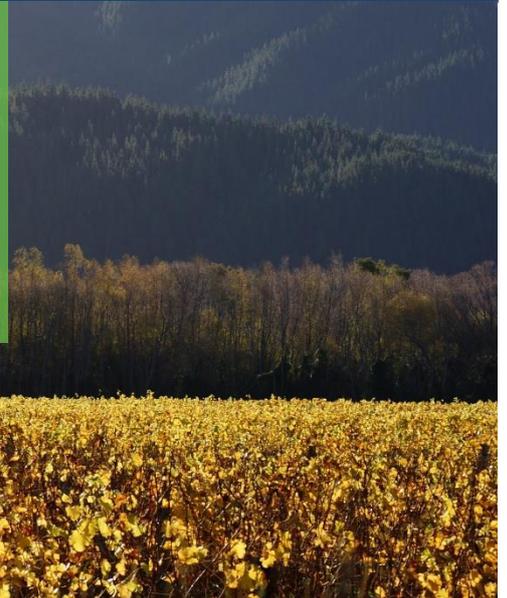


## Irrigation REPORT

# REASONABLE IRRIGATION WATER USE VOLUMES: WAIRAU PLAINS IrriCalc Modelling



PREPARED FOR  
Marlborough District Council

AQ24049

15/07/2024

PREPARED BY  
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## EXECUTIVE SUMMARY

Water meter data received by Marlborough District Council from growers indicates a wide range of annual irrigation water use by vineyards. In some areas actual irrigation water use is significantly less than the aliquot consented for use.

This project has used the irrigation system simulation model “IrriCalc” to model vineyard irrigation water use over a period of 26 years (1996 to 2022) with the aims of:

- Quantifying vineyard water demand for each Wairau Plain Freshwater Management Unit (FMU) for wet, average and dry seasonal conditions to confirm rates in MDC resource consents,
- Revealing why there are spatial differences between IrriCalc-defined water demand and measured actual use.

Modelled annual irrigation water use across groundwater-dominated FMUs on the Wairau Plains and Southern Valleys showed a large range in annual demand in response to seasonal conditions.

Annual irrigation water use assumed the entire FMU area is irrigated. The FMU boundaries are defined in the Marlborough Environment Plan and were supplied by MDC as ArcGIS files.

Analysis of the modelling results suggest that the spatial variation in metered annual irrigation water use across the Wairau Plains can largely be explained by spatial variations in the capacity of soils to store and transmit water. Spatial variations in the depth to the groundwater table are also likely to explain some of the variation, though the influence of shallow groundwater wasn't specifically modelled in this project.

Differences between growers in terms of their irrigation practices will also contribute to spatial variation in metered water use. Understanding the range of differences in practices is likely to require a comprehensive survey of growers.

# 1 INTRODUCTION

The proposed Marlborough Environment Plan (pMEP) annual limit for the Wairau Aquifer is probably too high, based on the results of recent computer model simulations of the effects of this volume being abstracted. Actual groundwater use is significantly less, based on the results of different assessment methods and sources of information.

An extrapolation of metered groundwater usage for vineyard irrigation across the Wairau Aquifer indicates average actual use is around 20 million m<sup>3</sup>/year. The recently released NZ Wine annual report for the 2020/21 irrigation season provides data showing average use is 137 mm/year irrigation depth across Marlborough. For the Wairau Aquifer alone this equates to a total annual use of 19 million m<sup>3</sup>/year.

Groundwater isn't just used for crop irrigation, with actual use of around 10 million m<sup>3</sup>/year for municipal supply and another 2 million m<sup>3</sup>/year estimated for food processing (wineries, etc.). Total actual average use under normal seasonal conditions is estimated to be around 32 million m<sup>3</sup>/year compared to the 73 million m<sup>3</sup>/year in the Marlborough Environment Plan (MEP). Permitted activity use of groundwater isn't included in these figures or the pMEP Wairau Aquifer limit.

MDC policy and environmental science staff need to understand the reasons for the discrepancy between forecast irrigation need and actual use. Ideally the allocation of each individual resource consent holder should match what's needed 9 seasons in 10, otherwise there is surplus "paper" allocation. Refining the Use component of individual water permits was the mechanism used by MDC to reconcile the historical consented overallocation relative to the new pMEP limit.

A review of IrriCalc demand for each Wairau Plain FMU was requested to confirm recent MDC consent practice and understand the spatial implications of any future reconciliation of pMEP limits on individual water permits.

The pMEP provides for a highly reliable water permit Use aliquot, with sufficient water for 9 seasons out of 10. To understand the implications of different adjustment approaches across the Wairau Plain, IrriCalc simulations for a range of seasons were required.

To improve the performance of their Wairau Plain computer model being used for pMEP limit setting, MDC recently reviewed many Wairau Plain vineyard water meter records to determine the spatial pattern of groundwater use. As expected, vineyard irrigation rates were higher in the west than the east, reflecting the higher groundwater tables and higher water holding properties of soils in the eastern part of the Plains.

## 1.1 Project aims

The aims of the project were:

- Simulate grape water demand by Wairau Plain FMU's for wet, average and dry seasonal conditions to confirm rates in MDC resource consents
- Discuss any spatial differences between IrriCalc defined water demand and actual use

## 1.2 Project approach

- IrriCalc was used to define irrigation demand for grape plants for each soil type in each FMU for 3 different seasonal conditions.
- MDC provided ESRI shapefiles of each Wairau Plain FMU as specified in pMEP. Outputs from the IrriCalc modelling were used to provide an estimate of the total (aggregate) irrigation demand in each FMU.
- Results from the simulations and commentary with respect to the anticipated water demand in each FMU for each of the three scenarios are presented in this report. This includes discussion of spatial patterns and variance with actual metered data.
- Limitations of the model and/or outputs have been specified.

## 2 OVERVIEW OF THE “IRRICALC” IRRIGATION SIMULATION MODEL

### 2.1 Introduction

Seasonal irrigation water use and drainage is primarily a function of rainfall, plant water use and irrigation management. Soil hydraulic properties indirectly affect irrigation water use. Interactions between these soil properties, rainfall, irrigation application system characteristics, and irrigation management determine how much of the applied water (including rainfall) is retained in the root zone of the soil, how much drains below the root zone, and how soon the next irrigation will be required.

The method used by Aqualinc to estimate irrigation water use is an implementation of the internationally accepted approach described by Allen *et al.* (1998)<sup>1</sup>. Aqualinc’s implementation uses IrriCalc to simulate the day-to-day operation of an irrigation system to avoid significant yield loss due to water stress. A rule-based approach to irrigation management is simulated. Application of the irrigation management rule on a daily basis, in response to modelled soil water status, determines the timing of irrigation and the amount to be applied. The various components of the rule are described below. The result of applying the irrigation rule in concert with a daily water balance model is a daily time series of drainage depth and irrigation application depth. The total amount of irrigation water used over a user specified irrigation season is calculated by summing the daily application depths.

The time series of seasonal irrigation water use is then analysed to determine the seasonal irrigation water use that would avoid crop yield loss, to a specified level of reliability (such as fully meeting irrigation requirements “nine years out of ten”, and substantially meeting requirements in the “tenth year”).

Computer modelling of irrigation system operation is a transparent method for estimating seasonal irrigation demand, based on use of a validated soil water balance model, defined irrigation management rules, and climate data.

In particular, it is a method that preserves the correlation between daily rainfall and other daily climate data, and it avoids the need to make major assumptions about the effectiveness of rainfall and efficiency of irrigation. The volume of drainage from each rainfall and irrigation event is an output, a result that depends on the soil water deficit at the time of the event and on the characteristics of the irrigation or rainfall event.

### 2.2 Summary of Key Assumptions

The key assumptions forming the basis for Aqualinc’s irrigation water use and drainage estimations are as follows:

- The irrigation actions determined by the irrigation system model are practical.
- Irrigation rules are consistently followed. For some rules, this implies that the soil water content in the root zone is continuously monitored and used for irrigation decision-making.
- Water is always available for irrigation, at the rate required, when irrigation is required according to the decision rule being used. Actual water availability can be a specified model input, but 100% availability is assumed for the purpose of estimating potential irrigation water demand.
- Assumptions specific to the soil-plant-atmosphere model (discussed below).
- Assumptions specific to the irrigation system model and irrigation management rules (discussed below).

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<sup>1</sup> Allen, RG; Pereira, LS; Raes, D; Smith, M (1998): *Crop evapotranspiration - Guidelines for computing crop water requirements*. Irrigation & Drainage Paper 56, Food and Agriculture Organisation of the United Nations, Rome.

## 2.3 IrriCalc's Soil Water Balance Model

The version of IrriCalc used for this project is a single-layer soil water balance model that uses the following equation to update the calculated soil water content on a daily basis given daily measurements or estimates of rainfall, irrigation, drainage and actual evapotranspiration.

$$S_{t_2} = S_{t_1} + R_{(t_2-t_1)} + I_{(t_2-t_1)} - D_{(t_2-t_1)} - AET_{(t_2-t_1)}$$

Where:

$S_{t_2}$	=	Soil water content at time $t_2$
$S_{t_1}$	=	Soil water content at time $t_1$
$R_{(t_2-t_1)}$	=	Rain between time $t_2$ and $t_1$
$I_{(t_2-t_1)}$	=	Irrigation between time $t_2$ and $t_1$
$D_{(t_2-t_1)}$	=	Drainage between time $t_2$ and $t_1$
$AET_{(t_2-t_1)}$	=	Actual evapotranspiration between time $t_2$ and $t_1$
$AET_{(t_2-t_1)}$	=	$K_c \times f(S_{t_1,a}) \times ET_{ref(t_2-t_1)}$
$K_c$	=	Crop factor applicable over time $t_1$ to $t_2$
$f(S_{t_1,a})$	=	Evapotranspiration reduction function
$ET_{ref(t_2-t_1)}$	=	Evapotranspiration for a well-watered reference crop between time $t_2$ and $t_1$

The evapotranspiration reduction function is an empirical function that takes a value in the range 0 to 1, depending on the ratio of soil water content on day  $t_1$  to the "field capacity" and the parameter "a". The parameter "a" is related to the volume of soil water that is readily available to the plant. The particular empirical function used in IrriCalc is described in Minhas *et al.* (1974)<sup>2</sup>, and has been used in New Zealand by Heiler (1981)<sup>3</sup> and Bright (1986)<sup>4</sup>.

Drainage is assumed to occur whenever the soil water content is calculated to be greater than "field capacity". The volume of drainage is set equal to the volume required to reduce the soil water content to "field capacity", and it is assumed that drainage occurs within the same daily time period as the rainfall or irrigation that raised soil water content above "field capacity".

Reference crop evapotranspiration is calculated from daily climate measurements using the Penman-Monteith method (FAO-56), with parameters appropriate for estimating evapotranspiration from a well-watered grass sward of 120 mm height.

Irrigation amounts are either calculated by an irrigation system model on each day of a defined irrigation season, or are input as time series measurements. The irrigation system model is described below. The option to input measured irrigation water use was not used in this project.

IrriCalc provides outputs of each component of the soil water balance on each day of the simulation, along with a check-sum that indicates mass conservation, and the accumulated volume of water used for irrigation.

<sup>2</sup> Minhas, BS; Parikh, KS; TN Srinivasan (1974): *Toward the structure of a production function for wheat - Yields with dated inputs of irrigation water*. Water Resources Research, 10:383-393.

<sup>3</sup> Heiler, TD (1981): *Simulation based design of water harvesting schemes for irrigation*. Agricultural Engineering Thesis #4. Agricultural Engineering Institute, Lincoln College.

<sup>4</sup> Bright, JC (1986): *Optimal control of irrigation systems - An analysis of water allocation rules*. Unpublished PhD Thesis, University of Canterbury.

## 2.4 The Crop Factor

The Crop Factor is a plant structure parameter that specifies the evapotranspiration of a plant population relative to a reference evapotranspiration.

Usually, the reference evapotranspiration is that of a well-watered pasture with canopy characteristics that are constant throughout the year. The key canopy characteristics are plant height, leaf area index, and the stomata resistance and canopy resistance to vapour transport.

The assumption that the reference crop is “well-watered” implies that there is a good store of water in the soil. It also implies that the form and hydraulic resistances of the plant’s root system are such that the root system is capable of supplying water at the flow rate required to meet the atmosphere’s capacity to evaporate and transport water away from the plant canopy.

The crop factor used by IrriCalc varies throughout the year. The crop factor changes throughout the year because of changes in the height, leaf area index, and form of real plant canopies. The crop factors used are either derived from field work done in New Zealand (for example, for vineyards) or from published overseas field work (for cereal crops, for example). See Section 3.1 for details on the crop factor used for vineyards in this project.

## 2.5 IrriCalc’s Irrigation System Model

The irrigation system model enables key irrigation system design and irrigation management parameters (or constraints) to be specified. These parameters include the depth and spatial uniformity of irrigation applications, the return period, the soil water level at which irrigation is triggered, the beginning and end of the irrigation season, and the maximum seasonal irrigation water use.

Table 1 shows the various combinations of irrigation system parameters that can be applied to replicate a wide range of irrigation systems and practices.

**Table 1: Irrigation management options available in IrriCalc**

Application depth	When to irrigate			
	Never	Every Return Period (number of days)	Trigger on soil moisture, providing the days since the last irrigation equal or exceed the Return Period	User supplied time series
Zero	✓			
Fixed depth (user defined)		✓	✓	
Variable depth (return soil moisture to a specified level)		✓	✓	
User supplied time series				✓

### 2.5.1 Irrigation Applications

Irrigation application times and depths are either input as a time series of actual irrigations or are determined in IrriCalc by the application of its irrigation management rules.

The application depth (as specified by the user or calculated by the irrigation model) is the spatial average of the water depth applied across the area wetted by the irrigator, or along the row for irrigated row crops. The spatial uniformity of the irrigation application is specified by Christiansen’s Uniformity Coefficient.

The amount of water that is retained in the soil due to an irrigation event is calculated using the method described in Bright (1986). Implicit in this calculation is the assumption that the spatial distribution of application depth can be represented by a normal distribution. The amount retained, and thus the amount of irrigation water that drains, is a function of the soil water deficit at the time of irrigation, the average application

depth, and the spatial uniformity of the irrigation application. The relationship between application efficiency, average application depth, and uniformity is illustrated in the following figure:

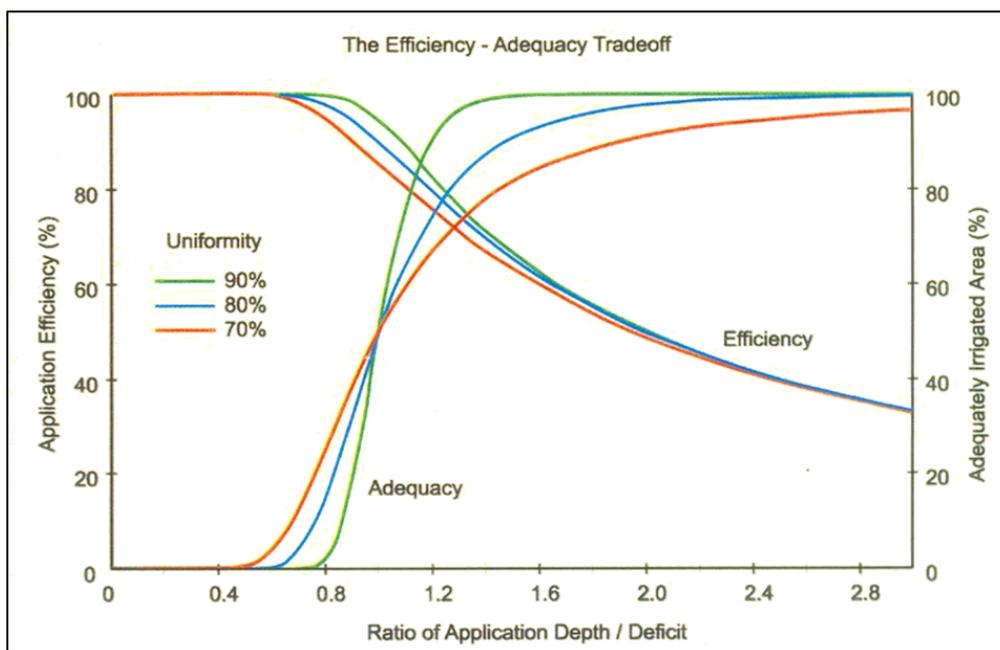


Figure 1: Relationship between application efficiency, application uniformity and application depth (source: Bright, 1986)

## 2.5.2 Application Efficiency

Application efficiency is defined as the ratio of the volume of irrigation water retained in the root zone of the soil to the volume of irrigation water applied to the land surface. The application efficiency varies between application events.

Application efficiency is not a direct output of an IrriCalc simulation but can be calculated for each irrigation event from the IrriCalc output files.

## 2.5.3 Irrigation System Capacity

Irrigation system capacity is an implicit constraint in IrriCalc. The combination of application depth and return period determines the irrigation system capacity according to the following rule:

$$\text{Maximum flow rate (l/s/ha)} = (\text{Application depth (mm)} \times 10,000) \div (\text{Return Period (days)} \times 86,400)$$

If the irrigation system capacity is known, then it is the model user's responsibility to check that the combination of application depth and minimum return period specified by the user does not result in the maximum flow rate being exceeded.

## 2.5.4 Maximum Seasonal Irrigation Water Use

The total amount of irrigation water used in any irrigation season is constrained to be less than the user-specified maximum seasonal irrigation water use. If the specified maximum is reached during an irrigation season, then irrigation is prevented for the remainder of that season. No attempt is made, in this version of IrriCalc, to optimise the use of the limited volume of water. The total volume of irrigation water used is re-set to zero prior to the beginning of each irrigation season.

To investigate how much irrigation water would have been used over a sequence of many years in the absence of a cap on total use, the specified maximum seasonal irrigation water use is simply set to a very large number to avoid it constraining water use in any season.

## 2.5.5 Data Needed to Run IrriCalc

The information required to apply IrriCalc is summarised below. The climate and soils data required are available throughout New Zealand, courtesy of fundamental databases maintained by NIWA and Manaaki Whenua Landcare Research.

### 2.5.5.1 Climate, Crop and Soils Data Required

- Daily time series for rainfall and potential evapotranspiration for the site of interest. These can be measured data or data from NIWA's virtual climate network.
- Crop factor time series (one year). For irrigated pasture in Canterbury, the crop factor time series is based on Van Housen (2015)<sup>5</sup>. Crop factors for dryland pasture have been derived from recorded lysimeter data around central Canterbury. Crop factors for other crops are generally sourced from FAO 56.
- Crop root depth (or depth of soil that supplies water to meet the crop's water needs).
- Water holding capacity of the soil to the depth of the crop's root (mm per mm of soil depth).
- Dates the crop is sown and harvested, or of bud break and leaf fall. For perennial crops, the dates are specified to cover a full year – typically 1 July to 30 June.

### 2.5.5.2 Irrigation System Data Required

If irrigation is simulated, then the following additional information is needed:

- The type of irrigation system to be modelled and some understanding of its operating requirements.
- The maximum and minimum application depths that are practical to apply.
- The uniformity of irrigation applications (Christiansen's Uniformity Coefficient).
- The minimum length of the irrigation rotation (days).
- The soil water content (%) at which irrigation is initiated (if irrigation timing is determined by soil water content).
- Maximum seasonal irrigation water use (if annual supply is limited).
- Beginning and end dates for the irrigation season.

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<sup>5</sup> Van Housen, J (2015): *Modelling the temporal and spatial variation of evapotranspiration from irrigated pastures in Canterbury*. A thesis submitted for a degree of Doctor of Philosophy at Lincoln University.

## 2.5.6 Model Calibration Example

A crop factor time series for irrigated pasture has been calibrated for use in Canterbury using data obtained from Canterbury Regional Council's (CRC) lysimeter network (Van Housen, 2015). The figure below shows that the modelled drainage using this crop factor time series with IrriCalc matches closely that measured at CRC's Methven lysimeter site.

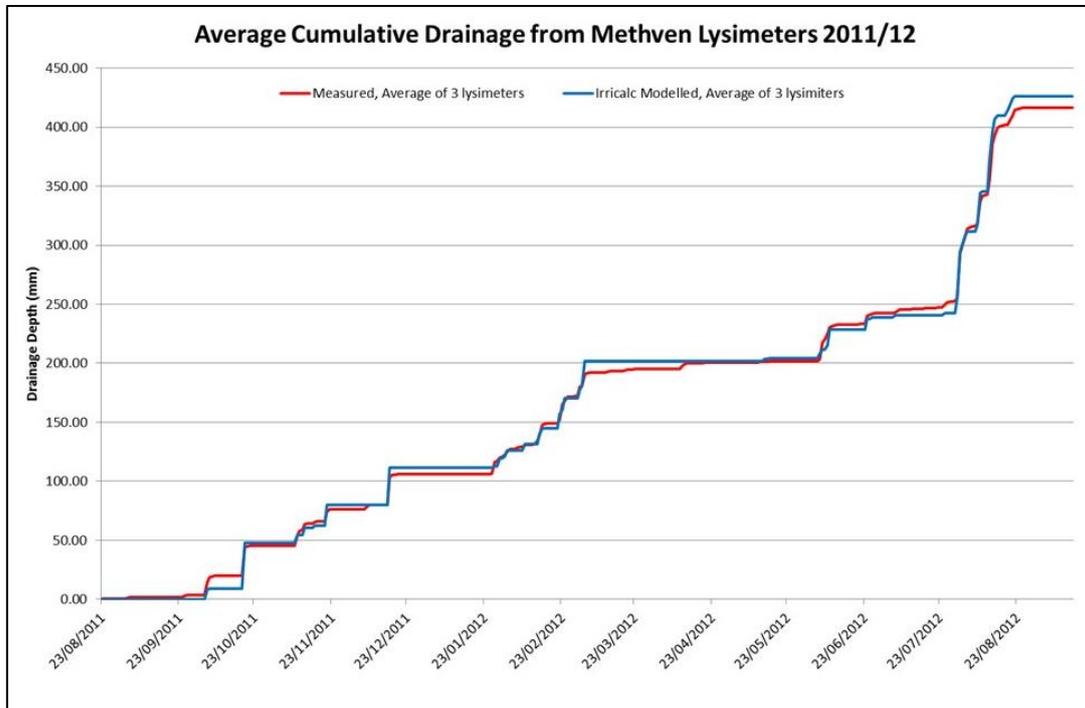


Figure 2: Comparison between measured and IrriCalc modelled drainage

### 3 IRRICALC MODELLING OF VINEYARDS ON WAIRAU PLAINS

#### 3.1 Model Inputs

##### 3.1.1 Climate

Daily climate data from the Blenheim Research Centre EWS was sourced from the CliFlo online database maintained by NIWA (site agent number 12430).

Daily Rain and Potential Evapotranspiration data available from 2 June 1996 until the date downloaded (21 November 2023).

##### 3.1.2 Soil

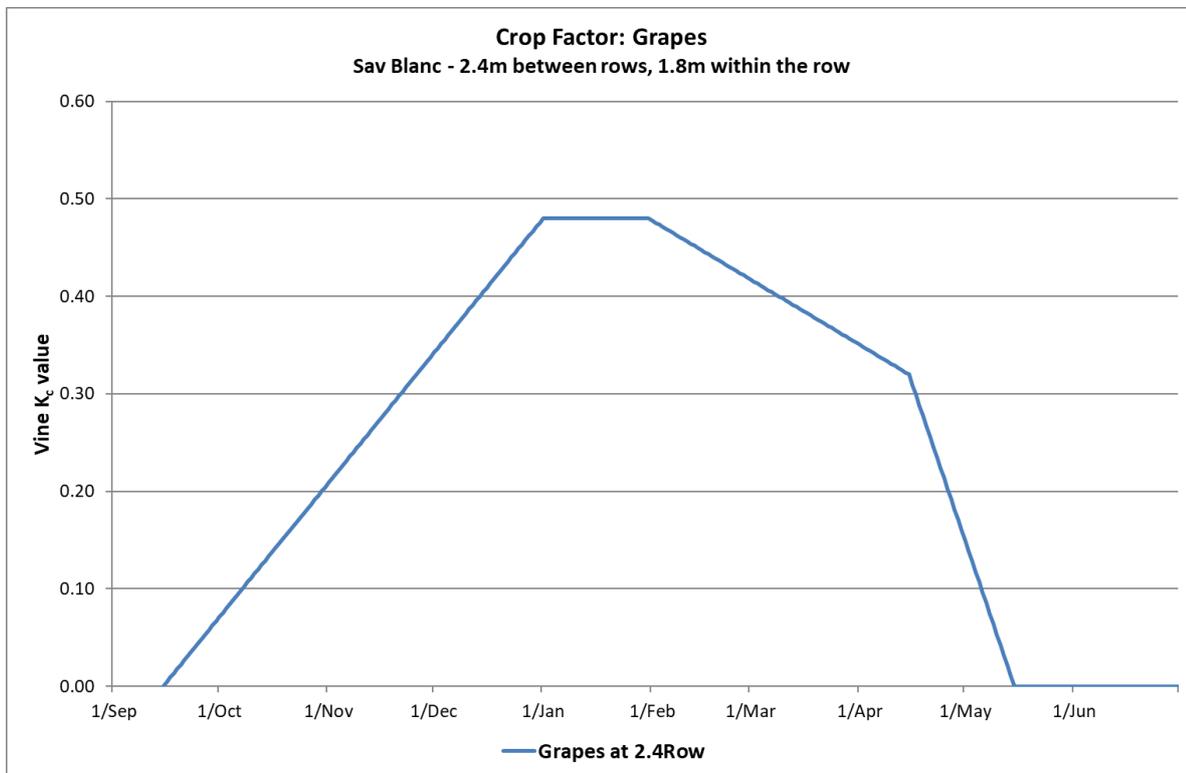
S-Map soil sibling polygons were intersected with aquifer zone boundary polygons to estimate the area of each soil type in each aquifer zone. The soil's capacity to store water within the top 1 metre of the soil profile was then obtained from the relevant S-Map soil fact sheets.

##### 3.1.3 Crop

The crop factor used in the modelling represents Sauvignon Blanc vines, planted at 2.4 metres between the rows, and trained according to the vertical shoot positioning system.

The crop factor varies throughout the season, as shown in Figure 3-1, and is derived from field work undertaken by Plant and Food Research in Marlborough<sup>6</sup>.

Figure 3-1: Crop factor used for vineyards



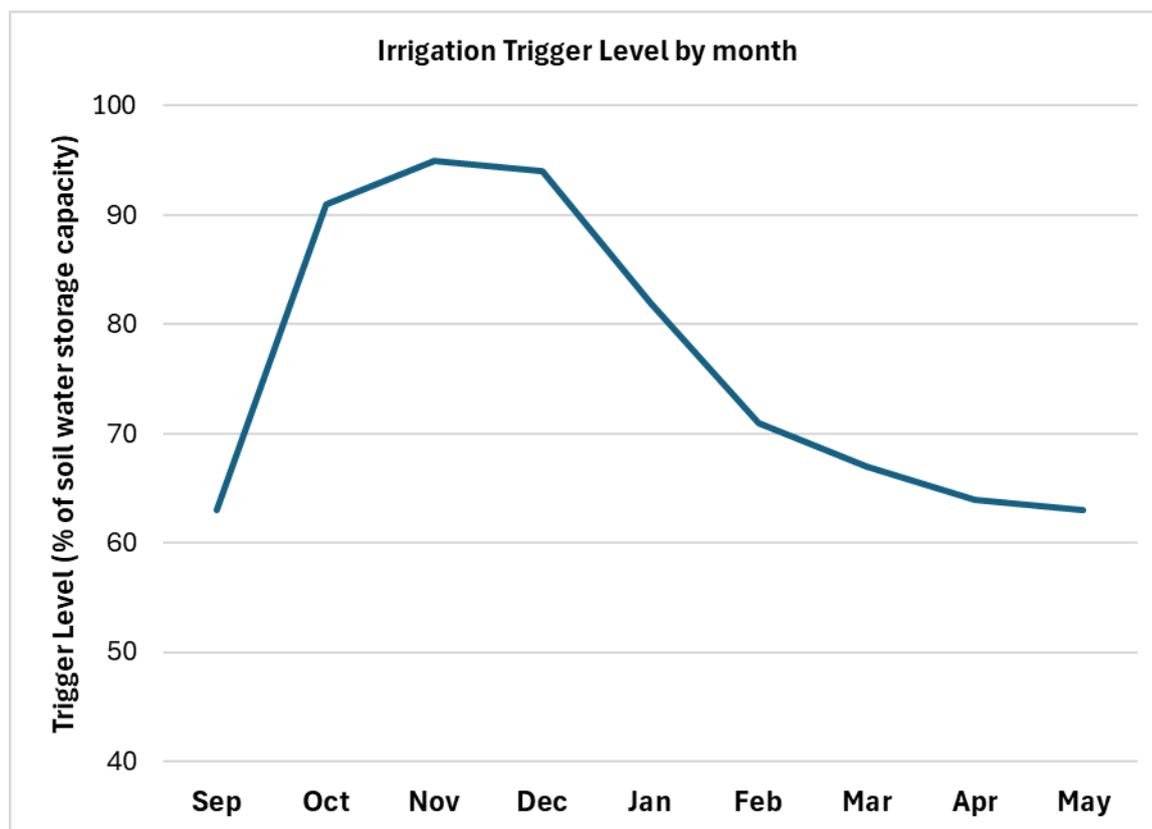
<sup>6</sup> Green, S; Caspari, J; Neal, S and Clothier B. (2000) Determination of the irrigation requirements of olives and grapes growing in Marlborough. A report prepared for the Marlborough District Council, HortResearch Client Report No. 2001/74. Marlborough Wine Research Centre, Blenheim.

### 3.1.4 Irrigation system

The irrigation strategy was to irrigate whenever the soil water content dropped to or below the irrigation trigger level. This varied throughout the irrigation season, as shown in Figure 3-2. An irrigation application depth of 2.2 mm/day (between 9 and 11 litres/vine per day, depending on the number of vines per hectare) was used. The minimum return period was one day, meaning that irrigation could occur every day if necessary.

Christiansen's Uniformity Coefficient was assumed to be 90%. For drip irrigation this has negligible effect on irrigation application efficiency because of the small daily application depth.

Figure 3-2: Irrigation trigger level used for vineyards



### 3.1.5 Other model inputs

In addition to the primary inputs described above, the following parameters were used:

- Irrigation season: 1 September to 31 May. This range was specified to ensure irrigation could occur as early as necessary and continue for as long as needed.
- Percent water loss between the vineyards water source and the surface of the soil: 5% of the amount applied to the soil.
- Simulation date range: 1 July 1996 to 30 June 2022 (a 26-year period).

## 4 IRRIGATION DEMAND-BASED REASONABLE USE LIMITS FOR WAIRAU FMUS

IrrCalc was used to simulate irrigation water use for each soil type present in each aquifer zone, using the inputs described in Section 3.

The annual volumes provided by the simulation of each soil type in each zone were aggregated to provide the zone totals shown in Table 4-1 below.

*Table 4-1: Total modelled annual irrigation water use for each aquifer zone.*

Aquifer Zone	Area	Average Annual Modelled Irrigation Use 1996/97 - 2021/22	Average Annual Modelled Use per Ha	Allocated Volume (90%ile)	Alloc Vol per Ha
	(ha)	(m3)	(mm)	(m3)	(mm)
Benmorven	1,922	3,079,411	160	3,795,786	197
Brancott	2,994	6,003,277	201	7,032,617	235
Lower Waihopai	2,510	3,804,181	152	4,681,207	186
Omaka Aquifer	2,829	5,521,908	195	6,499,296	230
Omaka River	6,507	11,167,074	172	13,475,260	207
Rarangi Shallow	1,250	2,125,455	170	2,644,149	212
Riverlands	5,074	6,649,782	131	8,722,833	172
Southern Springs	905	929,240	103	1,310,893	145
Taylor	5,210	11,220,474	215	13,004,234	250
Wairau Aquifer	14,369	14,847,106	103	20,742,620	144
All Zones	43,570	65,347,906	150	81,908,895	188

The range of variation in annual irrigation water use was expressed in terms of the averages of the three lowest demand years, three mid-range years and three highest demand years.

*Table 4.2: Modelled annual water use for representative low, medium and high demand years.*

Irrigation Demand Category	Annual Volume (cubic metres, total of all aquifer zones)	Range (across the 3 years averaged)
Low	42,182,126	1,255,714
Medium	63,516,757	438,193
High	89,083,256	12,073,598

Of note is the range, or spread, across the three highest demand years. The 2000/01 season was particularly high, at 95,104,073 cubic metres. This is about 16 percent higher than the 90<sup>th</sup> percentile annual volume.

The modelled area-weighted average volume used across all zones in 2020/21, assuming irrigation is based on the current variable trigger level regime, is 181mm.

## 5 SENSITIVITY ANALYSIS

The main sensitivities for the irrigation demand modelling are the area actually irrigated, the irrigation management rules and the crop factor time series (essentially the change in leaf area through the season).

The seasonal volume is directly proportional to the irrigated area. The results presented in Section 4 assume that the whole of the plan area of the aquifer zones is irrigated. If the actual irrigated area in each zone is 80% of the plan area, then the seasonal volume will be 80% of those in the table presented in Section 4.

Changing the irrigation management rule can make quite a difference to the average seasonal volume used, and the 90-percentile seasonal volume. For this sensitivity analysis the irrigation trigger level was changed to 50% of the soil water storage capacity for all months. This reduced the average annual volume by about 40% and the 90-percentile annual volume by about 25%, compared to the results presented in Section 4.

The degree of reduction due to changing irrigation management varies with soil type – the greater the soil’s water storage capacity, the greater the percentage reduction in seasonal water use.

Irrigation water use is also sensitive to summer pruning or leaf plucking of the vines, which would change the crop factor values because of the change in leaf area. Quantifying the effects of this wasn’t attempted as there is considerable variation in pruning practices (timing and severity).

The following table presents the results of analysing the sensitivity of annual volumes to irrigation management strategy. The results are presented by aquifer zone.

The modelled area-weighted average volume used across all zones in 2020/21, assuming irrigation is based on the trigger level of 50% of the soil’s capacity to store water, is 134.5mm.

Table 4-3: Sensitivity of Annual Volumes to Irrigation Management Strategy

Aquifer Zone	Area	Percent change from current		Current Irrigation Management Assumptions: irrigation trigger level varies by month				Irrigation Management assumed to have 50% trigger level for all months.			
		Ave Ann	Allocation	Sum Ave Ann Vol	Ave Ann Vol/Ha	Sum Alloc Vol	Ave Alloc Vol/Ha	Sum Ave Ann Vol	Ave Ann Vol/Ha	Sum Alloc Vol	Ave Alloc Vol/Ha
	(ha)			(m3)	(mm)	(m3)	(mm)	(m3)	(mm)	(m3)	(mm)
Benmorven	1,922	-41%	-24%	3,079,411	160	3,795,786	197	1,828,961	95	2,871,442	149
Brancott	2,994	-39%	-26%	6,003,277	201	7,032,617	235	3,673,594	123	5,212,210	174
Lower Waihopai	2,510	-40%	-21%	3,804,181	152	4,681,207	186	2,294,255	91	3,714,287	148
Omaka Aquifer	2,829	-39%	-26%	5,521,908	195	6,499,296	230	3,372,671	119	4,839,258	171
Omaka River	6,507	-39%	-24%	11,167,074	172	13,475,260	207	6,756,824	104	10,263,661	158
Rarangi Shallow	1,250	-39%	-28%	2,125,455	170	2,644,149	212	1,298,797	104	1,910,016	153
Riverlands	5,074	-43%	-26%	6,649,782	131	8,722,833	172	3,781,170	75	6,497,144	128
Southern Springs	905	-48%	-24%	929,240	103	1,310,893	145	486,839	54	992,595	110
Taylor	5,210	-38%	-27%	11,220,474	215	13,004,234	250	6,913,137	133	9,512,835	183
Wairau Aquifer	14,369	-48%	-28%	14,847,106	103	20,742,620	144	7,792,155	54	14,992,322	104
All Zones	43,570	-42%	-26%	65,347,906	150	81,908,895	188	38,198,402	88	60,805,769	140

## 6 DISCUSSION

Modelled annual irrigation water use summarised in Section 4 reveal a wide range of values across the aquifer zones. Average annual irrigation water use, for example, varies from 103mm/year to 215mm/year. This reflects differences in the main soil types present in each zone.

The sensitivity analysis showed that reducing the irrigation trigger level to 50% of the soil's capacity to store water resulted in significant reductions in modelled annual irrigation water use. The variable irrigation trigger level that has been used for IrriCalc modelling of vineyards to-date is conservative in the sense that it aims to achieve and maintain soil water contents within 10% of maximum capacity from October through to end of December, reducing in January and February (but still much higher than 50%). This is considered an appropriate risk management strategy for shallow soils that have low capacity to store soil water. However, it makes relatively little use of the capacity for deeper soils to store water and potentially misses out on storing much of the rainfall that occurs during the irrigation season. Adopting a lower trigger level increases the soil's capacity to capture this rainfall to help meet the vine's evapotranspiration demand and thus reduce the amount of irrigation water that's needed.

The difference between the two irrigation strategies in the 2020/21 season is a modelled average water use of 181mm, assuming the current variable trigger level, and 134.5mm assuming a constant trigger level of 50%. The industry reported average irrigation water use for 2020/21 of 137mm falls toward the lower end of the modelled range.

Pilot studies conducted by Aqualinc for coastal areas of Hawkes Bay and Bay of Plenty have shown that the combination of a high groundwater table relative to crop root depth and fine textured soils can significantly reduce the need for irrigation because of the upward flow of water into the plant rootzone from the water table. Parts of the Lower Wairau Plain are highly likely to have a lower irrigation need due to the combination of high groundwater and fine textured soils. In this situation, variation in groundwater level throughout the year becomes a significant consideration. In a drought year, when evapotranspiration is high, the water table may have dropped sufficiently to prevent sufficient upward movement of water to meet evapotranspiration demand. This matter is still to be investigated.

These observations suggest that the spatial variation in metered annual irrigation water use across the Wairau Plains can largely be explained by spatial variations in the capacity of soils to store and transmit water, and to spatial variations in the depth to the groundwater table.

Spatial variation in rainfall, primarily the steep rainfall gradient from the northern foothills out onto the Plains will likely explain some of the spatial variation, though this has not been tested in this work.

Differences between growers in terms of their irrigation practices will also contribute to spatial variation in metered water use. Understanding the range of differences in practices is likely to require a comprehensive survey of growers.

## 7 SUMMARY

This project has used the irrigation system simulation model "IrriCalc" to model vineyard irrigation water use over a period of 26 years (1996 to 2022) with the aims of:

- Quantifying vineyard water demand for each Wairau Plain Freshwater Management Unit (FMU) for wet, average and dry seasonal conditions to confirm rates in MDC resource consents,
- Revealing why there are spatial differences between IrriCalc-defined water demand and measured actual use.

Modelled annual irrigation water use across groundwater-dominated FMUs on the Wairau Plains and Southern Valleys showed a large range in annual demand in response to seasonal conditions.

Annual irrigation water use assumed the entire FMU area is irrigated. The FMU boundaries are defined in the Marlborough Environment Plan and were supplied by MDC as ArcGIS files.

Analysis of the modelling results suggest that the spatial variation in metered annual irrigation water use across the Wairau Plains can largely be explained by spatial variations in the capacity of soils to store and transmit water. Spatial variations in the depth to the groundwater table are also likely to explain some of the variation, though the influence of shallow groundwater wasn't specifically modelled in this project.

Differences between growers in terms of their irrigation practices will also contribute to spatial variation in metered water use. A comprehensive survey of growers is almost certainly required if increasing understanding of the range of differences in irrigation practices is desired.

## Appendix A: Annual Reasonable Use Volumes by Zone and Soil Type

Table A.1: Annual Use Volumes by Zone and Soil Type

Aquifer Zone	Soil Type	Area	Sum Area	PAW <sub>1000</sub>	Ave Ann Vol	Ave Ann Vol	90% percentile	Alloc Vol	Sum Ave Ann Vol 1996/97-2021/22	Ave Ann Vol/Ha	Sum Alloc Vol	Ave Alloc Vol/Ha
		(ha)	(ha)	(mm)	(mm)	(m3)	(mm)	(m3)	(m3)	(mm)	(m3)	(mm)
Benmorven	Awate_17a.1	3.3	1,922	114	126.1	4,186	161.7	5,368	3,079,411	160	3,795,786	197
	Glenr_5a.2	183.0		53	179	327,583	216	395,296				
	Glenr_5b.1	13.2		64	165.7	21,804	202.1	26,594				
	Mair_21a.1	164.6		77	153.1	252,069	188.3	310,023				
	Omrk_8a.1	475.0		25	257.3	1,222,170	289.9	1,377,019				
	Renw_1a.1	342.1		98	137.4	470,061	172.1	588,774				
	Temu_50a.1	492.6		162	99.8	491,615	143.2	705,404				
	Timu_20a.1	248.4		130	116.7	289,922	155.9	387,308				
Brancott	Awate_17a.1	114.3	2,994	114	126.1	144,119	161.7	184,807	6,003,277	201	7,032,617	235
	Glenr_5a.2	530.6		53	179	949,720	216	1,146,031				
	Glenr_5b.1	45.5		64	165.7	75,389	202.1	91,950				
	Mair_18a.1	13.4		98	137.4	18,472	172.1	23,137				
	Mair_21a.1	20.9		77	153.1	32,059	188.3	39,430				
	Omrk_8a.1	1410.3		25	257.3	3,628,769	289.9	4,088,535				

	Renw_1a.1	797.4		98	137.4	1,095,677	172.1	1,372,387				
	Waim_42a.2	61.3		170	96.4	59,072	140.9	86,340				
Lower Waihopai	Glenr_5a.2	109.7	2,510	53	179	196,406	216	237,003	3,804,181	152	4,681,207	186
	Glenr_5b.1	1.2		64	165.7	2,037	202.1	2,484				
	Mair_18a.1	141.9		98	137.4	194,915	172.1	244,140				
	Mair_21a.1	28.7		77	153.1	43,936	188.3	54,037				
	Omrk_8a.1	271.7		25	257.3	698,980	289.9	787,541				
	Raka_2a.1	76.2		67	161.9	123,305	196.3	149,505				
	Renw_1a.1	1786.4		98	137.4	2,454,477	172.1	3,074,348				
	Temu_49a.1	39.5		176	94.1	37,163	138.6	54,737				
	Waim_42a.2	54.9		170	96.4	52,963	140.9	77,412				
Omaka Aquifer	Awate_17a.1	121.3	2,829	114	126.1	152,963	161.7	196,146	5,521,908	195	6,499,296	230
	Benm_2a.3	0.7		75	154.7	1,104	189.4	1,352				
	Benm_2a.4	0.7		75	154.7	1,104	189.4	1,352				
	Glenr_5a.2	464.4		53	179	831,234	216	1,003,054				
	Glenr_5b.1	53.6		64	165.7	88,820	202.1	108,331				
	Mair_21a.1	81.9		77	153.1	125,315	188.3	154,127				
	Omrk_8a.1	1233.2		25	257.3	3,172,946	289.9	3,574,959				
	Paha_36a.1	152.2		102	134.3	204,419	167.5	254,953				
	Renw_1a.1	587.0		98	137.4	806,529	172.1	1,010,216				
	Sedg_8a.1	4.7		82	148.6	7,042	183.6	8,700				

	Temu_50a.1	120.1		162	99.8	119,848	143.2	171,966				
	Timu_20a.1	9.1		130	116.7	10,583	155.9	14,138				
Omaka River	Awate_17a.1	703.7	6,507	114	126.1	887,306	161.7	1,137,806	11,167,074	172	13,475,260	207
	Awate_2a.1	1.4		127	118.5	1,707	157.1	2,263				
	Benm_2a.3	15.3		75	154.7	23,627	189.4	28,927				
	Benm_2a.4	16.9		75	154.7	26,221	189.4	32,103				
	Eyre_3a.1	34.9		88	144.3	50,412	177.9	62,151				
	Fris_14a.1	428.8		133	115	493,166	154.8	663,845				
	Glenr_5a.2	686.3		53	179	1,228,440	216	1,482,363				
	Glenr_5b.1	187.7		64	165.7	310,987	202.1	379,302				
	Hind_18a.2	14.5		177	93.9	13,648	138.6	20,145				
	Mair_18a.1	242.3		98	137.4	332,924	172.1	417,003				
	Mair_21a.1	229.4		77	153.1	351,226	188.3	431,978				
	Omrk_8a.1	1808.8		25	257.3	4,654,102	289.9	5,243,779				
	Paha_36a.1	65.7		102	134.3	88,267	167.5	110,087				
	Raka_2a.1	132.9		67	161.9	215,227	196.3	260,958				
	Renw_1a.1	1437.8		98	137.4	1,975,491	172.1	2,474,396				
	Selw_13a.1	47.2		181	91.8	43,336	136.3	64,343				
	Selw_23a.1	150.4		171	96	144,419	140.9	211,966				
	Temu_49a.1	26.6		176	94.1	25,064	138.6	36,917				
	Temu_50a.1	123.0		162	99.8	122,772	143.2	176,161				

	Timu_20a.1	153.2		130	116.7	178,732	155.9	238,768				
Rarangi Shallow	Ashb_35a.1	0.6	1,250	60	170	1,050	206.7	1,277	2,125,455	170	644,149	212
	Raka_2a.2	6.6		67	161.9	10,618	196.3	12,874				
	Rang_15a.1	997.1		46	192.9	1,923,341	233.3	2,326,155				
	Tait_21a.1	59.6		235	71.5	42,622	117.8	70,222				
	Waim_42a.2	9.8		170	96.4	9,483	140.9	13,861				
	Ymai_18a.2	176.2		215	78.5	138,342	124.7	219,760				
Riverlands	Ashb_35a.1	1470.2	5,074	60	170	2,499,322	206.7	3,038,881	6,649,782	131	8,722,833	172
	Eyre_3a.1	218.7		88	144.3	315,586	177.9	389,069				
	Fere_16a.1	10.8		114	126.1	13,667	161.7	17,525				
	Glenr_5a.2	109.6		53	179	196,104	216	236,640				
	Glenr_5b.1	9.3		64	165.7	15,382	202.1	18,761				
	Kaia_1a.1	70.6		213	79.3	56,004	125.9	88,914				
	Motu_7a.1	1698.3		206	81.4	1,382,380	128.2	2,177,163				
	Omrk_8a.1	273.0		25	257.3	702,551	289.9	791,565				
	Raka_2a.1	118.9		67	161.9	192,547	196.3	233,459				
	Rang_15a.1	122.2		46	192.9	235,646	233.3	284,998				
	Sedg_11a.1	159.3		105	132	210,252	166.3	264,885				
	Sedg_8a.1	118.3		82	148.6	175,832	183.6	217,245				
	Selw_23a.1	29.4		171	96	28,242	140.9	41,451				
	Temu_49a.1	650.8		176	94.1	612,446	138.6	902,072				

	Waim_42a.1	14.3		170	96.4	13,823	140.9	20,204				
Southern Springs	Awate_17a.1	2.6	905	114	126.1	3,256	161.7	4,175	929,240	103	1,310,893	145
	Awate_2a.1	33.2		127	118.5	39,322	157.1	52,130				
	Flax_79a.1	100.6		191	87.7	88,242	132.8	133,621				
	Fris_14a.1	51.3		133	115	58,949	154.8	79,351				
	Hind_18a.2	4.7		177	93.9	4,452	138.6	6,572				
	Payn_1a.1	27.6		199	84.5	23,324	130.5	36,021				
	Pouk_1a.3	10.4		450	24.3	2,527	48.5	5,043				
	Renw_1a.1	77.8		98	137.4	106,909	172.1	133,908				
	Selw_13a.1	1.5		181	91.8	1,414	136.3	2,100				
	Selw_23a.1	77.4		171	96	74,330	140.9	109,094				
	Temu_50a.1	460.7		162	99.8	459,798	143.2	659,750				
	Timu_20a.1	57.2		130	116.7	66,718	155.9	89,129				
Taylor	Ashb_35a.1	31.1	5,210	60	170	52,906	206.7	64,328	11,220,474	215	13,004,234	250
	Awate_17a.1	124.6		114	126.1	157,076	161.7	201,421				
	Benm_2a.3	4.2		75	154.7	6,433	189.4	7,876				
	Benm_2a.4	4.7		75	154.7	7,276	189.4	8,908				
	Eyre_3a.1	212.3		88	144.3	306,301	177.9	377,623				
	Glenr_5a.2	1127.2		53	179	2,017,718	216	2,434,788				
	Glenr_5b.1	328.4		64	165.7	544,135	202.1	663,668				
	Omrk_8a.1	2906.3		25	257.3	7,477,785	289.9	8,425,223				

	Raka_2a.1	118.3		67	161.9	191,507	196.3	232,197				
	Raka_2a.2	10.6		67	161.9	17,172	196.3	20,821				
	Renw_1a.1	211.3		98	137.4	290,389	172.1	363,726				
	Temu_49a.1	2.8		176	94.1	2,606	138.6	3,839				
	Temu_50a.1	5.5		162	99.8	5,465	143.2	7,842				
	Timu_20a.1	123.1		130	116.7	143,704	155.9	191,975				
Wairau Aquifer	Ashb_35a.1	341.1	14,369	60	161.9	552,271	196.9	671,662	14,847,106	103	20,742,620	144
	Awate_17a.1	1072.5		114	120.1	1,288,029	154	1,651,595				
	Awate_2a.1	10.4		127	112.9	11,778	149.6	15,607				
	Fere_16a.1	76.8		114	120.1	92,248	154	118,287				
	Flax_79a.1	702.4		191	83.5	586,485	126.5	888,507				
	Fris_14a.1	0.6		133	109.5	652	147.4	877				
	Hind_18a.2	1093.3		177	89.4	977,435	132	1,443,193				
	Hind_9b.2	82.3		181	87.4	71,934	129.8	106,831				
	Kaia_1a.1	763.3		213	75.6	577,083	119.9	915,242				
	Motu_7a.1	1137.7		206	77.5	881,683	122.1	1,389,077				
	Raka_2a.1	815.2		67	154.2	1,256,990	187	1,524,365				
	Raka_2a.2	41.1		67	154.2	63,379	187	76,861				
	Rang_15a.1	1473.8		46	183.7	2,707,282	222.2	3,274,677				
	Rang_53a.1	191.3		83	141	269,744	174.9	334,597				
	Renw_1a.1	3.4		98	130.9	4,396	163.9	5,504				

	Selw_13a.1	778.1		181	87.4	680,024	129.8	1,009,921				
	Selw_23a.1	1879.8		171	91.5	1,720,000	134.2	2,522,666				
	Selw_26a.1	52.4		136	108.3	56,698	147.4	77,168				
	Selw_27a.1	287.0		136	108.3	310,780	147.4	422,982				
	Selw_35a.1	12.6		128	112.3	14,107	149.6	18,793				
	Tait_21a.1	2181.6		235	68.1	1,485,658	112.2	2,447,736				
	Temu_19a.1	476.8		180	88.3	421,055	132	629,437				
	Temu_49a.1	0.3		176	89.6	244	132	359				
	Uxbr_2a.1	78.5		150	101.1	79,393	141.9	111,433				
	Waim_42a.2	745.6		170	91.8	684,458	134.2	1,000,591				
	Ymai_18a.2	71.3		215	74.8	53,300	118.8	84,652				
Total of FMUs			43,570						65,347,906	150	81,908,895	188

