above the minimum flow. All other flow regimes presented in Table 4 do not have a sharing regime above the minimum flow.

This AEE is based on the "Proposed Regional plan pre storage flow regime" since this is the most recent flow regime and is the one with which the proposed irrigation scheme will comply.

The "Proposed Regional Plan pre storage flow regime" sets monthly variable A-and B-block allocation limits for the Hurunui River. Table 5 shows the proposed flow regime as set out in the Proposed Regional Plan.

Based on recent discussions with the Amuri Company Ltd it is assumed that A-block water from their existing A-block consent (i.e. 5 m<sup>3</sup>/s) may be able to be used to irrigate the command area for stage 1 when it is not being used by the Amuri Scheme. In other words the Amuri Scheme will irrigate their land first and if there is no demand or if the demand is less than 5 m<sup>3</sup>/s this 'surplus A-block water' is available to irrigate the command area on the south side of the Hurunui River. There is a possibility of releasing irrigation water from Waitohi storage to increase the reliability of the existing Amuri Scheme.

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Table 5: Proposed Hurunui and Waiau Regional Plan "Pre-Storage" Flow Regime (m <sup>3</sup> /s)											
Month	Minimum flow for A permits	Allocation limit for A permits	Flow for 100% use of A water	Gap between A and B	Minimum flow for B permits	Allocation limit for B permits	Flow for 100% use of B water	Minimum flow for C permits	Allocation limit for C permits	Flow for 100% use of C water	Total Allocation
January	15	6.2	21.2	5.8	27	10	37	n/a	n/a	0	16.2
February	12	6.2	21.2	8.8	27	10	37	n/a	n/a	0	16.2
March	12	6.2	18.2	8.8	27	10	37	n/a	n/a	0	16.2
April	12	6.2	18.2	8.8	27	10	37	n/a	n/a	0	16.2
May	12	6.2	18.2	0.8	19	10	29	n/a	n/a	0	16.2
June	12	6.2	18.2	0.8	19	10	29	n/a	n/a	0	16.2
July	12	6.2	18.2	0.8	19	10	29	n/a	n/a	0	16.2
August	13	6.2	19.2	0.8	20	10	30	n/a	n/a	0	16.2
September	15	6.2	21.2	5.8	27	10	37	n/a	n/a	0	16.2
October	15	6.2	21.2	5.8	27	10	37	n/a	n/a	0	16.2
November	15	6.2	21.2	5.8	27	10	37	n/a	n/a	0	16.2
December	15	6.2	21.2	5.8	27	10	37	n/a	n/a	0	16.2

### 2.4.2 Waitohi River

The current minimum flow site for the Waitohi River is located just above the Hurunui confluence and was set by the Hurunui River Water Management Plan (1980) at 350 L/s. In February 2008 Environment Canterbury reviewed the minimum flow and minimum flow site and in their '*Draft Flow and Allocation Regime: Waitohi River, Sheep Dip Creek and Washpen Stream report*' (Familton, 2008) they comment that '*the current minimum flow site is inappropriate because the flow is coming from surfacing groundwater sourced from the Hurunui not directly from the flow in the Waitohi River. A new minimum flow site is needed and the site identified, that would be useful for this purpose, is one above all the takes at Lake Sumner Road Bridge at NZMS 1 M33:713 166*'. To help improve the overall management of this water resource a permanent flow recorder site was installed at Lake Sumner Road Bridge in December 2007.

In summary the draft report mentioned above (Familton, 2008) recommends that the minimum flow site for the Waitohi River should be the Lake Sumner Road Bridge with a recommended minimum flow of 100 L/s in summer (1 October to 30 April) and 130 L/s in winter (1 May to 30 September).

The recommended summer minimum flow of 100L/s is based on the NIWA (2004) guidelines of 80% of the 7-day Mean Annual Low Flow (7D-MALF) whereas the winter minimum flow is based on the 7D-MALF. For a full discussion on Waitohi in-stream values and the considerations which lead to these minimum flow recommendations the reader is referred to the Hamilton (2008) ECan Draft Planning Report and the Gabbites (2006) Low Flow Report.

For this application it is proposed to set a conservative minimum flow release of 250 L/s at the outlet of Inches Road Reservoir (approximately 3 km upstream of Lake Sumner Road Bridge). This minimum flow is significantly higher than the estimated 7D-MALF (124 L/s, Gabbites, 2006). Based on the assumption that existing takes will become part of the scheme (see section 2.5) this will result in continuous flow in the naturally drying reach of the Waitohi River except when the reservoirs are at its lowest operating levels.

## 2.5 Existing Water Takes

Currently the natural hydrology of the Hurunui River has only been modified by abstractions below the Mandamus River confluence. Based on resource consent data supplied by Environment Canterbury the current abstractions in the Hurunui River catchment can be summarised as follows:

- There are currently 127 water permits that authorise the abstraction of surface water and hydraulically connected groundwater from the Hurunui River and its tributaries. An additional 6 applications for water permits are in process as at August 2011. A list with all current abstractions is included in Appendix C.

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- The sum of all surface water allocations for all surface water bodies in the Hurunui Catchment is approximately 11 m<sup>3</sup>/s.
- Apart from a small amount of domestic and stock water use, the demand for water from these existing takes is to provide an irrigation water supply.
- Current main stem allocation totals around 7.9 m<sup>3</sup>/s with the Amuri Irrigation Company Ltd taking 5.0 m<sup>3</sup>/s and other irrigators taking a sum total of 2.9 m<sup>3</sup>/s. A total of 6.2 m<sup>3</sup>/s is taken above the Pahau confluence and 1.7 m<sup>3</sup>/s downstream in the Domett Plains reach.
- The largest take is by the Amuri Irrigation Company Ltd which takes 5 m<sup>3</sup>/s from the Hurunui River just below the Mandamus River confluence.
- Current allocation in the Waitohi River totals 275 L/s, however only 3 takes have a minimum flow condition attached to the consent. These 3 takes have a total allocation of 102 L/s.

It is expected that consent holders in the area will buy into the scheme. A large proportion of the existing irrigators in the Waitohi River are already shareholders in the scheme and based on discussions between HWP and shareholders (with existing consents) this is considered a reasonable assumption. For the purposes of modelling it is assumed that they will be part of the scheme. The three takes with a minimum flow condition attached to the consent all have their irrigable land within the stage 1 command area.

### 3.0 Operating Rules for the Proposed Scheme

In broad terms the storage scheme consists of an intake on the Hurunui River and two reservoirs located in the Waitohi catchment (See Figure A2). Run-of-river water will be abstracted from the Hurunui River and Waitohi River water is harvested into the reservoirs subject to maintaining a minimum flow at the outlet of Inches Road reservoir.

The natural flow regime of both rivers would be altered by abstracting water and harvesting water into storage. Water is released from the storage sites into the distribution network to supply water to the irrigation scheme.

Seven Hills Reservoir is used as the primary source of water with the Inches Road Reservoir being used for irrigation in years when irrigation demand from storage is above average.

For the modelled 6,900 ha scheme, the peak daily irrigation demand is 3.9 m<sup>3</sup>/s or 0.337 million m<sup>3</sup> per day. Table 6 summarises the storage capacity of each reservoir together with the number of days each reservoir can meet the peak demand.

Table 6: Storage Capacity		
Storage Reservoir	Storage capacity m <sup>3</sup>	Number of days reservoir can meet peak demand
Seven Hills	7.3 million	21
Inches Road	3.9 million	12

Table 6 only provides an indication of the storage capacity and is a simplification of the supply-storage-demand situation when the scheme is operating.

The amount of storage available and required for irrigation will depend on the amount of inflow into the reservoirs and the availability of run-of-river water from the Hurunui River which is highly variable as a result of its dependence on Waitohi River and Hurunui river flows.

The scheme is proposed to operate subject to the following rules:

- On days when there is an irrigation demand, water is first abstracted from the Hurunui River intake (intake 1 on Figure A2). The run-of-river abstraction is subject to the minimum flow and allocation conditions of the "Proposed Regional Plan pre-storage flow regime".
- When there is a deficit in run-of-river supply (i.e. demand cannot be met by run-of-river alone), water is released from the storage reservoirs into the Waitohi River and taken out again further downstream at the Waitohi River intake (intake 2).

The intake on the Hurunui River (Intake 1, see Figure A1) will provide run-of-river water to the irrigable area. For the purpose of this modelling exercise it is assumed that the canal will be at the 305 m RL contour and that it will be designed to convey flows in both directions to ensure that it can be used to supply the irrigable area with run-of-river water

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from the Hurunui River but also to allow the irrigable area to be supplied with water from the Waitohi Reservoirs during times of low river flows in the Hurunui River. This canal may also be used to convey water from Waitohi Storage to supply irrigation to the area north of the Hurunui River (For example to top up the reliability of the existing Balmoral Scheme).

### 3.1 Irrigation Season

The irrigation season is taken to be 1 October through to 1 May. This is the standard irrigation season, however if the soil moisture levels are low in September or May it is assumed that irrigators will want to irrigate and in these years the irrigation season is extended to include September and/or May. Generally irrigation demand is relatively low in September and May and therefore all graphs and associated statistics which refer to the irrigation season are based on the standard irrigation season of 1 October through to 1 May.

## 4.0 Description of the Environment

### 4.1 Location

The gross irrigable area to which this application relates is approximately 8,600 ha as shown in Appendix A, Figure A1.

### 4.2 Climate

The climate in this area is similar to the Canterbury plains with a fairly consistent rainfall from month to month and a seasonal variation in temperature and evapotranspiration. Table 7 shows the mean monthly rainfall, evapotranspiration and temperature for the command area.

Table 7: Monthly Rainfall and Evapotranspiration Data for the Command Area			
Month	Rainfall <sup>1</sup> (mm)	Evapotranspiration <sup>1</sup> (mm)	Temperature <sup>2</sup> (°C)
January	44	132	17.25
February	49	102	16.89
March	53	82	14.66
April	50	48	11.68
May	52	28	8.36
June	57	20	5.75
July	66	20	5.27
August	66	33	6.80
September	58	57	9.32
October	61	88	11.34
November	52	108	13.05
December	54	127	15.86
<b>Average</b>	<b>662</b>	<b>845</b>	<b>11.35</b>
<p>(1) Based on synthetic daily rainfall and PET data from 1972 to 2011 produced by NIWA on a 5km x 5km grid.</p> <p>(2) Based on data from Culverden climate station from 1983-2011 (NIWA agent number 4527). This is the climate station with temperature data closest to the command area.</p>			

It is assumed that there is no spatial variation in rainfall and evapotranspiration within the command area.

### 4.3 Climate Change

As recognised in the report '*Climate Change Effects and impacts Assessments, A Guidance Manual for Local Government in New Zealand 2<sup>nd</sup> Edition*' (Ministry for the Environment, 2008) there is a lot of uncertainty associated with developing projections of future climate changes. However an indication of what is likely to happen in New Zealand and on a more regional scale has been described in the report mentioned above. A summary of this report with relevant information for the Hurunui Catchment has been given by Gareth Renowden in his evidence for the Hurunui Water Conservation Order (March 2008). In addition McKercher and Henderson (2003) researched shifts in flood and low flow regimes in New Zealand rivers associated with the shift in phase of the Interdecadal Pacific Oscillation (IPO). This section provides a summary of the available information on climate change relevant to the Hurunui Water Project and is primarily drawn from the three sources mentioned above.

Global warming and the climate change it brings are caused by the build-up of greenhouse gases in Earth's atmosphere. NIWA have recently modelled the expected temperature increase for New Zealand based on global climate models (GCMs). The projections for Canterbury are for an increase in average temperature of 0.9 °C by the 2040's and 2.0 °C by the 2090's. Rainfall is projected to decline only slightly at Christchurch and Hanmer, but increase by up to 8% at Tekapo. This reflects the trend towards increasing rainfall on the West Coast and at the Main Divide as a consequence of increasing westerly winds. The expectation is that flows in Canterbury rivers that have their catchments at or near the Main Divide will increase, and the incidence of drought will increase nearer to the coast. This would be in effect an intensification of the frequently observed pattern of "northwester" conditions in Canterbury: plenty of water in the rivers while surrounding farmland is dry.

Climate change associated with the Interdecadal Pacific Oscillation (IPO) however indicates a different trend. McKercher and Henderson (2003) have researched shifts in flood and low flow regimes in New Zealand rivers associated with the shift in phase of the IPO that occurred in 1977/1978. They found that flood and low flow regimes for many rivers were different in the periods 1947-1977, and 1978-1999, and that since 1999 there may have been a shift back to the 1947-1977 pattern.

The results of this study showed that there was no significant change in flood flows for the Hurunui River between the 1947- 1977 period and the 1978 – 1999 period. More importantly however the low flows in the Hurunui River were significantly higher over the 1978-1999 period (Increase of the order of 10 – 15 % in the medians of the low flow). At the time of writing this study, however, it is not clear whether the IPO moved to a state similar to that which prevailed for 1947-1977. If the IPO does move back to this state

then low flows in the Hurunui River may be more of a constraint on water supply in the coming decades.

In summary there are two processes which potentially affect future climate change in the project area. Climate change associated with global warming predicts a different effect on Hurunui River flows than climate change associated with the Interdecadal Pacific Oscillation. It is therefore difficult to predict the effect of climate change on flow in the Hurunui River and on the availability of run-of river water. However research does indicate that temperatures are expected to rise in the coming decades and that the incidence of droughts in the lower Hurunui catchment is likely to increase. This may warrant a conservative approach on required storage volumes.

#### 4.4 Soils

Figure A3 shows a map with the soils in the command area. The majority of the soils in the Command area are identified as Balmoral, Glasnevin and Waimakariri silt loam, stony silt and sandy loam, (Sheet 6, Soil map of the South Island, DSIR, 1968).

Table 8: Soils Characteristics of the HWP Command Area		
<b>Id</b>	<b>Soil Name</b>	<b>Soil Description</b>
13a	Glasnevin	Stony sandy loams, silt loams and shallow silt loam
13b	Balmoral	Mostly stony silt loams, some sandy loams
14b	Culverden	Mostly silt loams, stony silt loams
95a	Waimakariri Shallow	Sandy loams to silt loams; shallow and stony loams
18d	Domett	Mainly silt loams
15e	Waipara	Mainly silt loams, some shallow silt loams
89	Temuka	Silt loams to clay loams, some peaty loam topsoils
16fH	Tipapa Hill Soils	Mostly silt loams

#### 4.5 Hurunui Catchment

##### 4.5.1 General Catchment Description

Several reports describe the hydrology of the Hurunui catchment in detail. The most notable reports include Mosley (January 2002), Facer (2003), Bowden (1977) and Morland (1994). This description of the Hurunui catchment draws on information from these reports and available flow data from recorder sites in the Hurunui catchment provided by ECan.

The total Hurunui River Catchment area is approximately 2,671 km<sup>2</sup> and is bounded by the Waiau catchment to the north and the Waimakariri, Ashley and Waipara catchments to the south. The catchment of the Hurunui River is shown in Figure A4.

The river has two main branches upstream of the Hurunui/Mandamus confluence, these being the North Branch including Lake Sumner and the Hurunui South Branch. Lake Sumner influences the magnitude and duration of flood flows moving down the North Branch. The peak of a flood is lowered as water passes into storage and the rate of recession decreases as water is released from storage after the peak has passed. Both branches have their headwaters in the Southern Alps but the North Branch has a significantly greater portion of its area in the Alps. There are numerous alpine, foothills and lowland tributaries. Both branches flow through dry, extensively grazed grass and shrublands before forming a single channel as far as the Amuri plains. There the river becomes braided, and with the exception of a gorge through the Lowry Peaks Range, remains so to the sea.

Some of the water balance in the Culverden area has been modified by existing irrigation schemes. Some formerly dry streams now carry water. The river enters the Pacific Ocean approximately 11 km south of Cheviot and the river mouth is narrow, having no delta or mudflats.

Elevations in the Hurunui catchment range from 0 m at the River mouth to 1980 m at its headwaters. The catchment has one extensive flat area, the Amuri Plains, formed by broad coalescing glacial outwash fans. The plains lie between the Main Divide and the coastal hills and vary in elevation from 150-275m. Some 44.5 percent of the catchment is at an elevation less than 400 metres and 8 percent of its headwater area is at elevations in excess of 1500 m.

Hydrologically the catchment contains three regions:

- ✦ The Eastern Alps region covers the upper reaches of the catchment, characterised by prevailing winds from the west and highest rainfall.
- ✦ The Canterbury Plains hydrological region covers the area of the Amuri plains. This is the area of lowest rainfall and small surface runoff especially in the summer months.
- ✦ The Hurunui hydrological region, which comprises the rolling hill country and includes some of the ranges just east of the main divide. Average annual precipitation is of the order of 800 - 2,000 mm.

Figure A5 is an isohyetal map which shows average annual rainfall totals within the Hurunui catchment sourced from NIWA. Rainfall ranges from around 6000 mm/year in the Southern Alps to around 700 mm in the Amuri Basin. Most of the rain in the catchment occurs with north-westerly rains resulting in heavy falls over and just east of the Divide. The isohyetal map indicates a rapid decrease in rainfall totals with distance further east of the divide.

#### 4.5.2 General Catchment Description: Waitohi River

The Waitohi River is part of the Hurunui catchment and at the confluence with the Hurunui River it has a total catchment area of approximately 285 km<sup>2</sup>. The catchment is bounded by the Hurunui River catchment to the north, Seaward River to the west and the Waipara catchment and Waikari catchment to the south (See Figure A4). The Waitohi River leaves the hills at Lake Sumner Road Bridge and is a braided shingle river where it flows through the Amuri Plains. Elevations in the Waitohi catchment range from approximately 190 m at the confluence with the Hurunui River to approximately 1300 m at its headwaters.

The isohyetal map of the Hurunui catchment (Figure A5) shows that rainfall in the Waitohi catchment ranges from around 1600 mm/year in the upper catchment to around 700 mm/year in the Amuri Basin.

The most recent hydrological report on the Waitohi River is the Facer (2006) report. This report reviews the low flows in the Waitohi River at several different locations. Figure A6 shows the estimated natural gains and losses at and downstream of Lake Sumner Road Bridge under 7D-MALF conditions (copy from Facer, 2006 report). The estimated 7D-MALF and mean flow for each location is summarised in Table 9 below.

Table 9: Estimated Natural 7D-MALF and Mean Flow for Waitohi River Sites (L/s )			
Waitohi River Site Name	Catchment Area above site (km <sup>2</sup> )	2006 estimate of 7D-MALF	Estimated Mean
Lake Sumner Road Bridge	128.7	124	1310
Powers Road Bridge	139.4	103	1349
Bakers Road Ford	154.9	0	1330
Medbury Road (Upstream) Bridge	157.4	19	1242
State Highway 7	256.8	182	1927
1.6km Upstream Hurunui River confluence	268.1	338	1756

Figure A6 and Table 9 shows that during 7D-MALF conditions the main losing reach is between Powers Road Bridge and Bakers Road Ford and that downstream of Bakers Road Ford the Waitohi River starts to gain flow again. The main gaining reach is between Medbury Road Bridge and State Highway 7. Even though Figure A6 only shows the natural losses and gains during 7D-MALF conditions the Facer (2006) report comments that the losses between Powers Road and Bakers Road are very similar in winter and summer. The gains for the main gaining reach (between Medbury Road Bridge and State Highway 7) are generally higher in winter months due to higher flows in winter forcing the average values higher.

The mean flows tend to increase with distance downstream of Lake Sumner Road Bridge, especially downstream of the confluence with Washpen Stream (see Figure A8).

In summary the relevant conclusions from this report are:

- ✦ The Waitohi River flow disappears subsurface through its middle reaches, and would have done naturally, pre irrigation. The flow emerges again between the Medbury Road Bridge and the State Highway 7 site.
- ✦ Assuming natural conditions, the flow at the Lake Sumner Road Bridge would have to be in the vicinity of 150 L/s for there to be a flow of about 25 L/s at Bakers Road.

#### 4.5.3 Sub-Catchments and Flow Characteristics

There are a number of river flow recorder sites in the Hurunui catchment. The relevant sub-catchments with recorder sites relevant to this application are included in Table 10 together with their catchment areas, specific discharge and key flow statistics. The sub-catchment areas are shown in Appendix A, Figure A4. Comments on the record period and flow data for each of the recorder sites are included in Appendix C. The statistics provided in Table 10 provide an indication of the differences in flow characteristics between the sub-catchments of the Hurunui River. The Hurunui River at State Highway 1 flow recorder is downstream of most of the abstractions for irrigation, so flows will be modified and do not reflect the natural flows in the Hurunui River at this site.

It should be noted that the significantly differing record lengths for these sites means that comparisons are for indicative purposes only.

Recorder Site	Catchment Area (km <sup>2</sup> )	Specific Discharge (L/s/Km <sup>2</sup> )	Flow (m <sup>3</sup> /s)					
			Mean Flow	Median Flow	7-Day MALF	Lower Quartile	Upper Quartile	Mean Annual Flood
Hurunui at Mandamus	1070	49.0	52.5	39.2	17.3	27.4	61.0	523.9
Hurunui at State Highway 1	2518	28.7	72.2	55.7	21.4	37.4	83.6	756.2
Mandamus at Tekoa Road Bridge	160	25.6	4.1	1.80	0.49	0.87	4.00	156.67
Waitohi at Lake Sumner Road Bridge	122	11.4	1.390	0.396	0.076	0.150	1.416	59.776

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With rainfall totals rapidly decreasing in the catchment area downstream of the Hurunui at Mandamus flow recorder (See Figure A5) the specific discharge decreases as well. State Highway 1 has a specific discharge of 28.7 L/s/km<sup>2</sup> substantially lower than the Hurunui at Mandamus flow recorder. The Waitohi River at Lake Sumner Road Bridge only has a specific discharge of 11.4 L/s/km<sup>2</sup>. The relatively low specific discharge (compared to the Hurunui River main stem recorder sites) is largely due to the Waitohi catchment not receiving spill-over rainfall during northwest storms. This is reflected in the mean annual rainfall totals for the catchment as shown in Figure A5.

#### 4.5.4 Seasonal Flow Variability

As mentioned before most of the flow of the Hurunui River as it enters the scheme area is derived from precipitation in the upper catchment. In winter, much of this falls as snow, and this is not released to the river until spring. Therefore there is strong seasonality in the typical pattern of river flow, with higher flows from September to December. The summer and autumn months of February to April have the lowest flows. Table 11 summarises the mean monthly flows for the Hurunui at Mandamus recorder site.

Table 11: Mean Monthly Flow for the Hurunui at Mandamus (1956-2011) Recorder Site	
Month	Mean Monthly Flow Hurunui at Mandamus (m <sup>3</sup> /s)
January	47
February	34
March	33
April	39
May	50
June	52
July	51
August	55
September	65
October	79
November	70
December	56
<b>Yearly average</b>	<b>53</b>

Flood flows can occur at any time of the year in response to heavy rainfall in the catchment but typically the months with the largest floods are August – December. February and March are least influenced by floods.

## 5.0 Model Methodology

### 5.1 Modelling Approach—General Overview

The water balance/irrigation demand model was coded in Matlab, a programming language used in scientific and engineering research and design. The model integrates hydrology and water balance with irrigation demand and is driven by hydrological input data and irrigation demand.

The immediate benefit of this integrated approach is that interaction between the hydrological and irrigation components occurs within model simulations avoiding the need for information transfer between different programmes, which is both computationally inefficient and limits output.

Figures A1 and A2 show the proposed scheme area with the proposed storage sites and intake locations. The principal hydrological input data are the inflows into the reservoirs and the Hurunui at Mandamus flow series.

To model irrigation demand it was assumed that the scheme area may be divided into 4 soil types with different water holding capacities. Representative evapotranspiration and rainfall data sets have been used to update daily soil moisture content.

All irrigation areas are assumed to be spray irrigated. The following irrigation rule has been assumed for areas which are spray irrigated: a sub-area has an irrigation demand when the soil moisture balance for that area falls below 55% of the PAW (profile available water), and the daily irrigation demand continues until the PAW is reached.

The way the hydrological routing has been coded is as follows: for a given reservoir and period when water is harvested into storage (from the Waitohi River), it has been assumed that all inflow into the storage reservoirs is harvested subject to maintaining an environmental flow condition at the outlet of Inches Road reservoir. If the natural flow is less than the environmental flow (of 250 L/s), and stored water is available in the reservoirs, a release is made to meet the environmental flow condition. This modified flow is reflected in the Waitohi River downstream of Inches Road Reservoir.

If there is an irrigation demand, water is first abstracted from the Hurunui River flow. If there remains a deficit, water is released from the storage reservoir(s) into the Waitohi River and taken out further downstream at the Waitohi River intake (intake 2) to satisfy the irrigation demand.

It is important to recognise that the current model works on a daily timestep - all inputs are given as daily totals/averages. As a consequence it is not possible to simulate effects that occur on a much finer time scale, e.g. continuous time flow variability.

## 5.2 Simulation Period

Based on the availability of flow and environmental data, the simulation period was chosen to be 1972-2011. This was the longest period for which the flow record at the Hurunui at Mandamus flow recorder overlaps the environmental data (evapotranspiration and rainfall). The flow data includes extremely dry years (e.g. 1972, 2008), 'average' and 'wet' years, and therefore the effects of the scheme over a range of extreme and average conditions are able to be simulated.

The flow series for the Waitohi River are (partly) synthetic. The available historical flow record for the Waitohi River has been extended to the simulation period 1972-2011. Further details are given in section 6.4.1 and in Appendix D on how the hydrological inputs were synthesised.

## 5.3 Irrigation Efficiency

The proposed scheme uses predominantly canals to convey water to the farms and then spray irrigation methods to apply the water to the farm paddocks. As the proposed scheme will have a canal distribution system and will consist of spray irrigation there are two main areas of losses within the system. The canal network will have some leakage of water to ground and evaporation from the water surface. Typically losses from open races can be expected to be around 10% (McIndoe 2002). The second area of losses will occur from the canal farm intake to the farm paddock. Again approximately 10% losses are expected due to leakage and evaporation within the farm distribution systems. Therefore a total loss of 20% has been adopted for this scheme.

## 5.4 Hydraulic Assessment: Flow Ramping

The proposed irrigation scheme will involve abstractions and flow releases in existing waterways (Hurunui and Waitohi Rivers). These changes in flow (termed "flow ramping") may occur within relatively short periods of time and could result in rapid changes in water level in downstream affected reaches.

The effects of flow ramping on water levels and cross sectional areas have been assessed by making use of a hydraulic model, developed using the HEC-RAS software. This model was built specifically for the purpose of these flow ramping assessments, and is not necessarily an appropriate tool for use for other assessments. As a result it lacks resolution in some areas, where deemed not necessary for the purpose of the flow ramping assessments.

The model was constructed from assessments of cross section, bed slope and channel roughness. A site visit was required to assess specific parameters at the assessment locations. For the purpose of this assessment the rise and fall in discharge and water level has been controlled by ramping over 30 minutes.

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Model runs were conducted at minimum flow rates, with ramping applied for various scenarios. These flow change locations (as shown in Figures A1 and A2 and as described in Table 3) are as follows:

- An intake on the Hurunui River at 305.0 m RL or 280.0 m RL to supply run-of-river water to the distribution system (Intake no. 1). A flow change of up to 3.9 m<sup>3</sup>/s may occur at this point.
- An intake on the Waitohi River at 305.0 m RL or 280 m RL to supply water released from storage into the distribution system (Intake no. 2). The proposed abstraction rate at this location is up to 3.9 m<sup>3</sup>/s.

For the sake of simplicity, the flows in both the Hurunui River and the Waitohi River for all assessments was not increased with distance downstream (in reality this does occur due to tributary inflows), meaning that assessments at downstream locations are conservative in that the effects have been assessed against smaller flows than would actually exist.

Assessment locations were selected based on likely positions for recreational use and accessibility, as well as those locations being most affected by the proposed changes (immediately downstream of abstraction locations). These assessment locations are detailed in Table 12 below.

Location	Description	Model Chainage (m)
W1	Powers Road, Waitohi River	20,700
H5	The Peaks, Hurunui River	18,420
H6	Downstream of SH7, Hurunui River	1,360

## **6.0 Input Data**

### **6.1 Introduction**

This section provides a more detailed description of the required inputs for the demand and supply model. Some of this information given below will overlap with the information provided in Section 4.0 (Description of the Environment).

### **6.2 Climate**

Limited Potential Evapotranspiration (PET) data exists from a climate station in Culverden and a more extensive series is available at Hanmer, 30 km outside the catchment (Site G22581 and G22582). Due to the distance from the project area and its geographical orientation the data from this site is considered unsuitable to represent potential evapotranspiration (PET) for the potentially irrigable area. The PET data at the Culverden climate station (Site H22783) is too short to be of any practical use.

Two rainfall sites with long term daily rainfall records are available close to the project area. These sites are Riverside (H22781), located close to Rotherham and Waipara, Wattle Grove (H32072) located in Waipara Township. Both records, however, have significant gaps in the data (several months) and are therefore considered unusable as a continuous input series for our model.

Synthetic daily rainfall and PET data is available from 1972 to date produced by NIWA on a 5km x 5km grid. This data has been produced by spline interpolation using all short and long term climate data available in the area and also takes into account other factors such as topography. These daily time series are considered the best available continuous long term dataset in the project area. Table 13 provides a summary of the PET and rainfall within the command area. Between brackets the average rainfall totals are shown for the Glenallen rainfall station (agent H22961) which has relevant long term rainfall data available between 1972 and 2011 and is close to the command area.

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and Hydro Scheme

Table 13: Average Yearly Rainfall and Potential Evapotranspiration for Stage 1 Irrigation Area (1972-2011)			
<b>Irrigation Area (ha)</b>	<b>Areas</b>	<b>Average Yearly Rainfall (mm)</b>	<b>Average Yearly Potential Evapotranspiration (mm)</b>
Stage 1 Area	Hawarden North and South of Waitohi River	660 (670) <sup>1</sup>	840
(1) Glenallen (agent H22961)			

It is not expected that there is a large variability in PET and rainfall within the irrigable area, therefore only 1 rainfall and 1 PET series has been used. The data series consist of the average daily rainfall or PET from the NIWA 5km x 5km grid data located within the identified command area.

Immediately identifiable from Table 12 is that average yearly PET exceeds average yearly rainfall in all areas, reinforcing the need for irrigation.

### 6.3 Soils and Water Holding Capacities

Table 8 identifies the soils in the command area and their estimated water holding capacities (WHC) has been taken from the district scoping report (Tonkin and Taylor 2004). The soils have been classed into four different categories based on their estimated Soil Water Holding Capacities for the purpose of modelling irrigation water demand, namely 60, 90, 120 and 150 mm.

The spatial distribution and net areas for the irrigation area are shown in Appendix A, Figure A7 and Table 14.

Table 14: Net Area in Each Soil Water Holding Capacity Category					
<b>Irrigation Area (ha)</b>	<b>Net Area in Each Soil WHC Category (ha)</b>				
	<b>60 mm</b>	<b>90 mm</b>	<b>120 mm</b>	<b>150 mm</b>	<b>Total</b>
<b>Stage 1 irrigable area</b>	1,000	4,550	610	740	6,900

### 6.4 Hydrological Inputs

The hydrological inputs for the model are based on the long term flow series for the Hurunui at Mandamus Flow Recorder (1972 – 2011) and Waitohi at Lake Sumner Road Bridge flow recorder (2007-2011). A 39 year continuous flow series for the Waitohi River is required to enable modelling of the long-term reliability of the scheme and to assess the effects of the scheme over a range of climatic conditions (i.e. wet, average and dry years). Therefore a regression analysis was undertaken with two long-term flow recorder sites. Details of the regression are provided in Appendix D.

In order to determine inflow series for each of the storage reservoirs in the Waitohi River these synthesized long-term flow series were scaled to catchment size. For the Hurunui River two flow series were used to assess the effects of the proposed scheme on different reaches in the Hurunui River.

This section provides a description of the catchment scaling for the Hurunui River and Waitohi River.

#### 6.4.1 Waitohi River Inflows

The synthesized long-term flow series for the Waitohi River was used to determine the inflow series for each of the storage reservoirs as shown in Appendix A, Figure A8. The sub-catchments flowing into each of the reservoirs is shown in Figure A8. A scaling factor for each sub-catchment was determined to account for the area of the Waitohi catchment contributing to each proposed dam site, tributaries downstream of the storage sites and the Waitohi River intake location (intake 2). Scaling factors were found by determining the percentage of catchment that contributes to each site and scaling the synthesised Waitohi River flow at Lake Sumner Road Bridge accordingly. Table 15 below shows the catchment scaling factors used for the Waitohi River inflow series.

Table 15: Waitohi River Catchment Scaling Factors			
	Catchment Area (km <sup>2</sup> )	Scaling Factor	Mean Inflow (m <sup>3</sup> /s)
Seven Hills storage Inflow	100.5	85% <sup>(1)</sup>	1.14
Inches Road storage Inflow	16.6	12% <sup>(1)</sup>	0.16
Tributary below Inches Road	5.3	3% <sup>(1)</sup>	0.05
<b>Total</b>	122.4	100%	1.35
(1) Scaling factor adjusted to account for higher rainfall in the upper parts of the Hurunui Catchment			

The scaling factor was adjusted to account for higher rainfall in the upper parts of the Waitohi catchment and mean flows checked against the estimated mean flows from Gabites (2006) for several different locations in the Waitohi Catchment. For example the estimated mean flow at above Jacks Stream Confluence was estimated by Gabites (2006) at 1.15 m<sup>3</sup>/s. The Seven Hills storage reservoir is located just above Jacks Stream Confluence. The total estimated inflow into the Seven Hills storage reservoirs is 1.14 m<sup>3</sup>/s (see Table 15). These very similar flow estimates provide confidence in the catchment scaling and estimated inflow in the Seven Hills and Inches Road reservoirs.

### 6.4.2 Hurunui River Flows

Measured flows for the Hurunui River are available at the NIWA recorder site "Hurunui at Mandamus" (site number 65104). The natural flows at this site were used to estimate the natural flows at the Hurunui River intake (intake 1). A scaling factor to determine the increased flow at the intake location was determined based on catchment size while taking into account the higher rainfall in the upper parts of the Hurunui catchment. Flow statistics for the Mandamus River at the Tekoa Road Bridge recorder (ECan site 65102) were used to check the catchment scaling factor for the Hurunui River intake (see isohyetal map Figure A5). The Mandamus River is the main tributary flowing into the Hurunui River between the Hurunui at Mandamus flow recorder (site 65104) and Hurunui River intake (Intake 1). Table 16 below shows the catchment scaling factor used for the Hurunui intake site.

Table 16: Hurunui River Catchment Scaling Factors			
	<b>Catchment Area (km<sup>2</sup>)</b>	<b>Scaling factor</b>	<b>Mean flow (m<sup>3</sup>/s)</b>
Hurunui at Mandamus (NIWA site 65104)	1070	100%	54.5
Hurunui at 305 m RL or 280 m RL (intake 1) and existing Amuri intake	1230	108% <sup>(1)</sup>	58.6
(1) Scaling factor adjusted to account for higher rainfall in the upper parts of the Hurunui Catchment			

### 6.5 Natural Flow Characteristics

Summary flow statistics for the modelling period between 1972 and 2011 are shown in Table 17. Note that these flow statistics are slightly different from the statistics provided in Table 10 since they are based on the modelling period of 39 years and not on the (much shorter or much longer) record period from the recorder sites in the catchment.

Recorder Site	Catchment Area (km <sup>2</sup> )	Specific Discharge (L/s/km <sup>2</sup> )	Flow (m <sup>3</sup> /s)				
			Mean Flow	Median Flow	7-day MALF	Lower Quartile	Upper Quartile
Hurunui at Mandamus	1070	50.9	54.5	40.8	16.8	63.7	28.2
State Highway 1 <sup>(1)</sup>	2518	28.7	72.2	55.7	21.4	37.4	83.6
Waitohi at Lake Sumner Road Bridge	122.4	10.9	1.34	0.61	0.12	0.23	1.41

(1) Flow statistics for State Highway 1 are based on actual record period since this data has not been synthesized for the 39 year modelling period.

## 6.6 Hurunui Flow Regimes and Minimum Flow Conditions

It has been assumed that the flow allocation regime for the Hurunui River is given by the 'Proposed Hurunui and Waiau River Regional Plan' as shown in Table 5. For the Waitohi River a minimum flow of 250 L/s has been set downstream of the Lower Gorge 1 Reservoir. This minimum environmental flow of 250 L/s is maintained at all times except when the reservoirs are at their lowest operating level. When the reservoirs are at low inflow equals outflow with modified flows being the same as natural flows.

## 6.7 Existing Balmoral Irrigation Scheme Intake

To estimate the existing flows in the Hurunui River downstream of the existing Balmoral intake, an independent model was constructed to calculate the daily irrigation take at the existing Balmoral irrigation Scheme (BIS) intake location. Measured intake data is available from NIWA (Balmoral Irrigation Intake Race 65103) from 1985 till 2011. Only the last few years of data represent the current irrigation practices with approximately 4200ha of spray irrigation and 1000 ha of border dyke (pers. comm. Norm Williamson, Amuri Irrigation Company Ltd). Therefore it was necessary to create a long term irrigation demand series for the Amuri Scheme which represents the current irrigation practices.

The model assumed that the existing BIS scheme consists of approximately 4200 ha of spray and 1000 ha of border dyke irrigation. Higher losses (30% total losses) were assumed for this model compared to the HWP scheme to account for aged infrastructure and losses associated with border dyke irrigation. The existing BIS flow regime was used in the model with a maximum intake of 5 m<sup>3</sup>/s. The modelled intake was then compared to the most recent measured intake data. Figure 1 below shows the modelled vs.



## 7.0 Reliability of Supply

In estimating the reliability of the proposed irrigation scheme and the corresponding storage volumes it is necessary to consider the physical reality. Flows are subject to considerable variability which results in variability in the availability of run-of-river water for irrigation. Very dry years like 1972 are infrequent, with occurrences in the period 1972-2011 about 10% of the time. During these years there can be significant water deficit and large storage requirements to meet demand. Any reasonable measure of reliability will identify these extreme events.

In a broad sense there are two kinds of storage: short term storage designed to meet demand in 'average' years and bulk storage to meet demand during extreme events. The proposed stage 1 scheme is a short term storage scheme designed to meet demand in average years. This means that in average years the storage will not be drawn right down, with reservoir water levels being able to be maintained within a smaller range than during dry years.

For stage 1 a supply/demand ratio of 93% was used to infer required storage volume and irrigable area. The effects of the proposed scheme are also analysed in terms of effects on soil moisture content and irrigation season duration.

### 7.1 Supply and Demand Reliability

The traditional approach to reliability is based on considering supply and demand: a day is counted as unreliable if there is an irrigation deficit on that day, i.e. supply does not meet demand, all other days are counted as reliable. Different measures of reliability are obtained by using different statistical summaries, some of which are given below:

*Average Reliability:* This is based on the proportion of days over each irrigation year when supply meets demand; average reliability is then defined to be the average over all the irrigation years. The drawback of this commonly used measure is that over a long simulation period, a few 'bad' years when there have been significant numbers of days when there is an irrigation deficit are averaged over, and these effects can be partially concealed.

*Average Supply/Demand ratio:* This is based on the number of days when supply does not meet demand divided over the number of days with a demand over each irrigation year; average supply/demand ratio is then defined as the average over all the irrigation years.

*Full Reliability* considers that an irrigation year is reliable if supply meets demand on all days during the irrigation season. Typically the scheme is said to be fully or highly reliable if 9 out of 10 irrigation years are reliable.

*Consecutive Reliability* is based on counting the number of consecutive days in each irrigation season when supply is less than demand. Under the '10 consecutive day rule' a

scheme is said to be reliable if each irrigation year has no more than 10 consecutive days when supply is less than demand.

Average reliability and average supply/demand ratio corresponds to short term storage described in the previous section while full and consecutive reliability captures the effects of extreme years.

## 7.2 Soil Moisture

Soil moisture reliability considers the effects of the scheme on soil moisture content, and hence measures the real benefits of the scheme. Growth conditions are optimised when the soil moisture content is greater than 50 % of the PAW. The daily soil moisture index for a given soil type is the ratio of the moisture content to the PAW. This is averaged over the soil types to give a daily soil moisture index (SMI) for the scheme. A day is counted as reliable provided the SMI is greater than 50 %. In a good irrigation year the SMI is always greater than 50 %. In extreme dry years the SMI tends to drop off in the second half of the irrigation season. It is therefore interesting to consider the duration for each irrigation season that the SMI is greater than 50 %. These durations are considered in Section 9.0.

## 8.0 Assessment of Environmental Effects

### 8.1 Introduction

This section contains an assessment of the environmental effects of operating the proposed scheme described in the previous sections over the 39 year simulation period. Assuming 20% losses the peak irrigation demand for the 6,900 ha scheme is approximately 3.9 m<sup>3</sup>/s.

The effects of the proposed scheme depend on the operating rules, the irrigation demand and the hydrological conditions. The suggested operating scenario which has been adopted for this modelling is described in Section 3.0. Due to the different storage volumes for each reservoir and the proposed operation of the scheme, the typical effects on each of the reservoirs are distinctly different.

This document contains an assessment of effects with respect to the following:

- Lake levels for the Seven Hills and Inches Road reservoir, outflows at the outlet of Inches Road Reservoir;
- Hurunui River flows;
- Waitohi River Flows.

This assessment of effects is split into two parts. The first part will describe the operation of the scheme and associated effects based on an example year covering the 1981/1982 irrigation season. The second part contains a full description of the effects based on a wet, average, dry and large demand year together with overview statistics and graphs summarising the effects over the full 39 year simulation period. In this second part of the assessment, results are presented that show how the proposed system would have performed had it been in place during the past 39 years. These results are compared against measured parameters over this historic period.

### 8.2 Effects Based on Example Year

The effects of the scheme are highly variable depending on hydrological conditions and irrigation demand, and are best explained by example. The 1981/1982 irrigation year is considered an average year (i.e. not extremely dry or extremely wet) with Hurunui and Waitohi River Flows, irrigation demand and storage reservoir levels around average values.

#### 8.2.1 Effects Downstream of the Existing Amuri Intake

Figure 2 shows the existing and modified flows in the Hurunui River downstream of the Amuri intake (See Figure A2) together with the irrigation demand, run-of-river take and total irrigation release from storage. The graph at the bottom of Figure 2 shows the total storage volume in Seven Hills and Inches Road reservoir over the same period.

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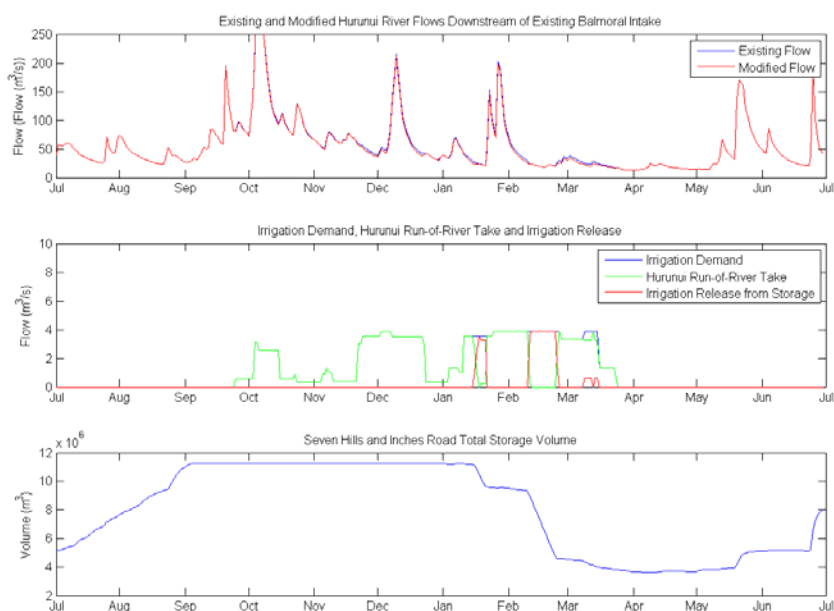


Figure 2: Existing and modified Hurunui River flows downstream of the existing Balmoral intake, Irrigation demand, run-of- river take and storage release, and total storage volume in the reservoirs for 1981/1982.

In this case, irrigation demand starts around the end of September and most of the irrigation demand is met from Hurunui run-of-river water without having to draw from storage. From mid-January through to the end of March river flows in the Hurunui River are low and water needs to be drawn from storage to meet the irrigation demand. The reduction in total storage volume in the reservoirs corresponds to the releases from storage. From the beginning of April the reservoirs start to refill due to inflows from the Waitohi River.

The points to note (for 1981/1982 as an example year) are:

- ✦ From July through to September and again from April through to June there is no change to the existing Hurunui River flows. No water is abstracted from the Hurunui River since there is no irrigation demand in these periods.
- ✦ From October through to March flows in the Hurunui River are slightly lower than existing flows due to run-of-river takes from the Hurunui River intake (intake 1).
- ✦ The low flows in the Hurunui River are protected by the minimum flows and therefore the lowest flows during the irrigation season are unchanged when irrigation demand is met from storage. For the 1981/1982 irrigation season this occurs mid-January and mid-February.

**Flow ramping assessment**

In order to assess the changes in water level likely to accompany changes in flow when abstraction is either started or stopped, a flow ramping assessment has been deemed to be required. When considering the effects due to flow ramping, minimum flows in both the Hurunui and Waitohi Rivers were used in order to gauge the maximum likely effect due to flow ramping. The abstractions were applied individually but with times overlapping such that total and individual effects could be deduced. Effects were assessed in the reach downstream of the existing Balmoral intake (at “The Peaks”) and also at State Highway 7.

Water level time series for The Peaks location are plotted in Figure 3, and those for State Highway 7 are plotted in Figure 4. In these figures the change in water level as the proposed abstraction is started (i.e. flow drop in the river) and successively stopped is plotted with time.

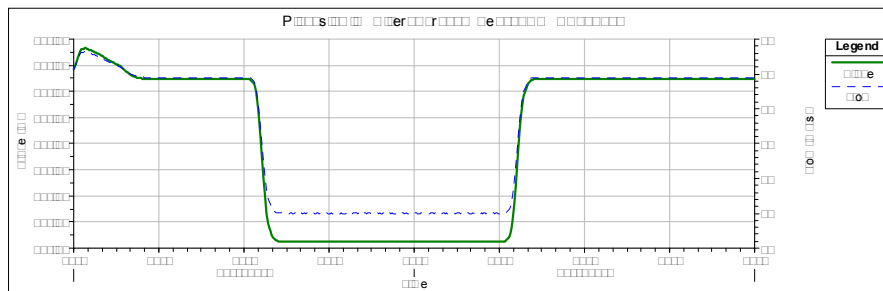


Figure 3: Flow Ramping Effects at The Peaks: Minimum Flow

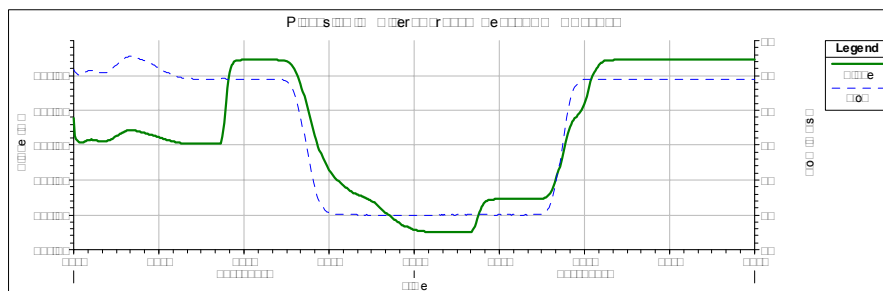


Figure 4: Flow Ramping Effects at State Highway 7: Minimum Flow

In Figure 3 it can be seen that water level at the Peaks starts at 280.69 m and then falls to 280.63 m (a drop of some 60mm) in response to the start of the 3.9m<sup>3</sup>/s abstraction at the Hurunui River intake (Intake 1). Water level rises by the same amount once the abstraction ceases.

In Figure 4 it can be seen that water level downstream of SH7 starts at 190.45 m and then falls to 190.35 m (some 100mm) in response to the start of the combined abstractions from Hurunui River (3.9 m<sup>3</sup>/s) and Waitohi River.

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The rate of rise and fall in discharge and water level has been controlled by ramping over 30 minutes in each case.

The above figures are anticipated to be useful for analyses relating to ecology, recreation and landscape. For example, the rate and magnitude of change in water level as flows are ramped up and down are likely to be required for assessments of safety for anglers using the river, or for available habitat for aquatic fauna.

8.2.2 Effects Downstream of Inches Road Reservoir

Figure 5 shows the natural and modified flows in the Waitohi River downstream of Inches Road Reservoir together with the total irrigation demand and the total storage volume in the reservoirs.

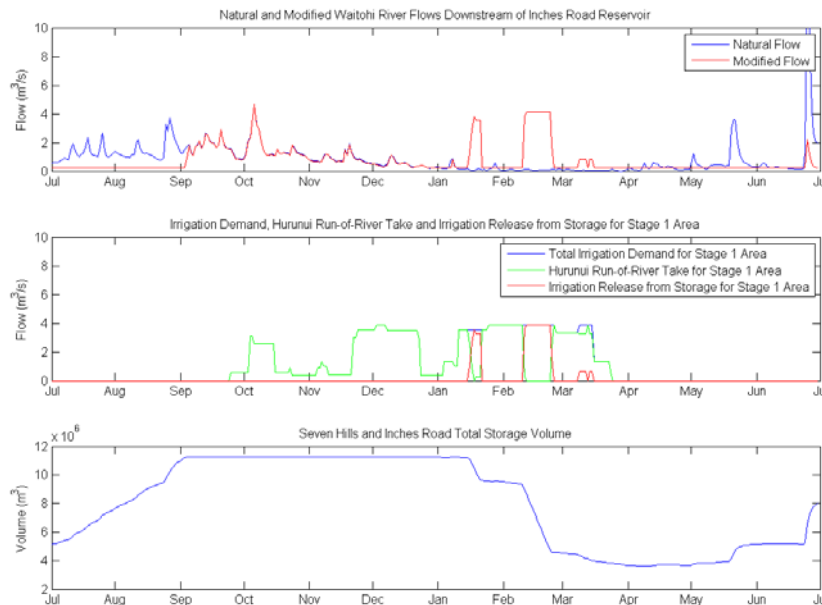


Figure 5: Natural and modified Waitohi River flows downstream of Inches Road Reservoir, Irrigation demand, run-of river take and storage release, and total storage volume for 1981/1982.

Figure 5 shows that the modified Waitohi River flows are lower than the natural flows when Waitohi River flows are harvested into storage and higher than natural flows when water is released from storage to meet irrigation demand, in the low flow summer months.

The points to note (for 1981/1982 as an example year) are:

- From July through to the end of August Seven Hills and Inches Road reservoirs are being refilled and Waitohi River flows are harvested into storage resulting in lower than natural flows in the Waitohi River.

- From the beginning of September through to mid-January the reservoirs are full and the flows are similar to the natural flows.
- From mid-January through to mid-March irrigation releases are made to meet irrigation demand which increases the natural flows by up to 3.9 m<sup>3</sup>/s (maximum irrigation demand). When irrigation demand is met from Hurunui run-of river water flows are stable at 250 L/s.
- From mid-March through to the end of June modified flows are stable at 250 L/s. In March the modified flows are higher than natural due to the environmental flow release of 250 L/s.

**Flow ramping assessment**

When considering the effects due to flow ramping, an initial flow of 0.25 m<sup>3</sup>/s from the Inches Road reservoir is assumed. This is the minimum environmental release, and flow is then ramped up to 4.15 m<sup>3</sup>/s, which allows for the peak abstraction rate of 3.9 m<sup>3</sup>/s.

Water level and flow time series for downstream of the Inches Road Reservoir are plotted in Figure 6. This plot shows a rise in water level of some 550mm in response to the flow release. In Figure 7 the cross section is shown schematically, with minimum and maximum water levels shown.

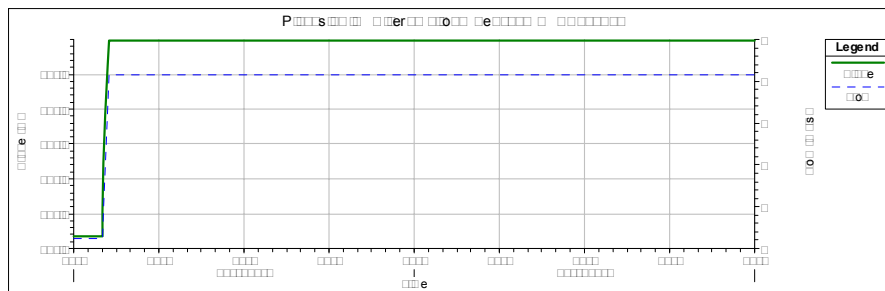


Figure 6: Flow Ramping downstream of Inches Road Reservoir

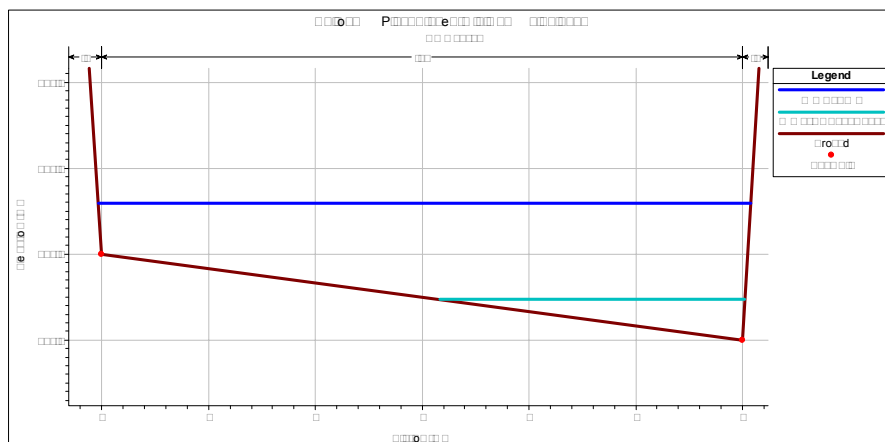


Figure 7: Schematic Cross Section and Water Levels downstream of Inches Road Reservoir

### 8.2.3 Effects Downstream of Waitohi River Intake (Intake 2)

At this stage details of the distribution network are unknown, therefore flows downstream of the Waitohi River Intake (intake 2) are not assessed in detail. A flow of up to 3.9 m<sup>3</sup>/s may be left in the river to provide a variable flow in the Waitohi River from this point. This water will be taken out further downstream to provide the lower end of the irrigable area with irrigation water. At this stage the distribution network is unknown and further detail on the effects on the Waitohi River downstream of the Waitohi River Intake (intake 2) will be provided when HWP is applying for the consents associated with the distribution network.

## 8.3 Effects for Full Simulation Period

This part of the assessment of environmental effects describes the effects of the scheme on lake levels and Hurunui and Waitohi River flows for the 39 years of simulation period.

### 8.3.1 Seven Hills Reservoir

The proposed Seven Hills Reservoir is the primary storage reservoir and provides a live storage of 7.3 million m<sup>3</sup> at an operating range of 20 m. Over the simulation period there is considerable variability in storage reservoir levels. In wet years the storage is hardly used whereas during average and dry years the live storage in the reservoir may be completely used. Figure E1 shows the drawdown of the Seven Hills storage reservoir and Figure E2 and Figure E3 shows the lake level duration curve for the whole simulation period and for the irrigation season. Based on the simulation period of a past series of 39 years, the live storage would have been completely used in 26 of these years. Table 18 shows a summary of the lake levels, volumes and duration of time that a certain level is exceeded for the whole simulation period and for the irrigation season.

RL (m)	Volume (Million m <sup>3</sup> )	% of time level exceeded (over whole year)	% of time level exceeded (over irrigation season)
400	7.3	46.2	39.9
395	4.5	65.3	61.3
390	2.3	74.6	72.2
385	0.9	81.4	77.4
380	0.0	88.9	83.6

Figure E2 and Table 18 shows that Seven Hills Reservoir is completely full for more than 46.2 % of the time and will be higher than 395 m RL for 65.3 % of the time. It is at its lowest operating level approximately 11.1 % of the time (i.e. 380 m RL level exceeded 88.9 % of the time).

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The mean lake level over the modelling period is 394.5 m RL, 5.5 m below the maximum storage level. The median lake level (equalled or exceeded 50% of the time) is 399.6 m RL, which is 0.4 m below the maximum storage level.

Figure E3 and Table 18 shows that Seven Hills Reservoir is completely full for more than 39.9 % of the time over the irrigation season and will be higher than 395 m RL for 61.3 % of the time. Over the irrigation season it is at its lowest level approximately 16.4% of the time (i.e. 380 m RL level exceeded 83.6 % of the time).

Table 19: Seven Hills Average Monthly Lake Levels (1972-2011)	
Month	Lake level (m)
January	395.3
February	390.0
March	386.6
April	387.0
May	389.2
June	393.3
July	396.8
August	398.9
September	399.5
October	399.7
November	399.6
December	398.4
<b>Year</b>	<b>394.5</b>

Seasonally, the lowest water levels in the reservoir will be from January to June which reflects the period where the reservoir is drawn down to meet irrigation demand and for the reservoir to recover. The reservoir will be full or near full in the winter months and in the first half of the irrigation season when demand is predominantly met from Hurunui run-of-river water.

### 8.3.2 Inches Road Reservoir

The proposed Inches Road Reservoir provides a live storage of 3.9 million m<sup>3</sup> at an operating range of 20 m. Over the simulation period there is considerable variability in storage reservoir levels. In wet years the storage is not used at all and demand is met

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from Hurunui run-of-river water and the Seven Hills Reservoir alone. During average years the reservoir is partly used and during dry years the live storage may be used completely. Figure E1 shows the drawdown of the Inches Road storage reservoir and Figure E2 and Figure E3 shows the lake level duration curve for the whole simulation period and for the irrigation season. Based on the simulation period of a past series of 39 years, the live storage would have been completely used in 15 of these years. Table 18 shows a summary of the lake levels, volumes and duration of time that a certain level is exceeded for the whole simulation period and for the irrigation season.

RL (m)	Volume (Million m <sup>3</sup> )	% of time level exceeded (over whole year)	% of time level exceeded (over irrigation season)
370	3.9	68.3	72.0
365	2.3	74.9	78.2
360	1.1	83.6	86.5
355	0.4	88.6	87.9
350	0.0	93.6	90.6

Figure E2 and Table 20 shows that Inches Road Reservoir is completely full for more than 68.3 % of the time and will be higher than 365 m RL for 75% of the time. It is at its lowest level approximately 6% of the time (i.e. 350 m RL level exceeded 94% of the time).

The mean lake level over the modelling period is 366.4 m RL, 3.6 m below the maximum storage level. The median lake level (equalled or exceeded 50% of the time) is 370 m RL.

Figure E3 and Table 20 shows that Seven Hills Reservoir is completely full for more than 72.0 % of the time over the irrigation season and will be higher than 365 m RL for 78.2 % of the time. Over the irrigation season it is at its lowest level 9.4 % of the time (i.e. 350 m RL level exceeded 90.6 % of the time).

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Table 21: Inches Road Average Monthly Lake Levels (1972-2011)	
Month	Lake level (m)
January	368.9
February	366.2
March	362.5
April	361.5
May	362.4
June	364.4
July	366.3
August	367.8
September	369.0
October	369.2
November	369.4
December	369.5
<b>Year</b>	<b>366.4</b>

Seasonally, the lowest water levels in the reservoir will be from March to May which reflects the period where the reservoir is drawn down to meet irrigation demand and for the reservoir to recover. The reservoir is typically only used in average and dry years towards the end of the irrigation season when Seven Hills Reservoir is drawn down completely. The reservoir will be full or near full from July to February due to irrigation demand being met from Hurunui run-of-river water and Seven Hills Reservoir.

## 8.4 Effects on Hurunui River Flows

### 8.4.1 Effects Downstream of Existing Balmoral Intake

Figure F1, F2 and F3 provide an overview of the modelled hydrological effects on Hurunui River flows downstream of the existing Balmoral intake. Figure F1 shows overlay plots of the existing and modified flows during wet, average, dry and a large storage demand year. The modified flows at this location are compared to the existing flows (and not the natural flows) since the existing Balmoral Scheme currently abstracts water from the Hurunui River at a maximum flow rate of 5 m<sup>3</sup>/s. The wet, average and dry years are based on Hurunui River flows at Hurunui at Mandamus with a dry year representing a 10<sup>th</sup>

percentile dry year and a wet year representing a 10<sup>th</sup> percentile wet year. A large storage demand year is included to assess the effects of the scheme when the live storage in the reservoirs is completely used (which may be considered a 10<sup>th</sup> percentile dry year in terms of the storage reservoir levels).

The main points to note from Figure F1 are:

- In 1983 (example wet year) the summer low flow period is relatively short. Hurunui River flows are relatively high through to the end of January. Flow variability is maintained (although slightly reduced) and from the end of March there is no irrigation demand resulting in no change to the existing flows from March onwards.
- The periods of low flows in the Hurunui River are generally longer in dry years, however due to flow restrictions water is not abstracted from the river when flows are naturally low. Existing flows below 12 m<sup>3</sup>/s are unchanged in the summer low flow period (i.e. 1973, February to mid-April).
- 1990 (example dry year) shows two low flow periods (November through to mid-December and February through to mid-April). Due to irrigation demand and modified flows are generally slightly lower than existing flows.
- In average and dry years flows are relatively high through to the end of January with modified flows lower than existing flows.

Figure F2 and F3 show comparative flow duration curves for the existing and modified flows over the whole year and over the irrigation season.

As can be seen, the existing flows are slightly reduced. The largest relative change is in the flow range between 22 m<sup>3</sup>/s and 40 m<sup>3</sup>/s.

### 8.4.2 Summary Statistics

The following table shows summary statistics for natural and modified flows:

Table 22: Summary Flow Statistics for Natural/Existing and Modified Flows (Period 1972-2011)					
	Mean	Median	7D-MALF	Upper Quartile	Lower Quartile
Hurunui River downstream of existing Balmoral Intake existing flows	56.9	42.2	15.7	66.9	28.6
Hurunui River downstream of existing Balmoral intake modified flows	55.8	41.0	15.4	65.7	27.3

As expected the summary statistics in Table 22 indicate a small reduction of river flows in the Hurunui River as a result of the proposed scheme for low, average and high flows.

The percentage decrease in mean flow of the Hurunui River is estimated at 1.9 %.

### 8.4.3 Effects on Floods and Flooding

The flow duration curves downstream of the existing Balmoral Scheme indicate that flows most affected by the takes are between 22 and 40 m<sup>3</sup>/s (Largest relative decrease in flows). The existing flood frequency or the duration of floods and larger freshes are largely unchanged. The proposed scheme will result in a small reduction of the magnitude of floods and flood frequency, however the impact on higher flows is expected to be relatively small.

## 8.5 Effects on Waitohi River Flows

### 8.5.1 Effects Downstream Inches Road Reservoir

Figures G1, G2 and G3 provide an overview of the modelled hydrological effects on Waitohi River flows downstream of Inches Road Reservoir. Figure G1 shows overlay plots of natural and modified flows during wet, average, dry and a large storage demand years. The main points to note from Figure G1 are:

- In all the example years flows are increased up to 4.15 m<sup>3</sup>/s when releases are being made from storage to meet irrigation demand. These releases typically occur when Waitohi River flows are naturally low.
- Flows are "stable" at 250 L/s when the storage reservoirs are harvesting Waitohi River flows into storage during and following an irrigation season.
- When there is no irrigation release from storage the environmental flow release of 250 L/s increases the natural flows in the summer low flow period in dry, average and wet years.
- During large storage demand years when the storage goes empty flows are the same as natural flows (i.e. mid-February through to mid-April in 1973).
- Natural flows are unchanged during periods when the reservoir is full and when there is no irrigation demand. These periods are confined to the high flow period in winter and/or the shoulders of the irrigation season.

Figure G2 and G3 show comparative flow duration curves for the natural and modified flows over the whole year and over the irrigation season. As can be seen the proposed operation of the scheme results in a redistribution of flows. Most of the water is harvested into storage outside the irrigation season resulting in a decrease in the occurrence of high flows. This stored water is released again in the summer low flow period. The flow duration curve therefore shows an increase in flows over the irrigation season with stable flows at 250 L/s and 4.15 m<sup>3</sup>/s reflecting the minimum environmental flow release of 250 L/s and the maximum irrigation release from storage of 3.9 m<sup>3</sup>/s (i.e. 250 L/s + 3.9 m<sup>3</sup>/s = 4.15 m<sup>3</sup>/s).

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The flow duration curve also shows the increase in flows over the summer low flow period. For the natural flows a flow of 250 L/s is exceeded 73 % of the time (using the full year period), or in other words the flow is less than 250 L/s 27 % of the time. If assessing the record for just for the irrigation season (1 October through to 30 April) the flow is less than 250 L/s for 40 % of the time. For the modified situation the flows are only less than 250 L/s when the storage reservoirs are empty (i.e. at or above 250 L/s for approximately 94 % and 91 % of the time for the whole year and irrigation season respectively).

### 8.5.2 Effects Downstream of Waitohi River Intake (Intake 2)

As discussed earlier at this stage details of the distribution network are unknown, therefore flows downstream of the Waitohi River Intake (Intake 2) are not assessed in detail. A flow of up to 3.9 m<sup>3</sup>/s may be left in the river to provide a variable flow in the Waitohi River from this point. This water will be taken out further downstream to provide the lower end of the irrigable area with irrigation water. At this stage the distribution network is unknown and further detail on the effects on the Waitohi River downstream the Waitohi river Intake (intake 2) will be provided when HWP is applying for the consents associated with the distribution network.

### 8.5.3 Summary Statistics

The following table shows summary statistics for natural and modified flows in the Waitohi River:

Table 23: Summary Flow Statistics for Natural and Modified Flows (Period 1972-2011)					
	Mean	Median	7D- MALF	Upper Quartile	Lower Quartile
Waitohi River downstream of Inches Road Dam natural flows	1.30	0.59	0.11	1.38	0.23
Waitohi River downstream of Inches Road Dam modified flows	1.29	0.38	0.19	1.51	0.25

The summary statistics in Table 23 indicate reduced Waitohi River flows for the median flow downstream of Inches Road reservoir. However, the upper and lower quartile and 7D-MALF are increased as a result of the minimum environmental flow release of 250 L/s and irrigation releases from storage. Note that the frequency of flood flows are decreased as a result of harvesting water into storage (see Figure G2)

## 8.6 Environmental Considerations

Boffa Miskell has provided input on environmental issues that may arise from operation of the scheme (i.e. minimum flows, flushing flow period, quantities etc.).

### 8.6.1 Flushing Flows

The FRE3 statistic is a measure of the frequency at which flushing flows occur on an annual basis. Specifically, the FRE3 statistic is the mean annual frequency at which the mean daily flow exceeds three times the median flow. The FRE3 statistic is closely linked with periphyton growth and invertebrate density. Flushing flows control periphyton biomass and a flow of around 3 times the median flow is generally required (substrate and flow pattern dependent) to disturb the bed of a river to such an extent that a substantial portion of the periphyton is lost from the reach due to abrasion, dislocation, and/or bed mobilisation. Clausen and Biggs (1997) found that periphyton biomass decreased with increasing FRE3, whereas invertebrate density had an increasing relationship.

Table 24 summarises the FRE3 statistic for natural and modified flows and provides an indication of the change in the frequency of flushing flows as a result of the proposed scheme. It is important to recognise that this reflects a particular set of operational rules.

Table 24: FRE3 Statistic for Natural and Modified Flows (Period 1972-2011)			
	Median natural/existing flow (m <sup>3</sup> /s)	FRE3	
		Natural/Existing flow	Modified Flow
Hurunui downstream of Existing Balmoral Intake	42.2	7.0	7.0
Waitohi downstream of Inches Road Dam	0.59	11.4	11.4

The frequency of flushing flows in the Hurunui River and immediately downstream of Inches Road reservoir is unchanged as a result of the proposed scheme. For the Waitohi River downstream of Inches Road the number of flushing flows are typically reduced following the irrigation season when water is being harvested into storage. However, during the irrigation season when releases are made from storage to meet irrigation demand there is an increase in flushing flows.

It has to be noted that in the typical low flow summer months (when periphyton growth can be an issue) low flows are generally augmented due to the minimum flow at the outlet of the Lower Gorge 1 dam of 250 L/s which may reduce the occurrence of periphyton growth.

### 8.6.2 Reservoir Inundation and Wave Action

Prolonged inundation of the lake edge above the root zone has the potential to degrade lakeside vegetation. Waves have the potential to increase the inundation area/lake shore of the proposed reservoirs on top of the proposed maximum operating level. Wave amplitude (and hence wave run-up) is dependent on fetch and wind velocity. The fetch is

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the distance over which waves are generated by a wind that is nearly constant in direction and speed. In other words it is the effective distance which waves have travelled in open water, from their point of origin to the point where they break. Due to the small fetch for the Seven Hills and Inches Road Reservoirs it is not expected that wave action will inundate the lake edge appreciably above the proposed maximum operating level.

## 9.0 Reliability of Supply for the Scheme

The upper plot in Figure H1 shows the total number of days that supply does not meet demand, and the lower plot shows the longest number of consecutive days that supply is less than demand. While there are 15 years in which supply does not meet demand throughout the irrigation season (*full reliability* of 62 % in the sense defined in section 7.0) there are only 9 irrigation years, where the deficit may be regarded as significant, and corresponds to the live storage being used completely together with a period of more than 10 consecutive days when supply does not meet demand and SMI values below 50 % (see below). In terms of *average supply/demand ratio* the scheme is 93 % reliable. In other words over the 39 year modelling period (on average) supply meets demand 93% of the time.

As noted in section 7.2 the *soil moisture index (SMI)* for a given soil is defined to be soil moisture balance divided by the PAW class. The SMI for the scheme is the average SMI over the soil types. Figure H2 show the SMI by irrigation year. The green line shows the average SMI without irrigation and the blue line shows the SMI with the irrigation scheme in place. In most years the SMI is greater than 50 % (i.e. SMI greater than 0.5) throughout the irrigation season. In 9 years out of 39 years the live storage in the reservoirs is used completely resulting in an SMI of less than 50 % towards the end of the irrigation season (March/April). In extremely dry years (i.e. 1972/1973 and 2000/2001) the live storage in the reservoirs is completely used in February resulting in an SMI of less than 50 % for the rest of the irrigation season. 2007/2008 is more extreme and shows two periods when the SMI is less than 50%: January and March onwards.

Note that there are a few irrigation years when the SMI drops below 50% without the live storage being used completely (i.e. 1974/1975 and 1978/1979). In these years there was no actual water deficit (i.e. storage water is still available), ET levels were uncommonly high, frequently greater than the irrigation application rate resulting in the SMI dropping below 50%.

The simulation suggests that for the majority of years the scheme has enough water for a complete irrigation season and is therefore reasonably reliable. In dry years the irrigation season will be shortened.

Uncertainty rests with the frequency of hydrological conditions which lead to extreme years of the type discussed. Climate change and the Interdecadal Pacific Oscillation have been discussed in broad terms in section 4.3, and while it is not possible to quantify the level of uncertainty, it is prudent to assume that the incident of droughts in the lower Hurunui Catchment may increase and therefore dry years may increase in frequency.

## **10.0 Mitigation Measures and Monitoring**

### 10.1 Mitigating Adverse Effects on the Environment

A minimum environmental flow of 250 L/s at the outlet of Inches Road reservoir has been set in consultation with Boffa Miskell. This will ensure a continuous flow in the Waitohi River during periods when the Waitohi River naturally goes dry. Flows during the summer low flow period (typically January through to April) are augmented except when the live storage is used completely (see section 8.5.1).

#### 10.1.1 Augmenting Waitohi River Flows

As discussed in section 4.5.2 the Waitohi River flow disappears subsurface through its middle reaches and naturally goes dry. Its main losing reach is between Powers Road Bridge and Bakers Road Ford. As discussed earlier at this stage details of the distribution network are unknown, therefore flows downstream of the Waitohi River Intake (which includes the main losing reach of the Waitohi River) are not assessed in detail. A flow of up to 3.9 m<sup>3</sup>/s may be left in the river to provide a variable flow in the Waitohi River from this point. This water will be taken out further downstream to provide the lower end of the irrigable area with irrigation water. At this stage the layout of the distribution network is unknown and further detail on the effects on the Waitohi River downstream of the Waitohi River Intake (intake 2) will be provided when HWP is applying for the consents associated with the distribution network.

### 10.2 Management and Operational Plans

Plans will be prepared for the management of the scheme and operation of the dams. A draft of these plans will be submitted 6 months prior to the operation of the scheme.

Apart from maintaining environmental flows, the actual operation of the scheme can only be confirmed when operational, therefore this plan will need to be reviewed annually.

### 10.3 Proposed Monitoring

#### 10.3.1 Water Takes

It is proposed that the rate at which water is abstracted from each of the intakes will be monitored on a continuous basis.

#### 10.3.2 Reservoir Levels

It is proposed that water levels in both reservoirs will be monitored on a continuous basis.

#### 10.3.3 Environmental Monitoring

As noted in section 6.2 there is an absence of reliable rainfall and evapotranspiration data in the command area. Consequently HWP is proposing to install weather stations to provide reliable rainfall, evapotranspiration and soil moisture data. This will provide information to shareholders so they can plan their irrigation and make the most efficient use of water.

With regard to flow monitoring it is proposed to monitor the flows in the Waitohi River at the outlet of Inches Road reservoir.

## 11.0 Conclusions

HWP proposes to abstract a maximum of 3.9 m<sup>3</sup>/s from the flow of the Hurunui River and to store Waitohi River water for the purpose of irrigating approximately 6,900 hectares of land for stage 1 of their proposed Waitohi Irrigation and Hydro Scheme. The hydrological effects of the scheme are summarised below.

### *Effects on the Hurunui River*

This assessment shows that immediately downstream of the existing Balmoral intake flows are slightly reduced (especially in the irrigation season). The largest relative change is in the flow range between 22 m<sup>3</sup>/s and 40 m<sup>3</sup>/s. The proposed scheme does not affect the flows below the minimum A-block flow as specified by the "proposed Hurunui-Waiiau River Regional Plan" flow regime. The mean flow in the Hurunui River is reduced by 1.9 % as a result of the proposed stage 1 irrigation scheme.

### *Storage Reservoirs*

This assessment of environmental effects shows that there is considerable variability in storage reservoir levels. Based on the simulation period of 39 years the total live storage of 11.2 million m<sup>3</sup> in the reservoirs will be used completely in 15 years. The effects on the storage reservoirs can be summarised as follows:

- Seven Hills is the main storage reservoir with an operating range of 20 metres. The mean lake level over the modelling period is 5.5 m below the maximum storage level of 400 m RL and water levels being higher than 395 m RL for 65 % of the time. Lake levels are typically at the lowest in the second half of the irrigation season with the lowest mean monthly lake level being March at a level of 386.6 m RL. The full operating range of 20 metres is used in 26 out of 39 years.
- Lake levels in the Inches Road storage reservoir can fluctuate between 350 m RL and 370 m RL (operating range of 20 m). This reservoir will only be used when the live storage in the Seven Hills Reservoir is completely used; therefore this reservoir is typically used towards the end of the irrigation season. The estimated mean lake level is 366.4 m RL with the seasonal lowest lake level in April. The full operating range for this reservoir will be used in 15 years over the historical modelling period between 1972 and 2011.

### *Effects on Waitohi River Flows*

This assessment shows the effects of the proposed scheme on the Waitohi River flows downstream of the reservoirs.

The main effects immediately downstream of Inches Road reservoir are related to the periods when river flows are harvested into storage and/or when water is released to meet irrigation demand. When water is harvested into storage river flows at the outlet of the reservoir are stable at 250 L/s and when water is released to meet irrigation demand

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(typically in the second half of the irrigation season) flows are increased by up to 4.15 m<sup>3</sup>/s. Natural flows are unchanged during period when the reservoir is full and when there is no irrigation demand. The mean flow in this stretch of the Waitohi River is unchanged.

Effects downstream of the Waitohi River Intake (Intake 2) cannot be quantified at this stage since the layout of the distribution system is unknown, however the Waitohi River below the main canal may convey up to 3.9 m<sup>3</sup>/s to augment Waitohi River flows in the summer low flow period.

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