Improved irrigation management via water metering information: 2009-2010 irrigation season

NIWA Client Report: CHC2010-091
June 2010

NIWA Project: CF105215

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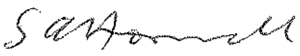

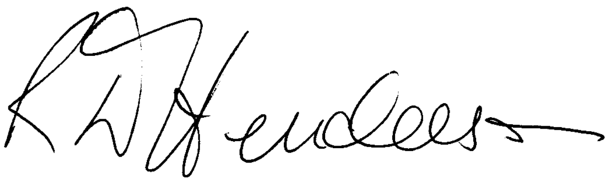

Graeme Horrell Roddy Henderson

Executive Summary

- Irrigation is by far the largest consumptive water use in New Zealand, and while consented volumes are known, no-one knows how much water is actually used for irrigation, because water use has not been widely and routinely measured.

- There is no institutional knowledge in New Zealand on how to interpret water use data in the context of water resource management. NIWA wishes to gain experience of interpreting on-farm water use data to see if it can lead to better water use and allocation decisions.

- The recent installation of water meters in the Waimakariri Irrigation Scheme offered the opportunity for NIWA to explore water use data.

- The report details of analysis of weekly water use data from September 2009 until April 2010 from a number of predominantly large water users where irrigation and rainfall were compared to calculated evaporative losses and plant available water.

- There is little evidence of excessive irrigation and it appears that most users should be applying more irrigation than was measured.

- Detailed analysis showed that many farms appear to build up large soil moisture deficits and soil moisture levels were often less than optimum for pasture growth.

- The low soil moisture levels were not primarily due to the lack of water availability from the scheme.

- Irrigation up to November was limited due to sufficient rainfall to meet evaporative demand and was limited in March due to low flows in the Waimakariri River.

- Soil moisture measurement driven irrigation scheduling may be a way to improve irrigation effectiveness.

1. Introduction and objective

1.1. Introduction

Irrigation is the single largest consumptive water use in New Zealand, accounting for 77% of consented water use (Lincoln Environmental 2000) but no-one knows how much water is used for irrigation, because water use is not yet widely and routinely measured. Published assessments of water use are unreliable, because they often depend on the consented maximum amount of water that can be taken by each user, not the actual use. This lack of reliable information on water use has been a critical information gap in water resource management.

The situation is changing rapidly, as a result of both the forthcoming National Environmental Standard for Water Metering, and the increasing pressure on New Zealand's water resources. Extensive networks of water meters are being installed in several regions, and the data collected by these meters will be the underpinning information for the next great leap in New Zealand water resources management.

There is no institutional knowledge in New Zealand on how to interpret water use data in the context of water resource management. This project is a step in developing that knowledge. There will be new demands for this expertise by water users, water managers, scientists, regional and central government.

Merely summarising the raw water use data provides a very limited view, and this project has the objective of turning these data into information. For example, imagine that all water takes were measured for several years, and suppose that the total measured water use in Canterbury increased by 5% each year, for 3 years in a row. At present no conclusion could be drawn from these data alone. What is required is a data analysis methodology which takes account of the key factors that determine water use. The raw data need to be interpreted in the context of numerous other information sources including: (i) reliability of the meter; (ii) the use for the water (e.g. how many hectares of which crops were irrigated?), (iii) the supply of water (were river takes restricted, or reservoir or groundwater levels unusually low?); (iv) characteristics of both the on-farm water infrastructure and any community irrigation scheme involved; (v) actual and best practices for irrigation.

Examples of end users who would benefit from this expertise include farmers and irrigation scheme operators who want to use the data to improve on-farm and scheme efficiency, Environment Canterbury who want to allocate water sustainably, ensure consents are complied with and interpret impacts of water use on water bodies, Ministry for the Environment who are responsible for state of the environment reporting, and Statistics New Zealand who propose to report on water use in 2010-2011 as part of the next National Water Accounts.

1.2. Objective

To enhance NIWA's capability in irrigation management (and water resources management and environmental information) by developing a structured methodology for interpreting measurements of water use.

The brief for the project comprises Appendix 1.

1.3. Example of water use data

The extent of water meters measuring irrigation in Canterbury was investigated for a previous project. We found there are few irrigation schemes in Canterbury that had systematic placement of on-farm water meters. It appeared that the Waimakariri Irrigation Limited (WIL) scheme on the North Bank of the Waimakariri River had the most comprehensive coverage of any scheme or area in Canterbury. The WIL Board and management were approached to see if they would agree to their shareholders participating in a survey to allow NIWA the use of the water meter data. They were pleased to agree to the survey, got behind the project and promoted it to their shareholders. NIWA is most grateful to the WIL Board for their positive encouragement of the survey. A pilot study was conducted during February and March 2009 (Duncan *et al.* 2009). This report presented here is an analysis of water use by the survey participants over the entire 2009/10 irrigation season.

2. The Waimakariri Irrigation Limited scheme

2.1. Description of scheme

The Waimakariri Irrigation Company scheme commands an area of 44,000 hectares in North Canterbury. The scheme is bounded by the Ashley River in the north and the Waimakariri River in the south and lies between Oxford in the west and Rangiora in the east. It serves 230 shareholders that irrigate 18,000 ha and the water is supplied by 1400 km of channels (races) that also distribute stock water.

2.2. Water source description and influence of water availability

The water source for the Waimakariri Irrigation Scheme is the Waimakariri River. Water is taken at Brown's Rock about 4 km downstream of the Waimakariri Gorge Bridge. It is a run of river scheme and many survey participants and shareholders approached for the survey commented on the unreliable water supply. Some of the participants counter the unreliability by supplementing their irrigation water supply with existing groundwater consents, but in most cases there is less water available from that source than from the WIL scheme. Other participants have, or are considering, on-farm storage. On-farm storage allows shareholders to take their full allocation whether or not there is an immediate need, unless their storage is full, and to use the stored water when the full supply is unavailable.

There appears to be two approaches to storage: the first is a small pond that enables the full allocation to be taken whenever it is rostered so that the allocation is not lost when irrigation temporarily stops, e.g., when irrigators are shifted: the second approach is to have a large pond with sufficient storage, for example, for 30 days of irrigation, so that irrigation can continue at design rates even though there is a partial or full restriction of water available from the scheme.

Dairy farmers are also able to maintain production by supplementary feeding when reduced irrigation reduces pasture production. Many farmers in the WIL scheme use a mix of approaches for maintaining production in the face of the unreliable water supply from the Waimakariri River.

2.3. Consent conditions

The resource consents are detailed in Appendix 2. The main features are the combined take of 12.6 m^3s^{-1} for both irrigation (10.5 m^3s^{-1}) and stock water (2.1 m^3s^{-1}). The full take can only be exercised when the flow in the Waimakariri River at the State Highway One recorder is more than 63 m^3s^{-1} and abstraction for irrigation must cease when the flow is less than 41 m^3s^{-1}. During summer (October – April) 41 m^3s^{-1} is exceeded ~95.5% of the time and 63 m^3s^{-1} is exceeded 79% of the time (de Joux naturalised time series 1967 to 2007).

Shareholders were initially allocated 0.45 l/s/ha (27.2 mm/week), but this has recently been increased to 0.525 l/s/ha (31.8 mm/week). Many study participants considered the initial allocation to be inadequate. One shareholder interviewed considered that he was only able to deliver 22 mm/week to the grass. On average 27 mm/week delivered to the soil should be sufficient to meet the atmospheric transpiration demand of pasture, but when the application efficiency of irrigation systems is taken into account 31.8 mm/week may be inadequate. There will be periods of dry northwest winds when potential evapotranspiration will exceed 31.8 mm/week.

A further constraint on irrigation efficiency that occurs when there is an unreliable water supply (as there is in this case) is the temptation to apply water to “top up” soil moisture, even when soil moisture levels are sufficient for optimum growth, when there is a likelihood of partial or complete water restrictions because of impending low river flows.

2.4. Description of the water meter

The water meter chosen by Waimakariri Irrigation Limited was a "Controlotron Prosol PCS" ultrasonic flow meter. The ultrasonic methodology requires no moving parts and does not require any intrusion into the pipe.

- Accuracy: The manufacturer quotes ± 1.0% of rate or better, with a sensitivity of 0.0003 ms^{-1}.

- The data logger has 1 megabyte of storage

- Recording interval and duration: The flow meters are currently configured to provide daily total use for the previous 64 days, monthly totals for the previous 64 months and annual values for the last 5 years. Currently this data has to be downloaded manually by scrolling through the data and recording it manually. We understand there is a pulse output that could be recorded on an external logger to provide more frequent data for a longer period. e.g., hourly data for an irrigation season.

2.4.1. Meter reliability

Our experience with the data that we downloaded from 15 water meters did not give us a high degree of confidence in the data. This is because of the large number of negative values among the data, the recording of positive values when there was no pumping, and two water meters consistently recorded volumes that were impossibly large and were excluded from the analysis. Most of the meters recorded some negative values, with one to many negative values being recorded, with many of the negative values being small. There were some small positive numbers which we accepted at face value. Low values and hence low application rates throughout the season for one particular farmer were not consistent with the good pasture growth observed on the farm. Regardless of these issues the overall results suggest that most of the meters were recording sensible volumes when the negative values are interpreted as indicating no flow. While we have not checked we suspect that in some cases there is insufficient distance between bends in pipes and the meters to provide sufficiently smooth flow at the meters to give accurate readings.

3. Description of farms

3.1. Participation

For the pilot survey in February and March of 2009 all WIL shareholders were invited to take part via letters from the WIL Chairman and NIWA. The letters were followed up by phone calls to shareholders starting with the largest shareholders. We were unable to contact some corporate shareholders. The conditions for participation were that the irrigation supply was metered and that the shareholder or his representative was prepared to fill in a simple diary indicating the duration of irrigation and the type of crop irrigated. Some shareholders approached were unable to participate because they did not have water meters. As we approached those with smaller numbers of shares it became clear that many did not have water meters and we stopped phoning as it was assumed those with even smaller numbers of shares did not have water meters.

Nineteen shareholders agreed to take part in the survey. Over one third of shareholders holding more than 1000 shares agreed to take part, but only 4% of those with less than 1000 shares were part of the survey (Figure 1). So even though we sampled only 8.4% of the shareholders they accounted for 21% of shares.

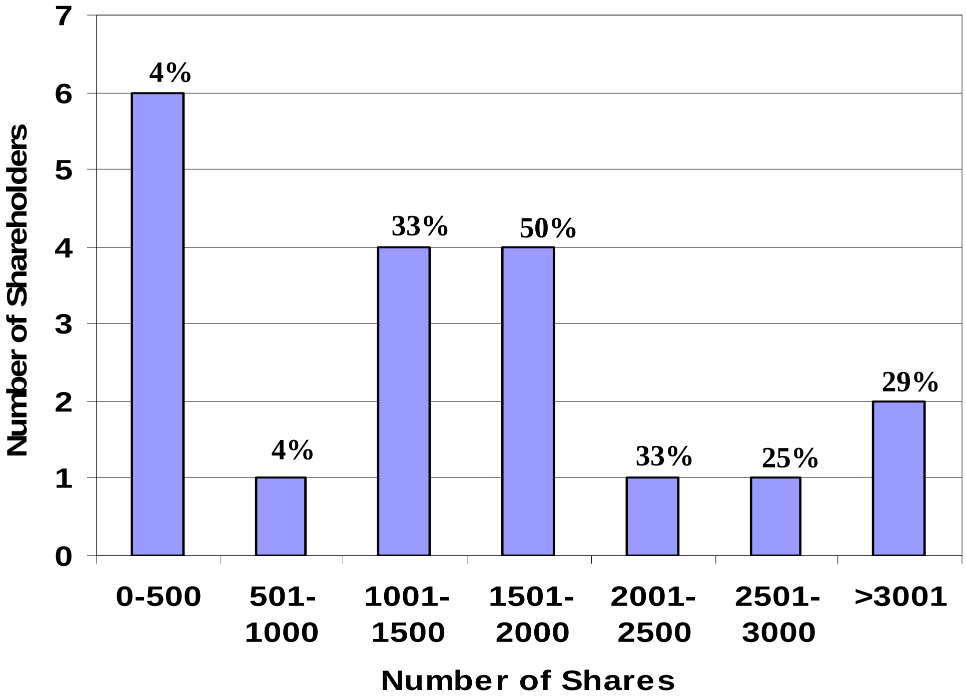

Figure 1: Distribution of shareholders in the survey by number of shares. The number above each bar indicates the proportion of survey participants in each share number range.

For the survey reported here for the full 2009/10 irrigation season we used water meter data from the same participants as for the pilot study conducted the previous season.

3.2. Farm types

The distribution of irrigation water within the scheme is ~50% to dairy farms, and 50% to non-dairy farms. The predominant type of farming for the survey participants was dairy farming, with only two farms with mixed sheep and cropping. Some cropping farmers considered the diary requirement to be too onerous, whereas for dairy farmers with centre pivot irrigators the diary requirement is easily fulfilled. For the dairy farms the whole of the effective farm area is usually irrigated.

3.3. Irrigator types in survey

Eight shareholders had one or more centre pivots as their primary irrigation system, 3 shareholders operated big guns and 2 shareholders used roto-rainers. For those with centre pivots, lateral sprinklers or K-line systems were used where the centre pivots could not reach. Some had mixed systems.

4. Climate conditions

The rainfall and Penman potential evapotranspiration (PET) at each farm was assessed using NIWA's virtual climate network (VCN) (Tait et al. 2006). Figure 2 is an example from the middle of the WIL area. The figure shows the need for irrigation because calculated weekly potential evapotranspiration exceeds weekly rainfall most of the time. Seven weeks had PET greater than the consented application rate of 31.8 mm/week and 5 of these weeks were consecutive weeks. However, only for 3 of those weeks PET exceeded rainfall by more than 30 mm.

The irrigation season (1 September 2009 to 30 April 2010) rainfall varied from 492 mm in the west to 320 mm in the east, while PET varied from 824 to 845 mm (west to east), with one farm having the highest PET and the lowest rainfall. That same farm applied the most irrigation of those surveyed.

5. Soil physical properties their distribution among properties

The soils of the area commanded by the WIL scheme are mapped as having four main groups of plant available water (PAW). For the each farm in the survey an area weighted PAW, based on these maps, was calculated and used in the assessment of irrigation effectiveness,. For each soil group mapped, a minimum, mean and maximum PAW is provided and for this exercise the maximum value was assumed. From the distribution of PAW among farms it appears that most of the farms surveyed are in parts of the scheme area with relatively low PAW. Figure 3 shows the distribution of PAW within the scheme area.

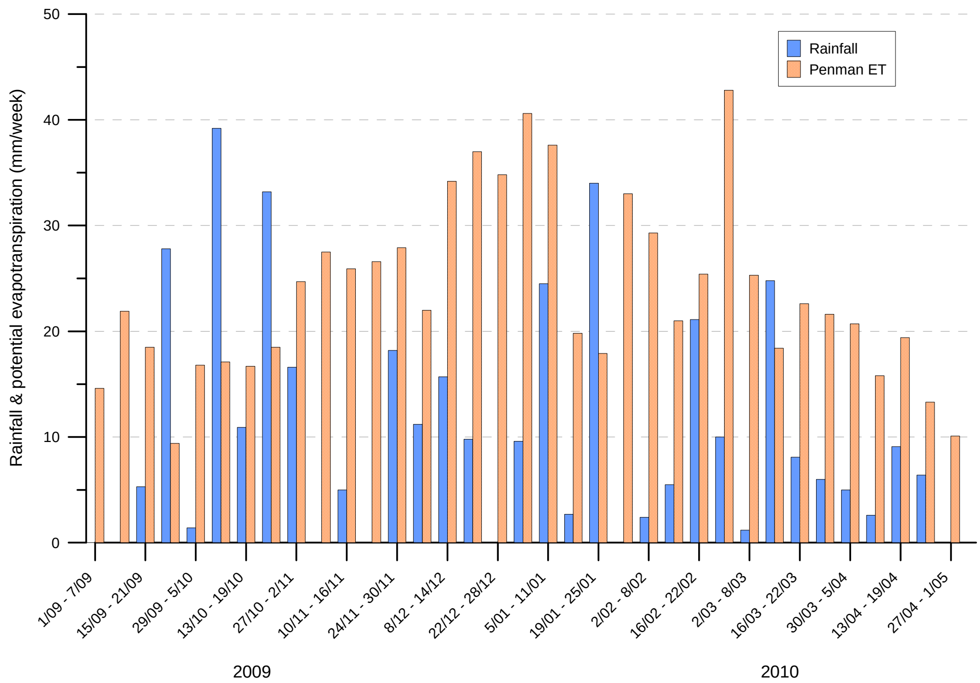

Figure 2: Weekly rainfall and potential evapotranspiration (Penman) for 2009/2010 irrigation season for the centre of the WIL Scheme area based on data from the NIWA virtual climate network.

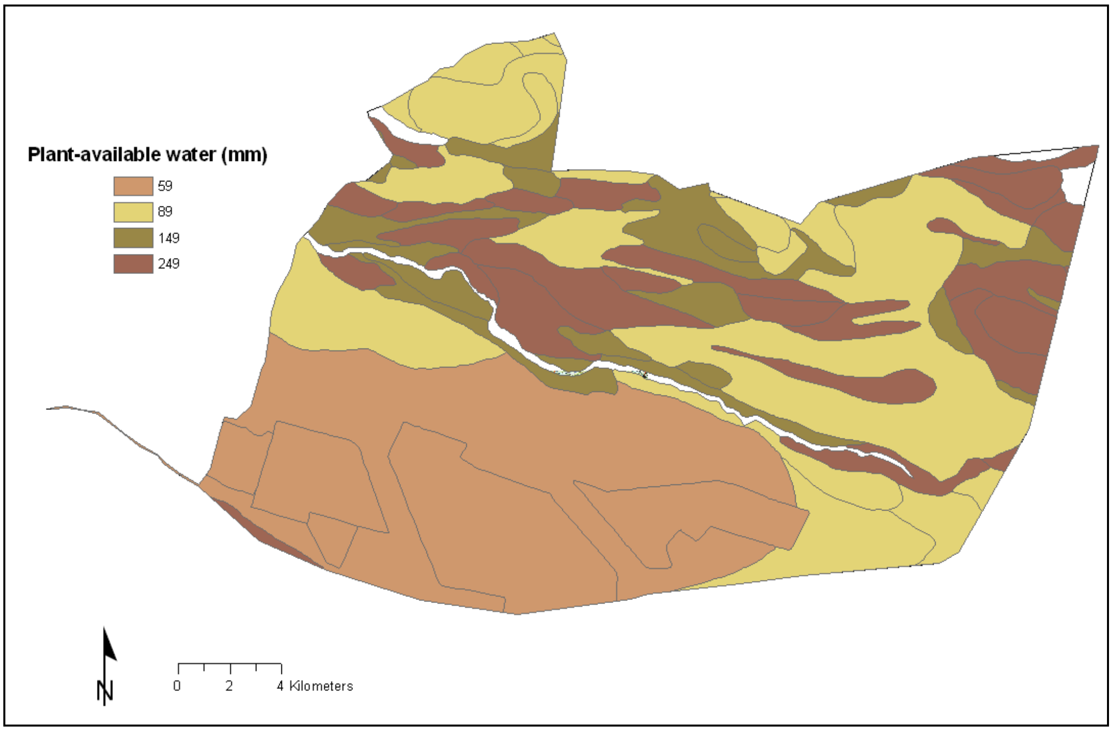

Figure 3: The distribution of plant available water within the area commanded by the WIL scheme

6. Interpretation of week to week variability in water use

The irrigation season water use data was analysed from 1 September 2009 to 1 May 2010. The data was manually downloaded every 60 days as indicated in Section 2.4. The data was subjected to a quality assurance process whereby negative values from the record were replaced by zero values. (N.B. this data will show greater water use than the monthly and annual totals from the meters as these totals include the negative values). In a few cases, where there were large values (several times larger than normal maximum daily use) at the start of an irrigation period, the volume was spread over the preceding few days if irrigation was common among other survey participants during that time. Records from two survey participants appeared to be in error as their metered water use was well in excess of their entitlement and information from WIL management indicated that the metered water use was well in excess of the ability of these shareholders to take such quantities of water. The data from these two sites was not used in the analysis.

Figure 4 shows the number of farms that were irrigating out of a potential number of 12 farms. The number of farms irrigating during any week ranged from one to all 12. Two farms had 2 pumps each and data from these two pumps were combined except where labelling indicates data for both pumps. For this season it was mid-November before most of the survey participants were irrigating. This probably reflects the 148 mm of rain received in September to early November that would have satisfied most of the potential evapotranspiration for that period. Those participants with lighter soils are presumed to have started irrigation first.

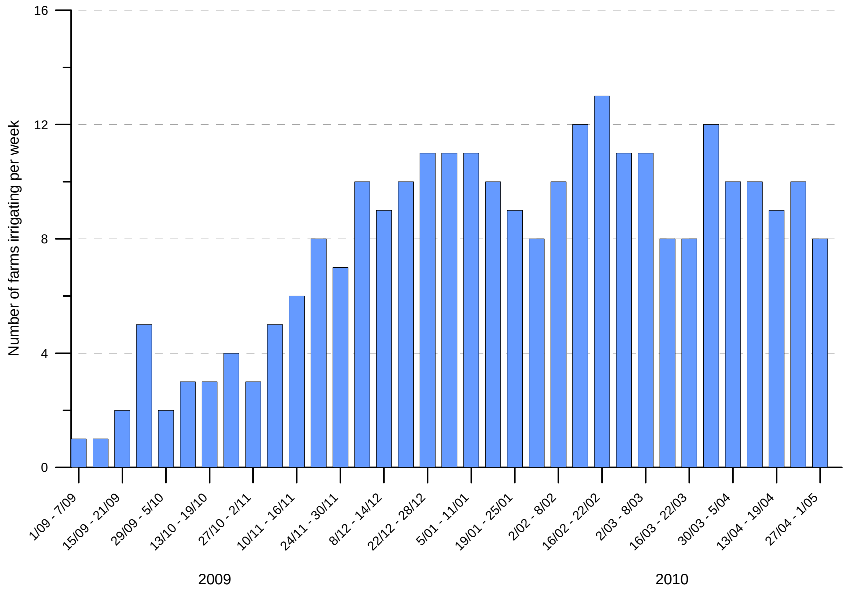

Figure 4: **The number of surveyed farms that were irrigating during the 2009-2010 irrigation season. Data from water meters shown here. Two farms have two water meters.**

When the meter indicated that a farm was being irrigated it was assumed that the water was applied evenly over the effective farm area. Distribution system losses were assumed to be zero and other potential areas of irrigation system efficiency such as uniformity of application were not considered. Nevertheless it should give a good general overview when the results are averaged over all surveyed farms. We present data for the majority of farms that have a PAW of 89 mm. Nine out of 12 farms have a PAW of 89 mm.

Figure 5 shows the minimum, maximum and mean irrigation applications per week from the 12 farms surveyed for the irrigation season. During most weeks from November to February an average of 10 to 20 mm per week were applied by those irrigating, although some irrigators were applying close to the maximum design rate of 31.8 mm/week. During that period average rainfall was about 11 mm/week (depending on location) so during that time the ground would have received 20 to 30 mm of water per week and the higher figure would have been similar to the PET for the period of 29 mm/week. Figure 5 shows maximum application rates between 40 and 53 mm/week. We suspect that these high application rates are from faulty meters rather than a reflection of actual application rates.

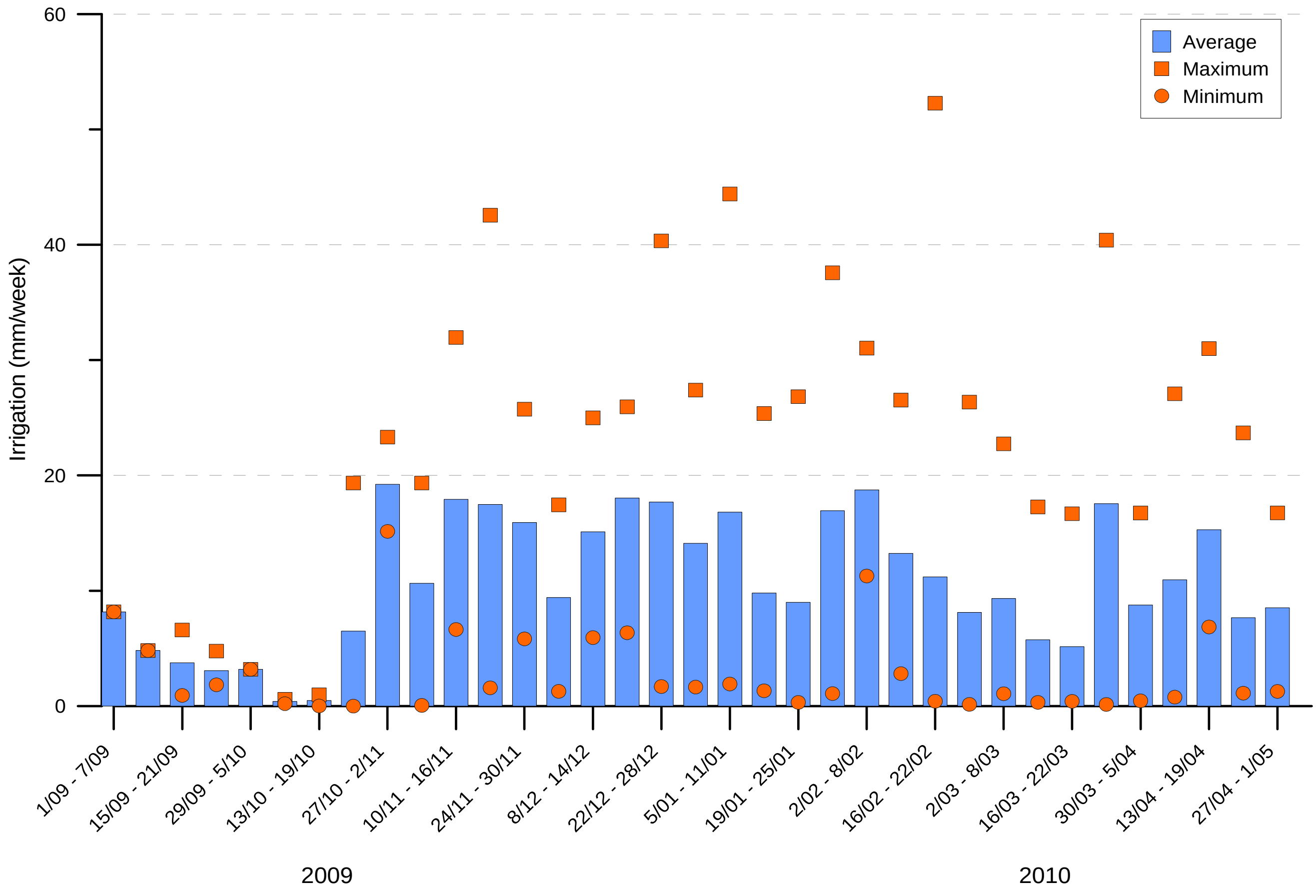

Figure 5: Weekly irrigation depths for the surveyed farms that were irrigating.

Figure 6 shows the weekly application rates for each farm determined by the water meter data. Again the slow start to irrigation can be seen as small applications were being made prior to December. Only on 6 weeks out of 420 potential farm-irrigation-weeks and 237 actual farm-irrigation-weeks was the design application rate of 31.8 mm/week. This indicates that over irrigation seldom occurs. It can be seen that after substantial (>20 mm) weekly rainfalls irrigation often, not always, ceases or application rates are reduced. The reduced extent and rates of application in March and April are attributed to a lack of water availability from the Waimakariri River and this issue will be discussed fully later. March and April were dry and irrigation was continued by most participants until the end of April.

Figure 7 shows the amount of rain and irrigation per week compared to potential evapotranspiration for a participant near the centre of the WIL scheme (same location as Figure 2). It shows that except for the 3 separate weeks early in the irrigation season when there were substantial rainfalls, there was less rainfall than was required to meet calculated potential evapotranspiration. For about half the weeks there is a close balance between potential evapotranspiration (PET) and rainfall plus irrigation. For four weeks there was substantially more rainfall plus irrigation than PET. We have not examined the data closely enough to see whether or not these occasions were results of timing issues, i.e., most of the irrigation applied before the rain occurred as could happen if the rain occurred at the end of the week. There were weeks in March and April when there was less rain plus irrigation than PET and these times coincide with times when the river was low and there was little water available to the scheme.

Figure 8 compares ideal and actual irrigation for two farms with different soil PAW and different access to irrigation water as one has a pond and the other has not. Ideal irrigation was assumed to be irrigation when soil moisture fell to 50% of PAW and the soil was either filled to 80% of PAW or 31.8 mm/week was applied, (whichever was the lower amount) and taking account of VCN rainfall and PET at the sites. Farm A has more rain, a soil with a large PAW, and is entirely dependant on WIL for irrigation water. Between 16 February and 22 March Farm A was without access to irrigation water from WIL whereas there should have been irrigation. After that, ideally there should have been more irrigation but WIL water was only available periodically and we do not know if that affected the ability of Farm A to be irrigated. Farm B has a lower PAW, has access to ponded water and was irrigated in a more ideal way than Farm A. Farm A with a limited supply of water applied 28 mm less than optimum irrigation. Farm B, which had much less rainfall than Farm A, but access to pond water, applied 53 mm more than it would have had it been applied ideally (see the table at the bottom of Figure 8). The farms had similar PET, but Farm B had 93 mm less rainfall and would have ideally have had to apply 134 mm more irrigation than Farm A.

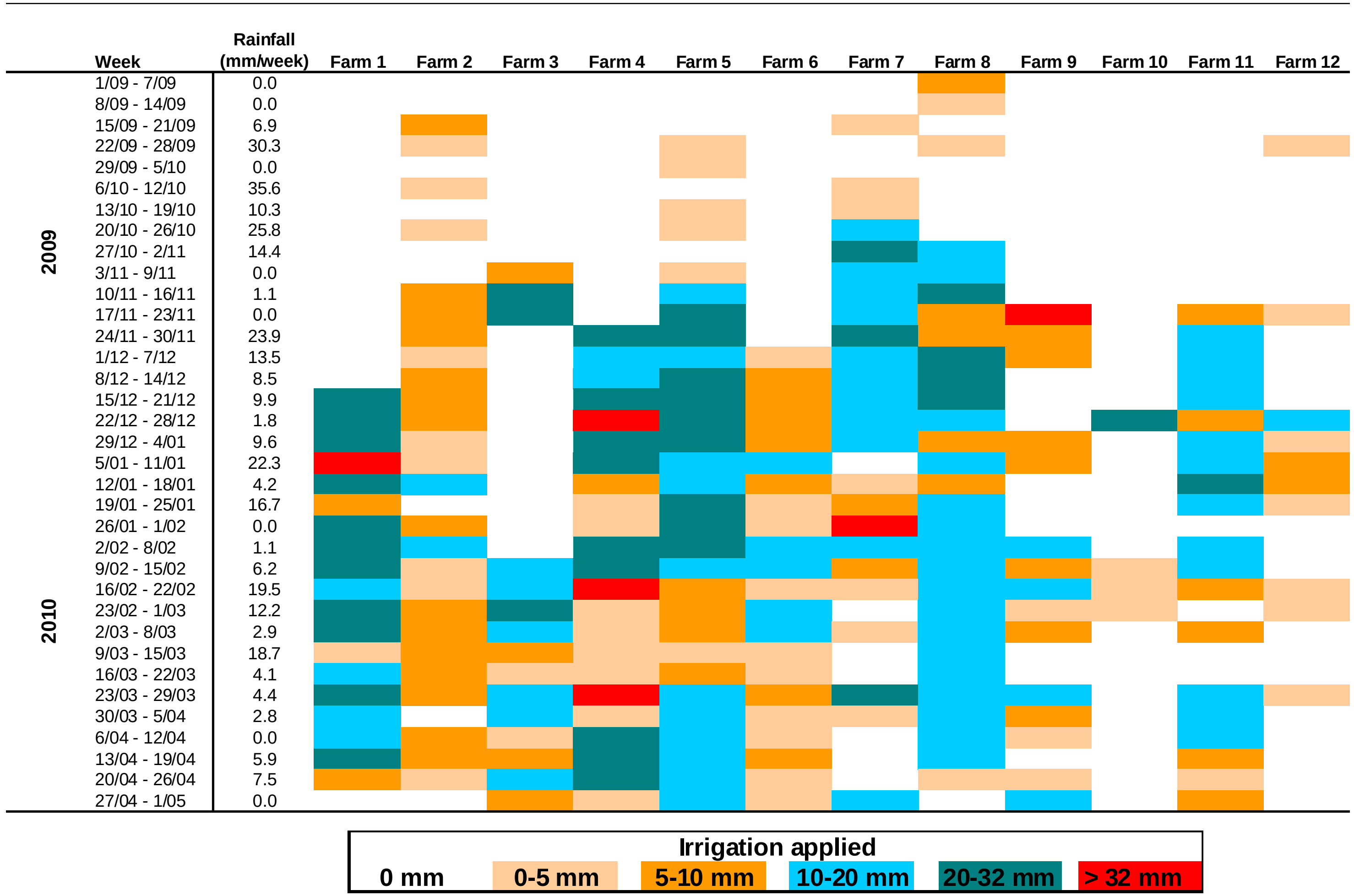

Figure 6: **Weekly irrigation depths for the surveyed farms and weekly rainfall at near the centre of the scheme.**

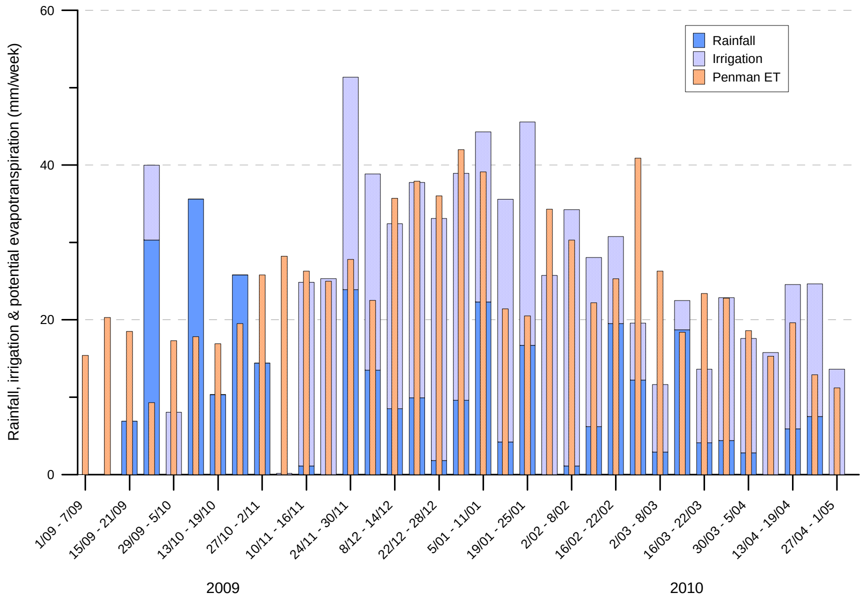

Figure 7: **Weekly rain and irrigation compared with potential evapotranspiration for the irrigation season for a farm near the centre of the WIL scheme.**

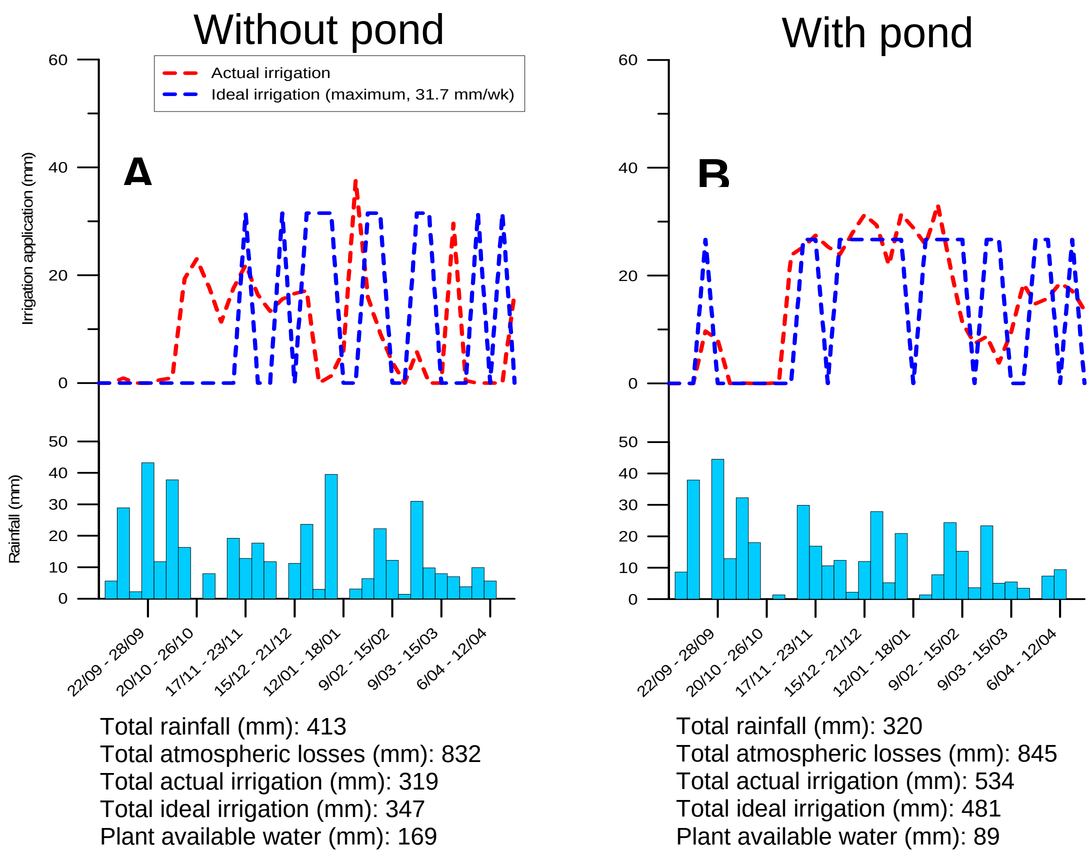

Figure 8: **Actual and ideal irrigation for two participants in the study.**

An interesting issue has been highlighted with the data in Figure 8. That is, the differences in rainfall (and PET) within the scheme. It is very clear from other work (Srinivasan and Duncan unpublished) that there are consistent rainfall and PET gradients from north west to south east within the scheme with rainfall decreasing and PET increasing. This means that irrigation requirements significantly increase towards the south east, and there could be equity issues within the scheme if each irrigator buys shares based primarily on the basis of irrigable area.

6.1. Availability of water to the scheme

One factor that affects water use is the availability of water to the scheme. Figure 9 shows the daily flows in the Waimakariri River, the daily take at the WIL intake at Brown's Rock, the flows when restrictions apply and the weekly rainfall. While it is clear that at quite low flows in the Waimakariri River the WIL take is restricted to the stock water take (2.1 m^3s^{-1}), when the Waimakariri flows are higher other factors appear to affect the WIL take. In October 2009 there was significant rainfall and the scheme take was low even though the Waimakariri River flows were at rates when restrictions would apply for only a few days. Later on in the season there is less rainfall, lower Waimakariri flows and low irrigation takes. It is apparent that both the amount of water available and the rainfall affect the water take by the WIL scheme.

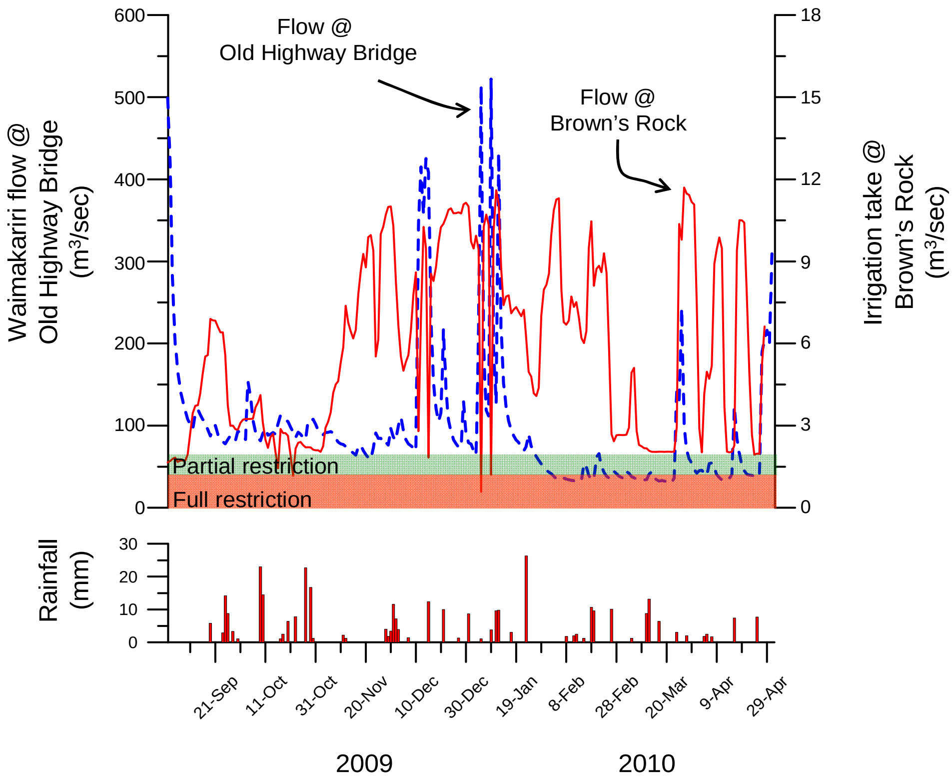

Figure 9: **Flow in the Waimakariri River at Old Highway Bridge, and at the WIL intake at Brown's Rock (right hand axis scale) and daily rainfall for the irrigation season and the flow rates in the Waimakariri River when restrictions to the take for WIL scheme occur.**

7. Comments on efficiency of irrigation

7.1. Irrigation efficiency

In this study we are concerned with comparing the amount of water sourced from the WIL scheme converted to an application depth and the rainfall compared with potential evapotranspiration, calculated soil moisture deficit and mapped soil moisture holding capacity. Examining other aspects of application efficiency is beyond the scope of the study. There are a number of measures of irrigation efficiency (Aqualinc 2006). These can take into account losses in the supply system, on farm distribution losses, uniformity of distribution, use by the plant and so on. This survey does not measure or calculate on-farm distribution losses (pipe leaks, etc that are assumed to be negligible), uniformity of application, including runoff, interception losses and evaporation of spray. Most of these types of losses are normally low, typically less than 5% each (Aqualinc 2006), except for uneven application that can range 0-30% and is typically 15% (Aqualinc 2006).

7.1.1. Summary of water use

For the 2009/10 irrigation season it seems that, in general, the farmers in the study were applying water in an efficient manner. Only on 2.5% of irrigation-farm-weeks was there irrigation in excess of the design rate of 31.8 mm/week (not consecutive weeks) assuming that the meters were measuring flows accurately. We did not examine the records to see if this was the result of a timing issue i.e., irrigation followed by heavy rainfall in the same week or heavy rain at the start of a week and irrigation at the end of the week. Closer analysis of data in early 2009 (Duncan *et al*. 2009) showed that where excess irrigation was apparent it was because of such timing issues.

7.2. Application rates

The maximum weekly application rate for the irrigation season was 52 mm/week (Figure 5). That rate is only excessive when applied to soils where the actual PAW is more than about 50% of its maximum value and there is low (<104 mm) potential PAW. In this case the potential PAW of the soil being irrigated was mapped as having a potential PAW of 89 mm and so the application was likely to have been excessive.

Only one participant applied more water than was required to meet the seasonal soil moisture deficit (PET - rainfall). Thus it is unlikely that too much water was being applied but the irrigators on average were applying less than was required to meet evaporative demand during the season.

There was insufficient information to determine whether there were differences in irrigation application rates between irrigator types.

7.3. Adequacy of irrigation

7.3.1. Accumulated soil moisture deficit

One measure of the adequacy of irrigation is to measure the accumulated soil moisture deficit. This was calculated by assuming that the soil was at field capacity on 1 September 2009. From that the weekly rainfall and irrigation were added and the weekly PET was deducted. If the sum of those values exceeded the PAW for the farm then soil moisture for the start of the week was reset to the PAW. Starting with the soil at field capacity is a reasonable assumption as NIWA's soil moisture sensor at Rangiora showed the soil was at field capacity on 1 September 2009. The maximum value of the accumulated soil moisture deficit for each participant is shown in Figure 10. For those participants with large deficits the deficit started in December and tended to grow as the season progressed. Those with smaller deficits tended to have their maximum deficits in February and the deficit became reduced as the season progressed. Large deficits indicate inadequate irrigation as measured by the meter either because of lack of supply, because the meter was under registering or because insufficient irrigation even though there was an adequate supply. Most of the large soil moisture deficits seemed to grow in December and January when water supply from the river was not limited. WIL Management commented that they expected a greater demand from irrigators during this period than actually occurred. This suggests that there were reasons apart from water supply that reduced irrigation application.

Most of the farms in the survey have PAW less than 89 mm, so a maximum deficit of more than 45 mm indicates that soil moisture levels were lower than required for optimum pasture growth that week. There were only two farms that kept soil moisture levels at more than 50% of PAW for more than 75% of the irrigation season (figure 11) and many had substantial soil moisture deficits indicating that soil moisture replenishment was inadequate for optimum growth for a long period.

7.3.2. Time when soil moisture was above 50% of PAW

To maintain full pasture production there is a rule of thumb that soil moisture levels should be maintained above 50% of PAW. Figure 11 shows the proportion of the irrigation season soil moisture values for each participating farm were above 50% PAW. For these calculations we used the VCN PET and rainfall, measured irrigation and farm PAW. We used similar soil moisture accounting as for the accumulated soil moisture deficit except that the weekly value was not allowed to go below zero. This method assumes that the entire PAW will be used at PET rates and we acknowledge that this will exaggerate the number of days the soil moisture is less than 50% PAW as soil moisture is used more slowly as soil moistures approach wilting point. Nevertheless we think that Figure 11 gives a good indication of how well the participants have been irrigating. It appears that in general soil moisture values are usually at lower than optimum for pasture growth with only a few farmers having good soil moisture values most of the time. It is likely that pasture growth would still be good at values above 40% PAW and inspection of the data (not shown) indicates that a significantly higher proportion of farmers meet that criteria more often.

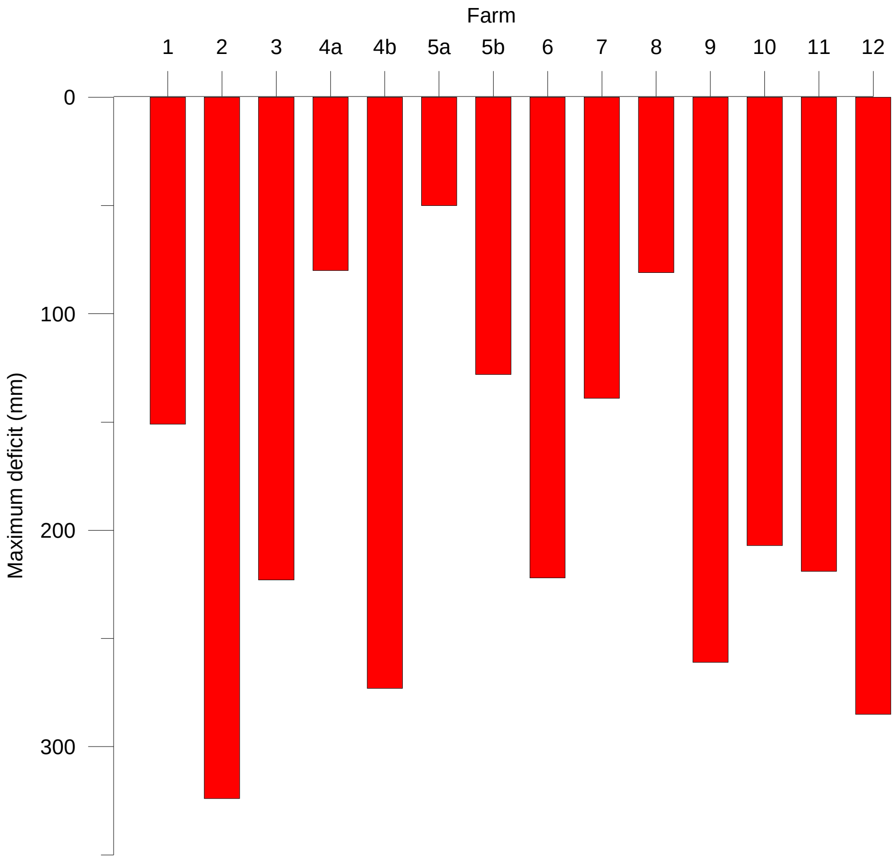

Figure 10: The maximum value of accumulated soil moisture deficit for farms surveyed during the 2009/10 irrigation season. Farms 4 and 5 have two water meters each serving different pumps and areas.

7.4. Improving irrigation performance with soil moisture measurement

It appears from the analysis that there is very little over irrigation and a large amount of under irrigation and it is not very clear why low soil moisture values are so prevalent even if Waimakariri water is not available all the time.

It is likely that soil moisture values and pasture production could be improved if irrigation scheduling was driven by soil moisture measurement rather than intuition.

Interviews with farmers revealed some interest in soil moisture measurement. However, only a few farmers were using it to drive irrigation scheduling and often there were maintenance issues with some part of the system, e.g., the devices used for down-loading the data did not work. It was astounding to the authors that many farmers had soil moisture sensors, but were not using the data for irrigation management. During the previous study (Duncan et al. 2009) there had been a reasonable amount of rain and most farmers used their intuition to cease irrigation, but one particular farm was continuing to irrigate. Soil moisture measurements from the farm indicated that irrigation was still required regardless of the rain, but at a lower frequency than if there had been no rain. The data showed the soil moisture levels moving nicely between 50% and 80% of PAW.

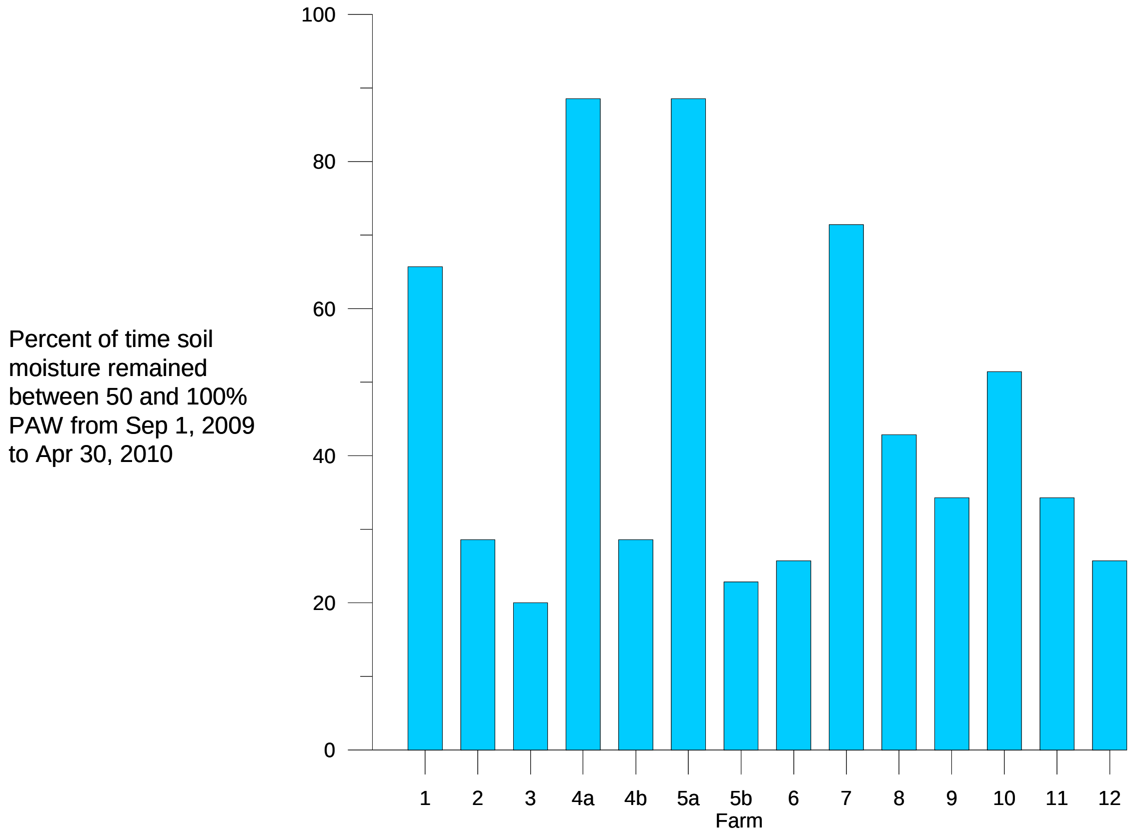

Figure 11: Proportion of the time that soil moisture was estimated to be between 50% and 100% of PAW in the farms surveyed for the 2009/10 irrigation season. Farms 4 and 5 have two water meters each serving different pumps and areas.

It seems that the focus that some farmers have on supplementary feeding and nitrogen application needs to be equally applied to irrigation management.

We strongly recommend that farmers deploy soil moisture sensors and keep them and their data retrieval and display systems well maintained and use them to schedule irrigation. Alternatively, commercial soil moisture measurement driven irrigation scheduling services are available and are currently used by some farms within the scheme.

8. Future work

- There is a need to survey other irrigation seasons to see whether the results are typical.

- Associated with the point above is the need to further investigate the reliability of the potential evaporation data to estimate evaporative demand in the WIL command area.

- There is need to have more shareholders in the survey, to provide sufficient numbers of farming types other than dairying and a wider range of irrigation methods for comparison.

- There is a need to obtain reliable daily flow data from the water meters and have a way of efficiently retrieving the data. We understand WIL is investigating a logging system that would provide real time telemetered data to a central data archive to meet this need.

- For the purpose of soil moisture deficit estimations, rainfall and PET data from NIWA's climate database were used. However, to improve the accuracy of predictions, it is necessary that rainfall and actual evaporation data be collected within the scheme. Development of such a dataset is critical in generalising the findings for the entire scheme.

9. Summary

- Little is known about on farm irrigation water use as there have been few on-farm water meters.

- NIWA wishes to gain experience of interpreting on-farm water use data to see if it can lead to better water use and allocation decisions.

- The recent installation of water use meters to share holders in the Waimakariri Irrigation Scheme offered the opportunity for NIWA to explore water use data.

- The report details an analysis of weekly water use data from September 2009 to April 2010 from a number of predominantly large water users where irrigation and rainfall were compared to calculated evaporated losses.

- Early in the season the water take from the Waimakariri River was limited by demand as there was sufficient rainfall to satisfy PET until November. In March the water take and irrigation was limited by low flows in the Waimakariri River.

- The measured application rates indicate that in general there was not enough rainfall and irrigation to meet evaporative demands.

- More detailed analysis shows that large soil moisture deficits built up on many farms and few farms were able to consistently maintain soil moisture at levels optimum for pasture growth.

- Lack of water from the WIL scheme did not appear to be the only reason for the low soil moisture levels.

- More water storage, both on- and off-farm would reduce the likelihood of lack of water for the scheme during low flow periods.

- Soil moisture measurement driven irrigation scheduling may be one way to improve irrigation effectiveness.

- There is still some doubt as the accuracy of the water meters and the results reported assume high accuracy. It was beyond the scope of this project to investigate the accuracy of the meters and the likely cause of any inaccuracies such as inadequate distance between pipe beds and meters.

10. Acknowledgements

We sincerely thank Richard Allison, Chair of Waimakariri Irrigation Limited, for endorsing and helping promote the study and Phill Reid, Manager Waimakariri Irrigation Limited for his help and enthusiasm in championing the work.

We sincerely thank all our farmer participants for their willingness to take part in the study and for the information they gave about their farms, irrigation and farming systems.

11. References

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Appendix 1: Contract for Capability Funds – 2009-10

SHORT TITLE:	Improved irrigation management via water metering information
PROJECT CODE:	**CF105215**
BP OBJECTIVE:	In conjunction with the National climate Centre and the National Hazards Centre, initiate Year 1 of a 3-year "Flagship Programme" on Water Resource Management.
PROJECT LEADER:	Maurice Duncan **DATE:** 25 June 2009
CHIEF SCIENTIST:	Clive Howard -Williams
APPROVER:	Bryce Cooper
ALLOCATION:	$50,000
RESEARCH TYPE:	Research
RESEARCH CATRGORY	2

RESEARCH OUTLINE:

The Flagship programme will assist in developing capability in the provision of underpinning climate and weather predictions and linked climate and hydrological and ecological datasets and models (both empirical and mechanistic) for the Canterbury Plains. The Flagship Programme is composed of four themes, which follow a logical sequence from climate predictions to water management.

Flagship Theme 1.Weather and Climate Predictions
Flagship Theme 2.Linking climate and water resources
Flagship Theme 3.Ecological effects
Flagship Theme 4.Prediction based adaptive management.

This Project: "Improved irrigation management via water metering information"

This specific capability funded project fits Flagship Theme 2. In 2009, NIWA initialised a study in the Waimakariri Irrigation Scheme to gather irrigation water use data from irrigation water use meters. Fourteen farm owners were contacted to take part in this study and details on their farm operations related to irrigation water use were collected. The goal of the present study is to continue the data gathering from the water meters for the irrigation year 2009/10, so that we have water use data for one complete season.

The project will allow us to develop an institutional knowledge in New Zealand on how to interpret water use data in the context of water resource management. There will be new demands for such expertise by water users, water managers, scientists, regional and central government. Examples of end users who would benefit from this expertise include farmers and irrigation scheme operators who want to use the data to improve on-farm and scheme efficiency, Environment Canterbury who want to allocate water sustainably, ensure consents are complied with and interpret impacts of water use on water bodies, Ministry for the Environment who are responsible for state of the environment reporting and Statistics New Zealand who propose to report on water use in 2020-2011 as part of the next National Water Accounts

RESEARCH OBJECTIVE

Contribute to the NIWA Flagship programme on Water Resource Management by developing a structured methodology for interpreting measurements of water use.

RESEARCH WORK PROGRAMME AND OUTPUTS

- Continue the collaborative partnership with the Waimakariri irrigation Community and keep other relevant stakeholders such as Regional Council informed.

- Obtain data on water use, and associated data on water meter type, irrigated areas and crop types, irrigation methods, irrigation scheme operations, river or groundwater levels, climate conditions, consent conditions

- Summarise the quality and consistency of water use data

- Meet with water users to gather information on factors determining water use patterns.
- Interpret the week-to-week variability in water use in the context of factors such as soil water conditions, water availability, crop growth

- Write a report summarising findings, present these to a community of irrigators, and to Regional Council staff.

National Centres: Freshwater Ecosystems

Site: Christchurch

Regional Manager: Charles Pearson

Regional Accountant: Jason Pegley

Appendix 2: Waimakaririr Irrigation Limited – Resource consent

RESOURCE CONSENT CRC000585.9

Pursuant to Section 104 of the Resource Management Act 1991

The Canterbury Regional Council (known as Environment Canterbury)

GRANTS TO:	Waimakariri Irrigation Limited
A WATER PERMIT:	To take and use water.
REVIEW TAKES EFFECT:	6 May 2010
EXPIRY DATE:	18 November 2031
LOCATION:	WIS main & distribution races bounded by m/f L35:350-580 M35:730-520 & M34:520-7, WAIMAKARIRI DISTRICT

SUBJECT TO THE FOLLOWING CONDITIONS:

1) Before any works are commenced under these consents the consent holder shall prepare and submit to the Canterbury Regional Council for approval a management plan for the construction and operation of the scheme and for the monitoring of any environmental effects arising from the scheme. The plan should give particular attention to the details of how:
   (a) The stock water supply is to be managed.
   (b) The irrigation component of the scheme is to be managed so the objective of using water efficiently is met.
   (c) The ground water recharge trials are to be conducted and evaluated.
   (d) The monitoring for groundwater levels and groundwater quality changes is to be accomplished;
   (e) The conditions imposed on these consents and on the land use consent granted for the scheme by the Waimakariri District Council are to be met.
   (f) Any failures to meet conditions on water and sediment discharges and on the exclusion of fish from the race system are to be remedied.
   (g) The effects of envisaged land use changes of the hydrological environment are to be remedied or mitigated.

   In August each year the consent holder and the Canterbury Regional Council shall jointly review and, if appropriate, amend the management plan for the ensuing year. The Canterbury Regional Council may invite submissions from interested parties as part of the review process. The consent holder shall at all times implement the provisions of the management plan except to the extent that these provisions or any of them are inconsistent with the conditions of this consent.

2) The lapsing period of section 125(1) RMA shall be three years.

3) Subject to Condition (6) below, up to 10.5 cubic metres per second of water may be taken for irrigation and storage, including up to 1.5 cubic metres per second of water for augmentation of groundwater surrounding the Eyre River.

4) The total volume used for storage shall not exceed 57,100,100 cubic metres during any 12 months period.

5) DELETED.

6) Whenever the unmodified flow in the Waimakariri River, as estimated by the Canterbury Regional Council from measurements at the Old Highway Bridge, at or about map reference NZMS 260 M35:818-547, for any 24 hour period ending at noon is:
   (a) Either:
      (i) 63,000 litres per second or greater; or

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(ii) equal to or greater than the sum of 41,000 litres per second plus the total abstractions authorised by permits which come within the category of "A" permits as defined by the Waimakariri River Regional Plan; or

(iii) greater than 41,000 litres per second and less than 63,000 litres per second and all water permit holders who are subject to same minimum flow restriction as is set out in (c), are adhering to a water sharing regime that restricts the total rate of abstraction from the Waimakariri River whenever the flow is at or above 41,000 litres per second; then the maximum rate of abstraction, during the next 24 hours, shall not exceed 10,500 litres per second.

(b) greater than 41,000 litres per second and less than 63,000 litres per second, except where (a) (ii) or (iii) applies, the maximum rate of take during the next 24 hours shall be equal to the rate shown on the vertical axis on the attached graph that corresponds to that flow on the horizontal axis, by reference to the diagonal line.

(c) at or less than 41,000 litres per second, no water shall be taken during the next 24 hours.

7) The consent holder shall within two years of the commencement of this consent:

(a) Install a water level measuring device in a location that will enable the determination of the continuous rate of flow and volume of water being taken to within an accuracy of 10 percent.

(b) The measuring device shall, as far as is practicable, be installed at a site likely to retain a stable relationship between flow and water level. The measuring device shall be installed in accordance with the manufacturer's instructions.

(c) The flow at the measuring site shall be gauged at least every twelve months whilst the consent is being exercised, and at any other time when required (for example, after flood events) as determined by a site inspection. Site inspections are to be carried out by the race operator at least once every month.

(d) Gauging and site inspections shall be carried out in accordance with the following manuals: Hydrologists Field Manual (NIWA 1991) and Procedure for Rating a Flow Situation (NIWA 1993) or equivalent publication.

(e) The level of water in the race, and times of abstraction, shall be recorded by tamper-proof electronic recording system such that the flow through the site is measured at least once every 15 minutes, and a record made either on site or at a remote location via telemetry of the total flow volume passing through the site in time increments not exceeding 60 minutes. The recorded data shall not be changed or deleted by any person, unless twelve months have passed since the date of recording.

(f) The measuring and recording devices described in clauses (a) and (e) shall be available for inspection at all times by the Canterbury Regional Council subject to providing adequate protection against vandalism which may require the consent holder's assistance on site to unlock or remove barriers.

(g) All data from the recording device described in clause (e), and the corresponding relationship between the water level and flow, shall be provided to the Canterbury Regional Council on request.

(h) Within one month of the commencement of this consent, at two-yearly intervals thereafter, and at any other time when requested by Canterbury Regional Council, the consent holder shall calibrate the measuring device and provide to Canterbury Regional Council:

(i) A certificate signed by a suitably qualified person certifying the current accuracy of the measuring and recording devices, and also certifying that the recording device described in clause (e) can be readily accessed in accordance with clause (f); and

(ii) Supporting information containing details of the calibration test.

(i) The recording system in (e) shall:

(i) Be set to wrap the data from the measuring device(s) such that the oldest data will be automatically overwritten by the newest data (i.e. cyclic recording); or

(ii) Store the entire season's data in each 12 month period from 1 July to 30 June in the following year, which the consent holder shall then download and store in a commonly used format and provide to the Canterbury Regional Council upon request in a form and to a standard specified in writing by the Canterbury Regional Council; or

(iii) Be part of the consent holder's SCADA system which stores and forwards data on a quasi-continuous basis to the consent holder's base station where it is stored in an industry-standard database, and can be provided in a commonly accepted format to the Canterbury Regional Council upon request in a form and to a standard specified in writing by the Canterbury Regional Council; or

(iv) Be connected to a telemetry system which collects and stores all of the data continuously with an independent network provider who will make that data available in a commonly used format at all times to the Canterbury Regional Council and the consent holder. No data in the recording device(s) shall be deliberately changed or deleted.

(v) The measurement and recording system(s) shall be installed and maintained throughout the duration of the consent in accordance with the manufacturer's instructions.

(vi) All practicable measures shall be taken to ensure that the flow measurement and recording system(s) are fully functional at all times.

(vii) Within on month of the installation of the measuring or recording device(s) or any subsequent replacement of the measuring or recording device(s), and at five-yearly intervals thereafter, and at any time when requested by the Canterbury Regional Council, the consent holder shall provide a certificate to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manager, signed by a suitably qualified person certifying that the measuring and recording system(s) have been installed in accordance with the manufacturer's specification.

8) In the event that the fish screens at the intake become ineffective, either through damage from any cause or through the need for maintenance, the taking of water under this consent shall cease until the screens' effectiveness has been satisfactorily restored. The consent holder shall within 24 hours of the screens' becoming ineffective notify the Canterbury Regional Council and the North Canterbury Fish and Game Council of the situation and of the remedial measures including fish salvage to be implemented.

9) (a) Representative samples of groundwater shall be taken:

(i) during August-September and April-May each year from each of the monitoring bores identified for the monitoring of Groundwater Quality effects in the management plan referred to in Condition (1);

(ii) monthly from three bores identified for monitoring of Groundwater in the management plan. One of these bores to be located up-gradient in terms of the direction of groundwater flow, of the area covered by the irrigation scheme, one bore to be located down-gradient the area of the irrigation scheme and one bore to be centrally located within the area of the scheme; and

(iii) all samples shall be analysed for nitrate-nitrogen, ammonia-nitrogen, conductivity, pH and e-coli bacteria by a laboratory accredited to NZS/ISO/IEC Guide 17025 or equivalent, defined by and accreditation body recognised as operating to ISO/IEC Guide 58 for those analysis; and

(iv) an annual report providing a summary of the results of the analyses of all samples taken shall be provided to the Canterbury Regional Council by no later than 30 June.

(a) Water level measurements shall be taken at least monthly from each of the bores identified for the monitoring of Groundwater Level effects in the management plan referred to in Condition (1) and an annual report setting out the levels and showing the mean level shall be provided to the Canterbury Regional Council by no later than 30 June.

(b) The consent holder may, on any working day during June in 2008 or any working day in June in any year thereafter, apply to the Canterbury Regional Council under Section 127(1) of the Resource Management Act 1991 to change or cancel Conditions (9)(a) or (9)(b) of this consent.

10) Charges, set in accordance with section 36 of the Resource Management Act 1991, shall be paid to the Regional Council for the carrying out of its functions in relation to the administration, monitoring and supervision of resource consents and for the carrying out of its functions under section 35 of the Act.

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11) The Canterbury Regional Council may, on the last working day of July each year, serve notice of its intention to review the conditions of this consent for the purposes of:
(a) Dealing with any adverse effect on the environment which may arise from the exercise of the consent; or
(b) Complying with the requirements of a regional plan.

12) By 1 July 2007 the consent holder shall submit a Water Use Management Plan (the Plan) to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manager. The purpose of this plan will be to promote the reasonable and efficient use of water within the Waimakariri Irrigation Scheme (the Scheme) as a whole, as well as on individual shareholder properties within the scheme. The plan will describe:
(a) The operation and monitoring of the Scheme, storage and intakes from the Waimakariri River and the distribution of water to the shareholders properties.
(b) The monitoring of water supplied to individual shareholders.
  (i) A programme of evaluation of the operation of individual shareholder on-farm operations including:
  (ii) the area irrigated;
  (iii) the Profile Available Water of the soils that occur on the property;
  (iv) quantification of local rainfall and evapotranspiration;
  (v) a description of the irrigation system, its pumping rate and return period;
  (vi) a demonstration that the irrigation system achieves the following objectives:
    1. That the volume of water used for irrigation does not exceed that required for the soil to reach field capacity; and
    2. Avoid leakage from pipes and structures; and
    3. Avoid the use of water onto non-productive land such as impermeable surfaces and river or stream riparian strips.

This programme of evaluation shall be established so that shareholder properties are evaluated at least once every five years.
For the avoidance of doubt, the completion of the on-farm survey shall be subject to land owner permission and the consent holder shall use all reasonable endeavours to obtain such permission.
(c) The distribution of educational material on efficient irrigation practices to all shareholders.
(d) An annual reporting programme to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manager, to describe the results of implementing the Plan over the preceding 12 months.

13) (a) The results arising from the implementation of the Plan required in accordance with Condition (12) shall be used to develop a maximum annual volume for the use of water.
(b) A current estimate of the maximum annual volume shall be included in the report on the Plan that is provided to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manager, by the 30 June each year. That estimate shall be based on all the monitoring data that has been gathered up to the time that the report is produced.

Issued at Christchurch on 10 June 2010

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