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Ground-water abstraction from the Wairau Plains

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A report prepared for

Marlborough District Council and EnviroLink

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Plant & Food Research, Palmerston North

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Contents

Executive summary

Ground-water abstraction from the Wairau Plains

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The Marlborough District Council (MDC) is currently seeking to define the volumes of water used for irrigation of wine grapes. This information is needed to establish sustainable limits for groundwater abstraction. A measurement and modelling approach was adopted for this study. Seasonal irrigation records (November to April) and soil moisture readings were assembled from a large number of monitor sites (> 300 vineyards) between the years 2004 and 2011. Modelling was carried out using Plant and Food Research's SPASMO model (Soil Plant Atmosphere System Model) that simulates the daily water and nutrient balance for a given land use, soil type and microclimate. A standard deficit-irrigation strategy was adopted for all simulations, where the vines were grown under a mild water-stress from verasion until harvest (i.e. the fruit ripening stage).

For the purpose of calculation, the land area under vineyard production was identified using a GIS map of vineyard property boundaries. The corresponding soil series under each vineyard was identified from the Functional Soil Layer map (Landcare Research). The physical and hydraulic properties were deduced from soil profile descriptions (texture, depth, stone content, water retention, drainage class) in the New Zealand Soils database. Daily climate data (1972-2011) were assembled on a 5 km grid using NIWA's Virtual Climate Network of stations. The crop factor for wine grapes, that relates actual vine water use to the evaporative demand (ETo, mm/day), was derived from >10 years of sap flow data from grape vines from Marlborough. Grower records and model outputs of irrigation use were grouped according to the nearest climate station and the representative soil type. Daily values of irrigation were summed up on a monthly basis to generate two estimates for water take from each aquifer zone.

Our analysis revealed large differences in irrigation use across the plains that could be explained by differences in soil water holding capacity and summer rainfall. There was a very good correspondence between the two estimates of water take from the two large aquifer zones (Southern Valleys and Upper Wairau recharge area) that represent 75% of the planted vineyard area. The model tended to overestimate actual irrigation take from the coastal zones, where the grape plantings are younger and the groundwater is shallower that we had modelled. More importantly, our analysis revealed that grape growers, on average, are using substantially less water than they have been allocated. These findings will enable the Council to draw conclusions about current water allocation policies and also to assess the sustainability of water takes for irrigation of wine grapes cf. aquifer recharge of the Wairau Plains.

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1 Background

Grape vineyards are the dominant land use and their irrigation represents a major abstraction of ground-water from the Wairau Plains. At present, the Marlborough District Council (MDC) irrigation records for vineyards are incomplete. Council is seeking to define the volumes of water used for wine grape production. This information is needed to establish sustainable limits for ground-water abstraction.

2 Task

Plant & Food Research (PFR) was contracted to determine, via measurement and modelling, the water take for irrigation of wine grapes on the Wairau Plains. To support this work, MDC supplied us with a GIS map of the current land area under vineyard production (Fig. 1), and a second GIS map detailing the aquifer zones (Table 1). PFR's task was to define actual water takes, for vineyard irrigation, from each aquifer zone.

2.1 Approach 1:

The first approach is based on measurements. Here, we used actual irrigation volumes and soil moisture readings provided by Fruition Horticulture (FH). Data were provided from a large number of monitor sites (> 300 vineyards) between 2004 and 2011 (Fig. 1). Vineyard records (weekly values of irrigation and soil moisture) were first grouped according to aquifer zone and soil series. Irrigation volumes from each vineyard were then summed up on a monthly basis, and statistics (mm/day) were scaled (L/s) according to the total vineyard area (ha) above each aquifer zone. This scaling provided one estimate of the monthly and annual water takes. With this scaling we did not make a distinction for grape variety, irrigation strategy or vine age and vigour; rather we gave an equal weighting to each vineyard data set.

2.2 Approach 2:

The second approach is based on modelling. Here, we used our SPASMO model (Soil Plant Atmosphere System Model) to simulate irrigation demand for a range of locations (climates) and soil types across each aquifer zone. SPASMO works on a daily basis, at the paddock scale, and all model outputs for the soil-water balance are expressed in terms of mm/day. For these calculations, we used local soil, crop and climate data. Climate records (1972-2011) were assembled on a 5k grid using NIWA's Virtual Climate Network of stations. Within each 5k grid, we used a GIS map of the Functional Soil Layer Map (Landcare Research) and a GIS map of the vineyard property boundaries to determine land areas and corresponding soil series under each vineyard. A profile description for the soil's physical and hydraulic properties, needed for the modelling, was deduced using data from the New Zealand soils database (NZSDB, Landcare Research). Local values for the crop coefficients for wine grapes that relate vine water use to the evaporative demand (ET_o, mm/day) were derived from >10 years of experimental data from Sauvignon vines in Marlborough. A standard irrigation strategy was adopted for all simulations (as described by Fruition Horticulture). The vines were irrigated according need (i.e. non-stressed) from budburst up to fruit-set. Deficit-irrigation (reducing soil moisture) was imposed between fruit-set and veraison, and a mild water stress was maintained until harvest. Model outputs from SPASMO (irrigation, mm/d) were grouped according to aquifer zone, climate zone, soil series and vineyard area. Irrigation volumes associated with each aquifer zone were then summed up on a monthly basis. Statistics of irrigation use (mm/month) were scaled (L/s) according to the total vineyard area (ha) above each aquifer zone. This scaling provided a second estimate of the monthly and annual water takes. It accounted for variation in soil and climate but did not consider other factors (vine age, variety, irrigation strategy, ground-water depth).

3 Results

3.1 Measurements

A statistical summary of the field data for irrigation is presented in Tables 2-8. For each aquifer zone, and for the whole of the Wairau Plains, we have provided estimates of the monthly irrigation takes (L/s). The results are expressed in terms of an average, a standard deviation and an upper quartile (75%) each month of the irrigation season (November to April) spanning the years 2004-2011. Records from between 4 and 199 vineyards (fewer monitor sites on the smaller aquifers) were used to compile estimates of water abstraction from each aquifer zone. For the purpose of calculation, vineyard data were equally weighted across a range of vineyard ages (young, developing, established), varieties (Cabernet, Chardonnay, Pinot gris, Pinot noir, Riesling and Sauvignon blanc), irrigation strategies (developing, conservative, standard, young) and soil types. A statistical summary, representing averages and ranges for each aquifer zone, is plotted in Figs 3-8.

3.2 Modelling

A statistical summary of the model outputs for irrigation is presented in Figs 3-8. For each aquifer zone, we have provided model estimates of the monthly irrigation takes (L/s) in terms of an average and a standard error each month of the year. These model outputs are based on daily simulations spanning the years 1972-2011. We first assembled model outputs associated with each climate grid. Then we summed up the outputs across each aquifer zone taking into account the vineyard size and the soil type. For the purpose of modelling, we have considered only an established Sauvignon blanc vineyard with a standard irrigation strategy and a typical vineyard management.

4 Discussion

As expected, on average, the highest water takes occur during the middle of the summer (February and March) and lower water takes occur during the shoulders of the irrigation season (November and April). We see a reasonable correspondence between measurement and modelling average water takes from the larger aquifer zones (e.g. Zone 1 – Wairau Recharge and Springs section = 5050 ha; Zone 6 – Southern Valleys section = 5650 ha). These represent about 75% of the planted grape area. For these two big aquifer zones, we have a large number of monitor sites (>150) and a greater proportion of well-established vineyards (i.e. the monitored vineyards better match what we have modelled). The modelling does, however, predict higher water takes than recorded, on average, from Zones 2-5. Reasons to explain some of this discrepancy include: a limited set of monitor data (e.g. Zones 5 has between 4 and 12 vineyard sites); shallow ground-water (e.g. Zones 2 and 3); predominance of young and developing vines (e.g. Zone 4); different irrigation strategies being employed across the vineyards. Furthermore, the modelling accounts for all soil types above each aquifer, albeit limited to ‘average soil properties’ and mapped soil series, while the data do not. Ultimately, we are also trying to model ‘behaviour’ of the irrigation manager – their decisions may change over time due to improved understanding of irrigation and/or changes in irrigation strategy to match market demands for fruit yields of quality. Thus, some difference between measured and modelled water take is expected since we do not have data from every vineyard on the Plains.

5 Conclusion

In general, model calculations of the average water take tend to be a little higher than the corresponding volumes calculated from the vineyard data, although some questions remain over how best to average and interpret the actual water use records. In both cases, we see a wide spread in monthly water takes, e.g. as shown by the upper quartiles (UQ) calculated from the vineyard data. Indeed, the max upper quartile is about 3 times the mean. The spread of model outputs is shown here only by the standard error of the mean, although more detailed statistical processing could be undertaken, e.g. a probability analysis of model outputs. We advise taking the larger value of the model and measurement estimates. Additional analysis of the model outputs (e.g. to provide probability estimates for monthly water take, based on data or model outputs) can be provided to council upon request.

6 Acknowledgements

This work was funded by an Envirolink medium advice grant (No. 976-MLDC62) from the Ministry of Science and Innovation (MSI). Mr Greg Dryden (Fruition Horticulture) was subcontracted to provide vineyard data from monitor sites.

Figures 1 - 8

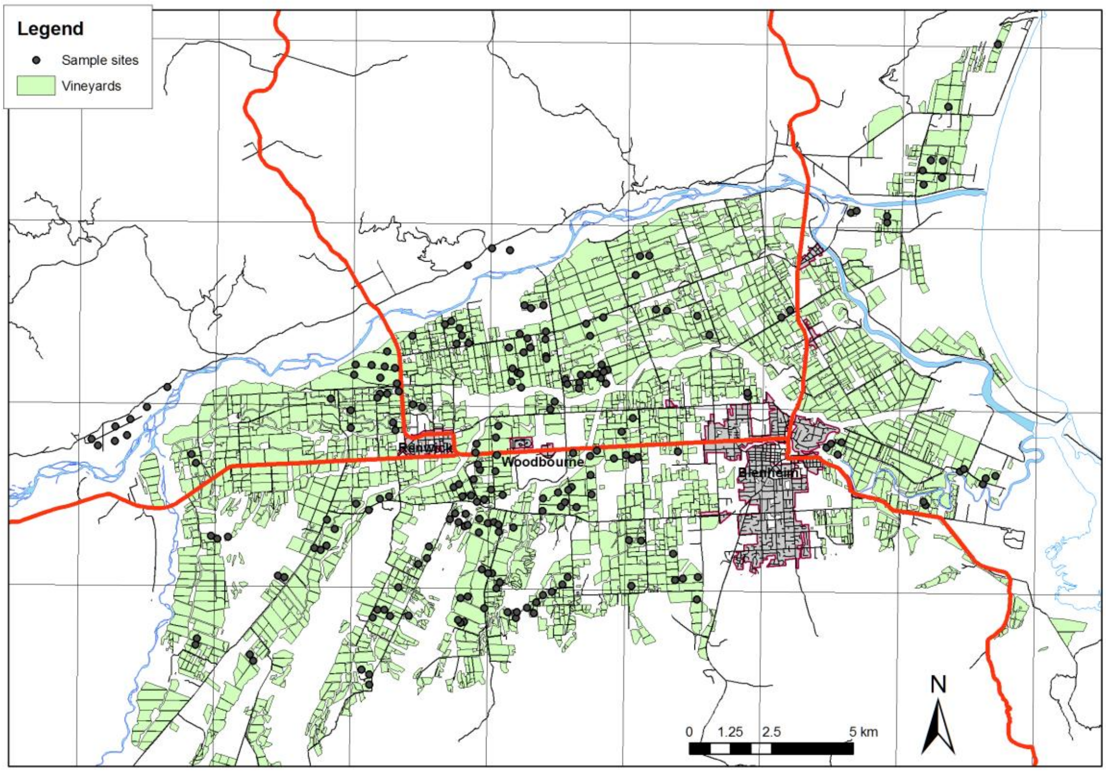

Figure 1. Map of the Wairau Plains showing vineyard areas (shaded pale green) and sites that are monitored by Fruition Horticulture (markers). The data were supplied by Greg Dryden, Fruition Horticulture.

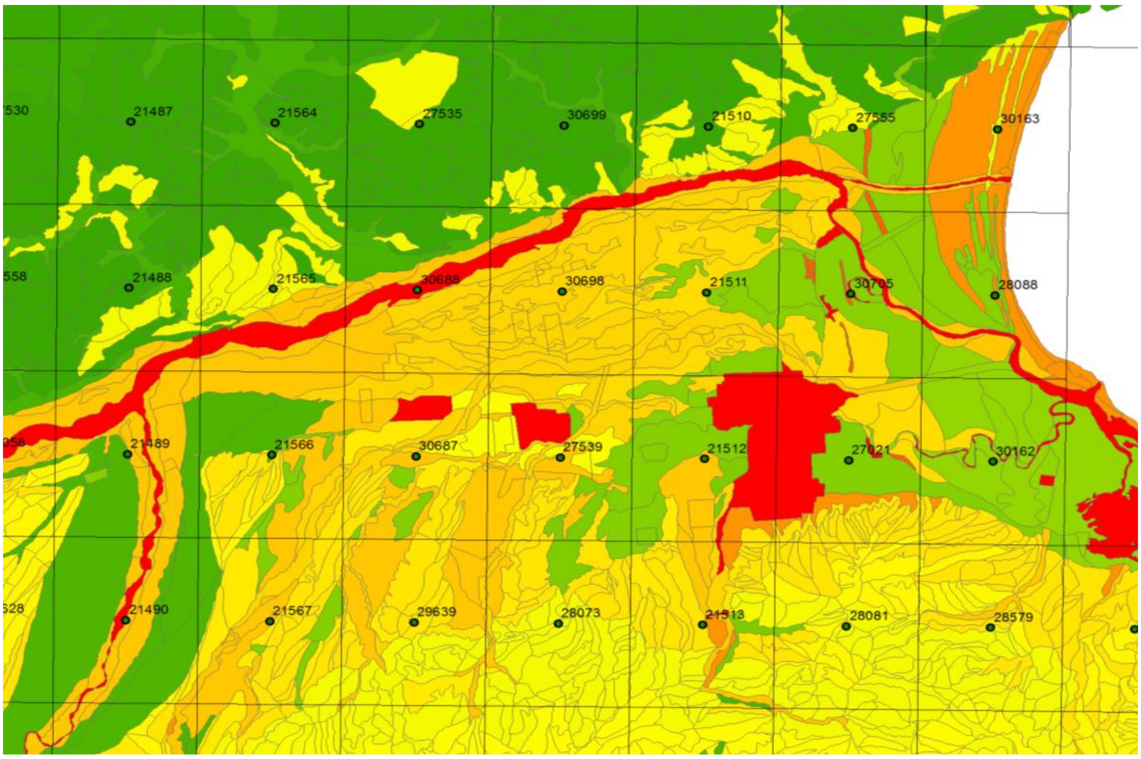

Figure 2. Map of the Wairau Plains showing soil series (shaded) and climate stations (markers). Climate data (1972-2011) were downloaded from NIWA's Virtual Climate Network using the Cliflo software (www.cliflo.niwa.co.nz).

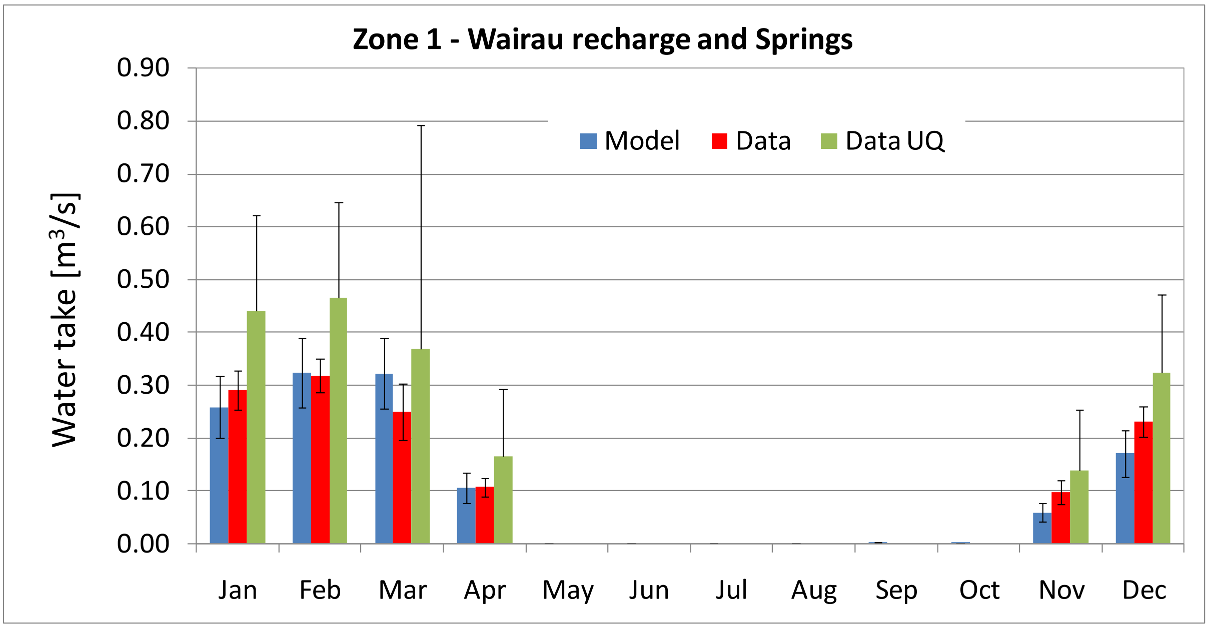

Figure 3. Model calculations of monthly water takes from the Wairau Recharge and Springs aquifers. The average and maximums are based on climate data from 1972-2010. Data records were assembled from between 80 (2004) and 170 (2011) monitored sites (Fruition Horticulture).

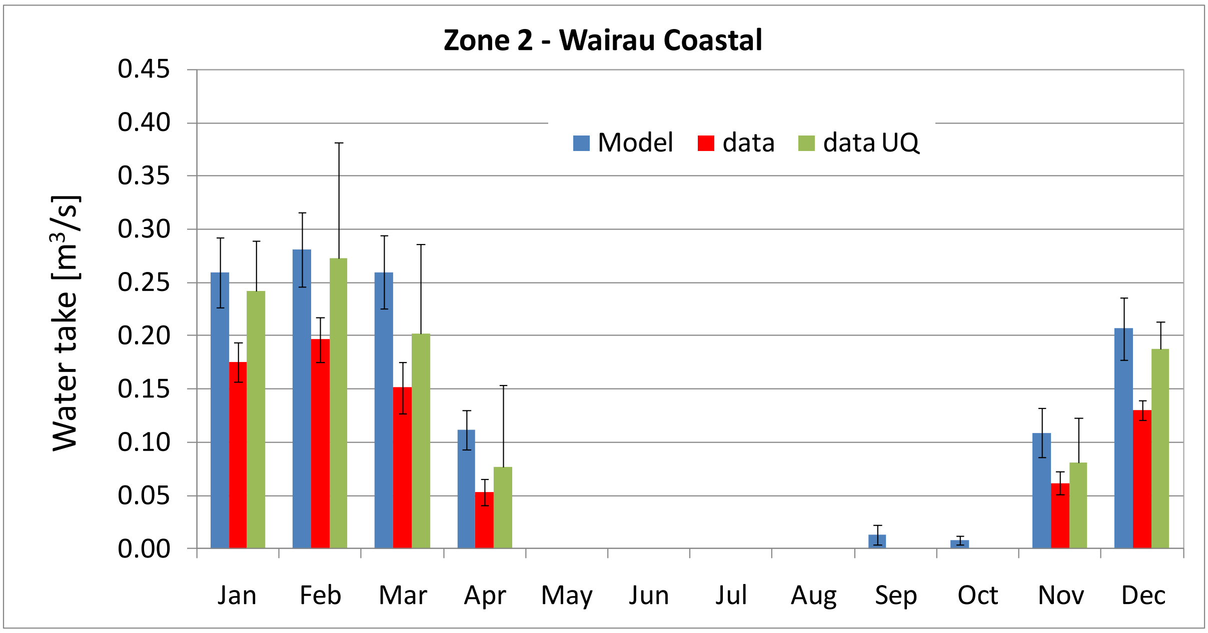

Figure 4. Model calculations of monthly water takes from the Wairau coastal aquifers. The average and maximums are based on climate data from 1972-2010. Data records were assembled from between 12 (2005) and 40 (2011) monitored sites (Fruition Horticulture).

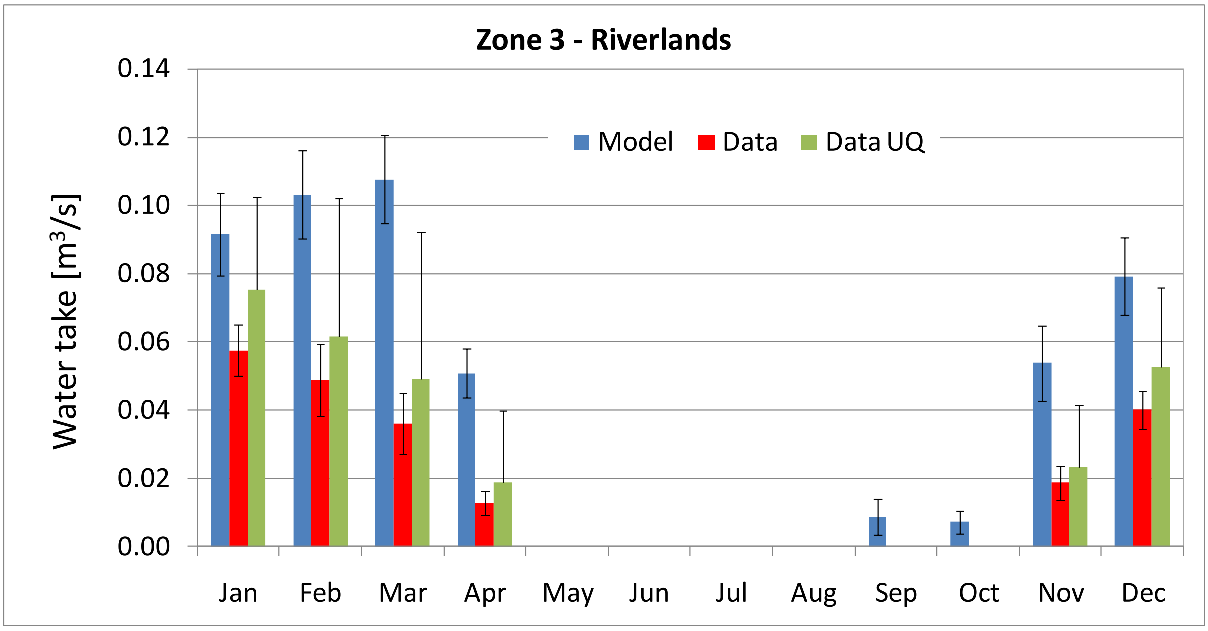

Figure 5. Model calculations of monthly water takes from the Riverlands aquifers. The average and maximums are based on climate data from 1972-2010. Data records were assembled from between 4 (2004) and 13 (2011) monitored sites (Fruition Horticulture).

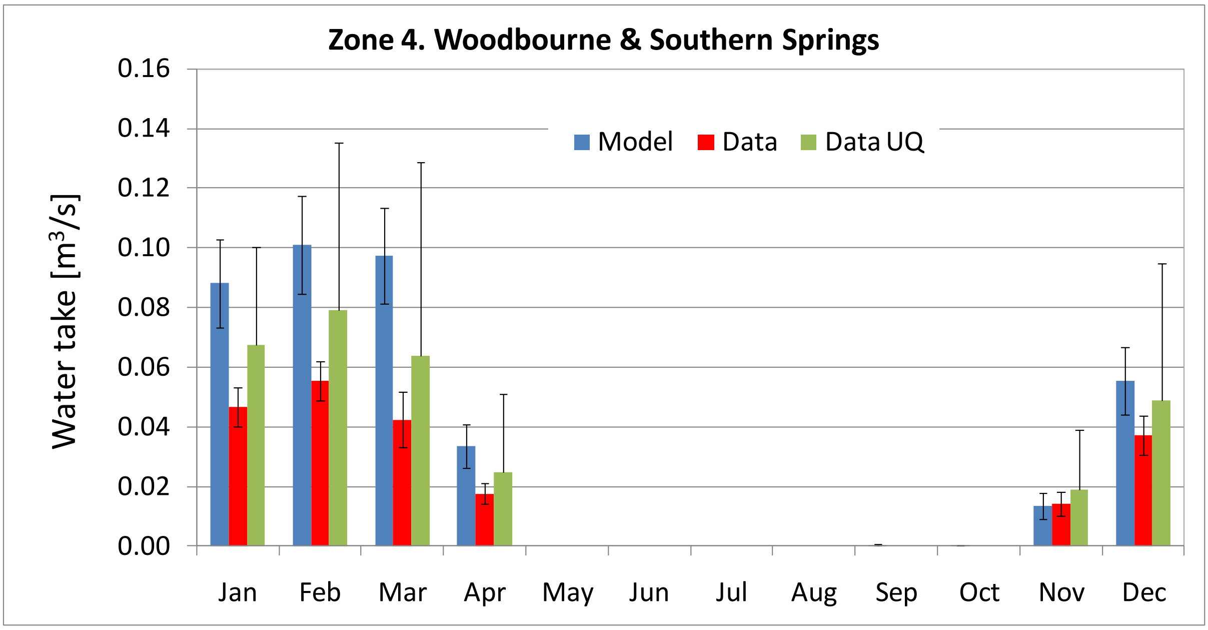

Figure 6. Model calculations of monthly water takes from the Woodbourne and Southern Springs aquifers. The average and maximums are based on climate data from 1972-2010. Data records were assembled from between 54 (2004) and 99 (2011) monitored sites (Fruition Horticulture).

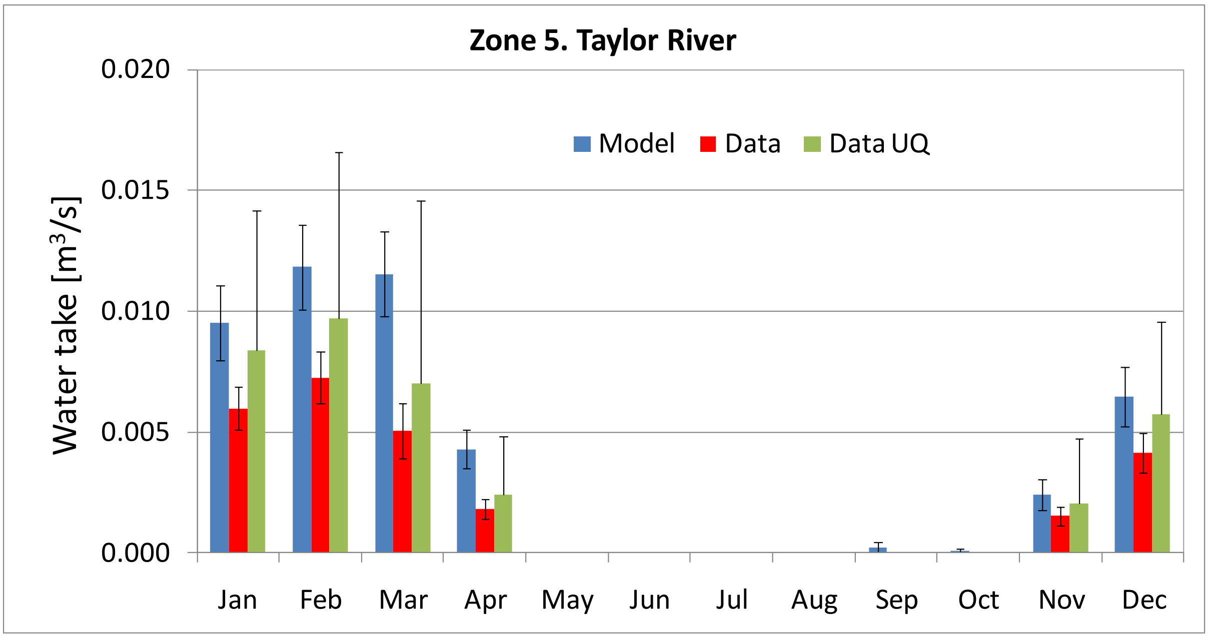

Figure 7. Model calculations of monthly water takes from the Taylor River aquifer. The average and maximums are based on climate data from 1972-2010. Data records were assembled from between 15 (2004) and 36 (2011) monitored sites (Fruition Horticulture).

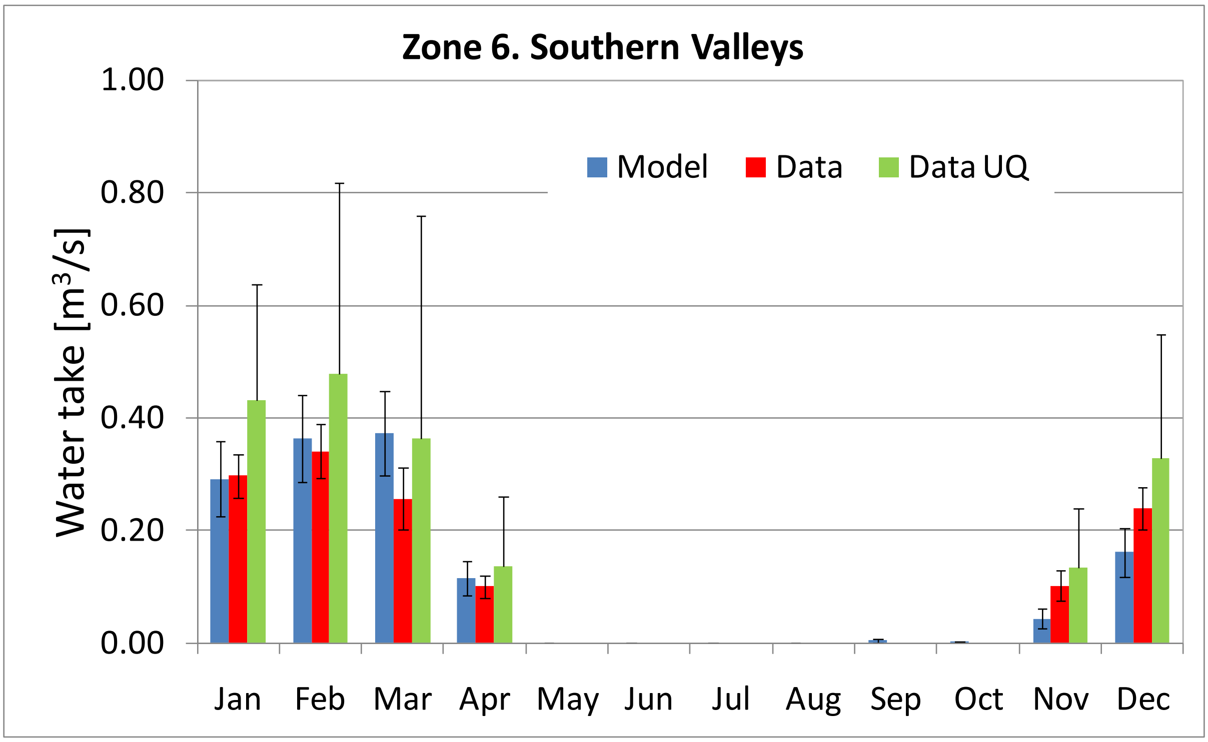

Figure 8. Model calculations of monthly water takes from the Southern Valleys aquifers. The average and maximums are based on climate data from 1972-2010. Data records were assembled from between 75 (2004) and 160 (2011) monitored sites (Fruition Horticulture).

Tables 1 to 8

Table 1. A list of aquifer names and zones on the Wairau Plains. The ‘area’ refers to the planted vineyard area (ha), and this was determined using a GIS map provided by Marlborough District Council. Within each zone, a GIS map of Functional Soil Layers (Landcare research) was used to define the range of soil series.

Zone no.	Aquifer names	area (ha)
1	Wairau Aquifer - Recharge Sector	3579
1	Wairau Aquifer - Springs Sector	1471
2	Wairau Aquifer - Coastal Sector	254
2	Wairau Aquifer - CS under Rarangi Shallow Aquifer	256
2	Wairau Aquifer - Lower Wairau Sector	1406
2	Rarangi Shallow Aquifer	182
2	Rarangi Shallow Aquifer over Wairau Aquifer CS***	256
3	Lagoons Transition Sector	207
3	Riverlands Aquifer	366
3	Riverlands Transition Sector	153
4	Southern Springs Sector	362
4	Woodbourne Sector	652
5	Taylor Fan Aquifer	84
5	Taylor River Gravels Aquifer	28
6	Benmorven Aquifer	850
6	Brancott Aquifer	791
6	Fairhall River Gravels Aquifer	53
6	Lower Waihopai Aquifer	2080
6	Omaka Aquifer	691
6	Omaka River Aquifer	1073
	Grand Total	14792

Table 2. Average irrigation volumes taken from Zone 1 – Wairau Recharge and Springs section. Data were assembled from between 80 (2004) and 170 (2011) monitored sites (Greg Dryden, Fruition Horticulture). UQ = the upper quartile.

Aquifer area		5050	ha				
Year		Jan	Feb	Mar	Apr	Nov	Dec
2004	UQ	0.53	0.35	0.15	0.16	0.04	0.34
	average	0.36	0.29	0.10	0.10	0.04	0.26
	stdev	0.25	0.24	0.11	0.10	0.07	0.35
2005	UQ	0.17	0.39	0.37	0.04	0.23	0.30
	average	0.10	0.28	0.25	0.03	0.16	0.20
	stdev	0.11	0.30	0.22	0.05	0.14	0.14
2006	UQ	0.43	0.33	0.27	0.15	0.06	0.21
	average	0.32	0.23	0.20	0.09	0.05	0.15
	stdev	0.24	0.21	0.21	0.11	0.10	0.14
2007	UQ	0.38	0.35	0.45	0.23	0.21	0.34
	average	0.24	0.22	0.29	0.15	0.13	0.23
	stdev	0.20	0.21	0.21	0.12	0.13	0.19
2008	UQ	0.43	0.51	0.30	0.12	0.08	0.19
	average	0.29	0.33	0.24	0.07	0.04	0.13
	stdev	0.26	0.25	0.21	0.07	0.06	0.15
2009	UQ	0.57	0.49	0.11	0.19	0.10	0.41
	average	0.36	0.33	0.07	0.12	0.08	0.29
	stdev	0.31	0.27	0.10	0.15	0.13	0.26
2010	UQ	0.62	0.65	0.79	0.29	0.25	0.47
	average	0.41	0.43	0.53	0.19	0.18	0.35
	stdev	0.29	0.34	0.42	0.19	0.19	0.25
2011	UQ	0.40	0.65	0.49	0.16		
	average	0.25	0.44	0.32	0.10		
	stdev	0.25	0.33	0.27	0.12		
All years	Max UQ	0.62	0.65	0.79	0.29	0.25	0.47
	average	0.29	0.32	0.25	0.11	0.10	0.23
	stdev	0.10	0.08	0.14	0.05	0.06	0.08

Table 3. Average irrigation volumes taken from Zone 2 – Wairau Coastal section. Data were assembled from between 12 (2004) and 40 (2011) monitor site (Greg Dryden, Fruition Horticulture). UQ = the upper quartile.

Aquifer area		2097	ha				
Year		Jan	Feb	Mar	Apr	Nov	Dec
2004	UQ						
	average						
	stdev						
2005	UQ	0.13	0.28	0.15	0.03	0.12	0.17
	average	0.09	0.16	0.10	0.03	0.09	0.14
	stdev	0.05	0.17	0.08	0.05	0.05	0.08
2006	UQ	0.25	0.23	0.11	0.00	0.05	0.17
	average	0.16	0.14	0.09	0.01	0.04	0.09
	stdev	0.12	0.14	0.08	0.01	0.05	0.08
2007	UQ	0.29	0.20	0.27	0.11	0.11	0.21
	average	0.15	0.16	0.17	0.08	0.08	0.16
	stdev	0.16	0.10	0.11	0.05	0.06	0.09
2008	UQ	0.26	0.22	0.17	0.06	0.05	0.19
	average	0.20	0.17	0.15	0.05	0.04	0.12
	stdev	0.17	0.08	0.08	0.04	0.05	0.13
2009	UQ	0.29	0.30	0.14	0.07	0.04	0.20
	average	0.24	0.21	0.09	0.05	0.03	0.13
	stdev	0.26	0.17	0.10	0.05	0.04	0.08
2010	UQ	0.27	0.31	0.29	0.15	0.11	0.18
	average	0.21	0.24	0.24	0.10	0.09	0.14
	stdev	0.12	0.11	0.13	0.06	0.09	0.08
2011	UQ	0.22	0.38	0.28	0.12		
	average	0.17	0.29	0.22	0.07		
	stdev	0.09	0.16	0.12	0.06		
All years	Max UQ	0.29	0.38	0.29	0.15	0.12	0.21
	average	0.18	0.20	0.15	0.05	0.06	0.13
	stdev	0.05	0.06	0.06	0.03	0.03	0.02

Table 4. Average irrigation volumes taken from Zone 3 – Riverlands section. Data were assembled from between 4 (2004) and 13 (2011) monitored sites (Greg Dryden, Fruition Horticulture). UQ = the upper quartile.

Aquifer area		726	ha				
Year		Jan	Feb	Mar	Apr	Nov	Dec
2004	UQ						
	average						
	stdev						
2005	UQ		0.01	0.01	0.00	0.03	0.03
	average		0.01	0.01	0.00	0.02	0.02
	stdev		0.01	0.01	0.00	0.01	0.01
2006	UQ	0.04	0.04	0.02	0.00	0.04	0.06
	average	0.03	0.02	0.01	0.00	0.03	0.05
	stdev	0.03	0.02	0.01	0.00	0.03	0.02
2007	UQ	0.10	0.07	0.06	0.02	0.04	0.08
	average	0.07	0.05	0.05	0.01	0.03	0.06
	stdev	0.04	0.03	0.01	0.01	0.02	0.04
2008	UQ	0.08	0.06	0.06	0.02	0.00	0.04
	average	0.06	0.06	0.05	0.02	0.00	0.03
	stdev	0.05	0.02	0.02	0.02	0.01	0.02
2009	UQ	0.08	0.05	0.02	0.02	0.01	0.05
	average	0.05	0.04	0.02	0.01	0.01	0.04
	stdev	0.03	0.03	0.02	0.01	0.01	0.02
2010	UQ	0.10	0.10	0.09	0.03	0.02	0.06
	Average	0.09	0.08	0.06	0.02	0.01	0.04
	Stdev	0.04	0.04	0.03	0.02	0.01	0.03
2011	UQ	0.06	0.10	0.09	0.04		
	Average	0.04	0.08	0.06	0.02		
	Stdev	0.02	0.05	0.04	0.02		
All years	max UQ	0.10	0.10	0.09	0.04	0.04	0.08
	Average	0.06	0.05	0.04	0.01	0.02	0.04
	stdev	0.02	0.03	0.02	0.01	0.01	0.01

Table 5. Average irrigation volumes taken from Zone 4 – Woodbourne and Southern Springs section. Data were assembled from between 54 (2004) and 99 (2011) monitored sites (Greg Dryden, Fruition Horticulture). UQ = the upper quartile.

Aquifer area 1014 ha

Year		Jan	Feb	Mar	Apr	Nov	Dec
2004	UQ	0.08	0.06	0.03	0.02	0.00	0.05
	average	0.06	0.05	0.02	0.02	0.00	0.05
	stdev	0.05	0.04	0.02	0.02	0.01	0.08
2005	UQ	0.02	0.05	0.07	0.00	0.04	0.05
	average	0.01	0.04	0.04	0.00	0.03	0.03
	stdev	0.02	0.05	0.05	0.01	0.02	0.03
2006	UQ	0.07	0.08	0.06	0.02	0.01	0.04
	average	0.05	0.05	0.04	0.01	0.01	0.03
	stdev	0.04	0.05	0.05	0.02	0.02	0.03
2007	UQ	0.05	0.04	0.08	0.03	0.03	0.04
	average	0.04	0.03	0.05	0.02	0.02	0.03
	stdev	0.04	0.04	0.04	0.02	0.02	0.04
2008	UQ	0.06	0.06	0.05	0.02	0.00	0.02
	average	0.05	0.05	0.04	0.01	0.00	0.01
	stdev	0.06	0.05	0.04	0.01	0.01	0.02
2009	UQ	0.08	0.08	0.01	0.02	0.01	0.06
	average	0.05	0.05	0.01	0.02	0.01	0.04
	stdev	0.05	0.06	0.01	0.02	0.01	0.04
2010	UQ	0.10	0.12	0.13	0.05	0.04	0.09
	average	0.07	0.08	0.08	0.04	0.03	0.07
	stdev	0.06	0.07	0.08	0.04	0.04	0.06
2011	UQ	0.08	0.14	0.09	0.03		
	average	0.04	0.08	0.06	0.02		
	stdev	0.05	0.07	0.05	0.03		
All years	max UQ	0.10	0.14	0.13	0.05	0.04	0.09
	average	0.05	0.06	0.04	0.02	0.01	0.04
	stdev	0.02	0.02	0.02	0.01	0.01	0.02

Table 6. Average irrigation volumes taken from Zone 5 – Taylor River section. Data were assembled from between 15 (2004) and 36 (2011) monitored sites (Greg Dryden, Fruition Horticulture). UQ = the upper quartile.

Aquifer area 111.6 ha

Year		Jan	Feb	Mar	Apr	Nov	Dec
2004	UQ	0.010	0.009	0.003	0.003	0.000	0.005
	average	0.008	0.007	0.003	0.002	0.001	0.004
	stdev	0.007	0.006	0.002	0.003	0.001	0.003
2005	UQ	0.002	0.009	0.007	0.000	0.003	0.008
	average	0.001	0.007	0.005	0.000	0.003	0.004
	stdev	0.002	0.007	0.006	0.001	0.002	0.004
2006	UQ	0.008	0.008	0.005	0.001	0.000	0.003
	average	0.006	0.006	0.004	0.001	0.000	0.002
	stdev	0.003	0.005	0.005	0.001	0.001	0.001
2007	UQ	0.006	0.003	0.007	0.003	0.003	0.004
	average	0.005	0.003	0.005	0.002	0.002	0.003
	stdev	0.005	0.003	0.003	0.001	0.003	0.005
2008	UQ	0.007	0.009	0.005	0.002	0.000	0.004
	average	0.005	0.007	0.004	0.001	0.001	0.002
	stdev	0.005	0.007	0.003	0.001	0.002	0.002
2009	UQ	0.010	0.008	0.000	0.002	0.001	0.006
	average	0.007	0.006	0.001	0.001	0.001	0.005
	stdev	0.008	0.006	0.001	0.002	0.002	0.004
2010	UQ	0.014	0.015	0.014	0.005	0.005	0.010
	average	0.009	0.011	0.010	0.004	0.003	0.009
	stdev	0.008	0.009	0.006	0.005	0.002	0.008
2011	UQ	0.011	0.017	0.015	0.003		
	average	0.006	0.011	0.009	0.002		
	stdev	0.005	0.008	0.006	0.002		
All years	max UQ	0.014	0.017	0.015	0.005	0.005	0.010
	average	0.006	0.007	0.005	0.002	0.002	0.004
	stdev	0.002	0.003	0.003	0.001	0.001	0.002

Table 7. Average irrigation volumes taken from Zone 6 – Southern Valleys section. Data were assembled from between 75 (2004) and 160 (2011) monitored sites (Greg Dryden, Fruition Horticulture). UQ = the upper quartile.

Aquifer area 5650 ha

Year		Jan	Feb	Mar	Apr	Nov	Dec
2004	UQ	0.51	0.37	0.15	0.13	0.07	0.30
	average	0.38	0.28	0.10	0.08	0.05	0.26
	stdev	0.27	0.24	0.11	0.09	0.10	0.40
2005	UQ	0.19	0.39	0.37	0.01	0.24	0.40
	average	0.11	0.28	0.24	0.03	0.20	0.25
	stdev	0.14	0.31	0.24	0.06	0.21	0.17
2006	UQ	0.47	0.34	0.26	0.08	0.07	0.23
	average	0.33	0.23	0.20	0.06	0.05	0.16
	stdev	0.23	0.23	0.23	0.11	0.13	0.16
2007	UQ	0.33	0.26	0.46	0.19	0.24	0.30
	average	0.23	0.19	0.31	0.13	0.16	0.23
	stdev	0.22	0.19	0.25	0.11	0.20	0.23
2008	UQ	0.42	0.47	0.32	0.12	0.04	0.13
	average	0.31	0.35	0.26	0.08	0.03	0.08
	stdev	0.32	0.30	0.28	0.12	0.06	0.11
2009	UQ	0.49	0.47	0.06	0.13	0.07	0.41
	average	0.33	0.35	0.06	0.09	0.05	0.28
	stdev	0.31	0.30	0.11	0.12	0.08	0.25
2010	UQ	0.64	0.71	0.76	0.26	0.22	0.55
	average	0.44	0.49	0.51	0.20	0.17	0.40
	stdev	0.33	0.41	0.44	0.26	0.19	0.30
2011	UQ	0.40	0.82	0.54	0.17		
	average	0.25	0.55	0.36	0.12		
	stdev	0.29	0.44	0.33	0.15		
All years	max UQ	0.64	0.82	0.76	0.26	0.24	0.55
	average	0.30	0.34	0.26	0.10	0.10	0.24
	stdev	0.10	0.12	0.14	0.05	0.07	0.10

Table 8. Average irrigation volumes taken from Zone 7 – All of the Wairau Plains. Data were assembled from between 144 (2004) and 299 (2011) monitored sites (Greg Dryden, Fruition Horticulture). UQ = the upper quartile.

Aquifer area 14792 ha

Year		Jan	Feb	Mar	Apr	Nov	Dec
2004	UQ	1.71	1.19	0.44	0.40	0.17	0.99
	average	1.23	0.88	0.32	0.28	0.15	0.74
	stdev	0.80	0.66	0.33	0.28	0.26	0.85
2005	UQ	0.64	1.22	1.10	0.11	0.86	1.05
	average	0.41	0.95	0.74	0.09	0.60	0.72
	stdev	0.45	0.86	0.61	0.17	0.64	0.45
2006	UQ	1.49	1.09	0.88	0.30	0.17	0.72
	average	1.04	0.74	0.62	0.20	0.15	0.51
	stdev	0.70	0.65	0.57	0.29	0.27	0.44
2007	UQ	1.10	1.04	1.38	0.68	0.74	1.05
	average	0.76	0.69	0.97	0.42	0.47	0.76
	stdev	0.64	0.62	0.66	0.32	0.48	0.62
2008	UQ	1.33	1.53	1.09	0.34	0.29	0.77
	average	0.99	1.07	0.84	0.25	0.16	0.50
	stdev	0.82	0.74	0.70	0.30	0.24	0.57
2009	UQ	1.77	1.71	0.44	0.63	0.34	1.38
	average	1.22	1.22	0.33	0.40	0.25	0.98
	stdev	1.05	0.90	0.48	0.49	0.37	0.74
2010	UQ	1.99	2.14	2.43	0.97	0.86	1.49
	average	1.38	1.52	1.71	0.65	0.62	1.10
	stdev	0.86	1.01	1.16	0.61	0.58	0.70
2011	UQ	1.28	2.14	1.73	0.51		
	average	0.83	1.55	1.15	0.36		
	stdev	0.76	1.06	0.92	0.37		
All years	max UQ	1.99	2.14	2.43	0.97	0.86	1.49
	average	0.98	1.08	0.83	0.33	0.34	0.76
	stdev	0.31	0.33	0.46	0.17	0.21	0.22