Irrigation Water Use Assessment

Summary and analysis of compliance monitoring data for the Riversdale groundwater zone

Liquid Earth
October 2011

Table of Contents

Table of Figures

1.0 Introduction

1.1 Water use compliance monitoring

At the current time virtually all consents for large-scale water abstraction in Southland have conditions requiring measurement and recording of the rate and/or volume of abstraction. Such monitoring of consumptive (and non-consumptive) water use is an integral component of effective water resource management providing a basis to:

- Characterise the dynamic response of a water resource to abstraction

  Abstraction has the potential to alter the natural balance between recharge and discharge in an aquifer system resulting in adverse effects on the environment. Monitoring water use allows observed effects within the aquifer system and hydraulically connected waterbodies (i.e. short and long-term changes in aquifer storage, alteration to natural recharge, throughflow or baseflow discharge rates) to be related to water use, enabling refinement of sustainable limits for consumptive water use.

- Ensure technical water use efficiency

  Technical water use efficiency refers to a range of performance indicators that can be used to characterise volumetric water use within a productive system in terms of units of production per unit of water used. Although there are many definitions of irrigation efficiency, they can be grouped into three main categories of irrigation efficiency, application efficiency and distribution efficiency.

  Irrigation efficiency describes the volume of water applied to an irrigated area that is used beneficially to support crop growth. Irrigation efficiency can be calculated in a range of alternative ways such as water use efficiency (WUE) which is defined as:

$$WUE = \frac{Production\ (kg/ha)}{Irrigation\ water\ use\ (m^3/ha)}$$

  Application efficiency is a similar concept to irrigation efficiency but relates to system performance during a single irrigation event and can be characterised in terms of concepts such as water application efficiency (WAE) where:

$$WAE = \frac{Volume\ of\ water\ required\ to\ replace\ crop\ evapotranspiration}{Volume\ of\ water\ applied\ to\ irrigated\ area}$$

  Distribution efficiency is a measure of the evenness of irrigation whereby uneven application of water contributes to lower application efficiency. Distribution efficiency is typically quantified in terms distribution uniformity (DU) which describes the evenness of water application to a crop over a specified area or Christiansen’s uniformity coefficient (CU) which describes the performance of sprinkler systems.

  Measurement of both rate and volume at which irrigation water is applied is therefore required to evaluate technical water use efficiency.

Situations of inefficient irrigation can equally apply to situations where water is applied in excess of soil water holding capacity (resulting in excess water draining through the soil profile) or where insufficient water is applied to maintain optimum growing conditions (in which case the productive benefit derived from a given volume of water is less than that occurring where soil moisture is maintain in the optimum range).

- <u>Achieve Allocative Efficiency</u>

  In economic terms, allocative efficiency is achieved when the maximum benefit is able to be derived from the available water resource (i.e. the entire allocation available is utilised for the greatest productive benefit). In terms of overall resource management, allocative efficiency is an outcome of the manner in which access to the available water resource is assigned to individual resource users.

  One of the primary factors contributing to sub-optimal allocative efficiency is where the rate and/or volume of water allocated to an individual user exceed that actually used. Often this situation arises because of the desire for individual users to maximise their reliability of supply (i.e. to ensure sufficient water is available to meet crop demand during climatic extremes). However, where water is allocated on this basis, it typically results in a significant proportion of available allocation being held by users who rarely (if ever) utilise their full allocation. This processes effectively 'ties up' water that could otherwise be accessed by other users thereby reducing overall allocative efficiency and the overall productive benefit able to be derived from the resource.

  The process of increasing allocative efficiency can also provide greater certainty regarding environmental outcomes resulting from abstraction. Often, where allocative efficiency is low, management of a water resource within nominated environmental limits (such as baseflow in spring fed streams) relies heavily on the fact that individual users never utilise their full allocations. However, the potential exists for unanticipated environmental effects to occur if the rate and/or volume of water use increases as a result of greater utilisation of the available allocation (either by individual users or through mechanisms such as transfer of allocation via RMA Section 136). As a consequence, efficient water resource management seeks to ensure the volume of water authorised by resource consents reflects 'reasonable' water use under nominated climate parameters which, for irrigation, are typically expressed in terms of a nominated reliability of supply (e.g. the water deficit occurring 1 year in 10 low rainfall period).

1.3 Report Background

While measurement and recording of water use data is a standard requirement on a majority of large-scale water takes in the Southland Region, the existing water use compliance data set suffers from a range of issues associated with data availability and quality including:

- Non-supply of water use records;
- Intermittent or irregular recording of water use;
- Issues with calibration and recording of electronic water use data;

- Various unresolved issues associated with recorded water use (e.g. volumes exceeding system capacity, duplicate records, out-of-season water use, recording cumulative use for multiple production bores)

The report provides an overview of irrigation water use in Southland, utilising data recorded in the Riversdale groundwater zone. This data set provides the most comprehensive record of water use in the Southland Region and reflects the considerable time and effort invested by Environment Southland staff in collating and improving the quality of water use records from this area.

1.3 Riversdale Groundwater Zone

The Riversdale groundwater zone is a highly permeable unconfined aquifer system hosted in shallow alluvial gravels underlying the recent floodplain on the true right bank of the Mataura River between Ardlussa and Mandeville. The aquifer system consists of a heterogeneous sequence of alluvial gravel materials (comprising intermixed silt, sand and gravel) between 10 to 30 metres thick which overlies low permeability mudstone sediments of the East Southland Group. The aquifer system is recharged by infiltration of local rainfall as well as appreciable flow loss (>1.6 m^3/s) from the upstream section of the Mataura River between Ardlussa and the Riversdale-Waikaia Road Bridge. Groundwater flows in a south-easterly direction through the aquifer system and is ultimately discharged back to the Mataura River between Pyramid and the Otamita Bridge either by direct seepage into the bed of the Mataura River or discharge to the numerous spring-fed stream that originate across the downstream section of the aquifer system.

The Riversdale groundwater zone was the first area in Southland to see development of large-scale pasture irrigation during the early 2000's. Between 2002 and 2005 a significant number of consents for pasture irrigation (sourced from groundwater) were issued in this area. The rate of resource development in this area then slowed between 2006 and 2009 due, in part, to the decreasing reliability of supply associated with minimum flow cut-offs applied to resource consents classified as being hydraulically connected to the Mataura River. In more recent years, application for additional allocation from the Riversdale groundwater zone have been declined by Environment Southland (a decision upheld by the Environment Court) on the basis of potential cumulative effects of abstraction on baseflow in the Meadow Burn and other spring-fed streams draining the aquifer system.

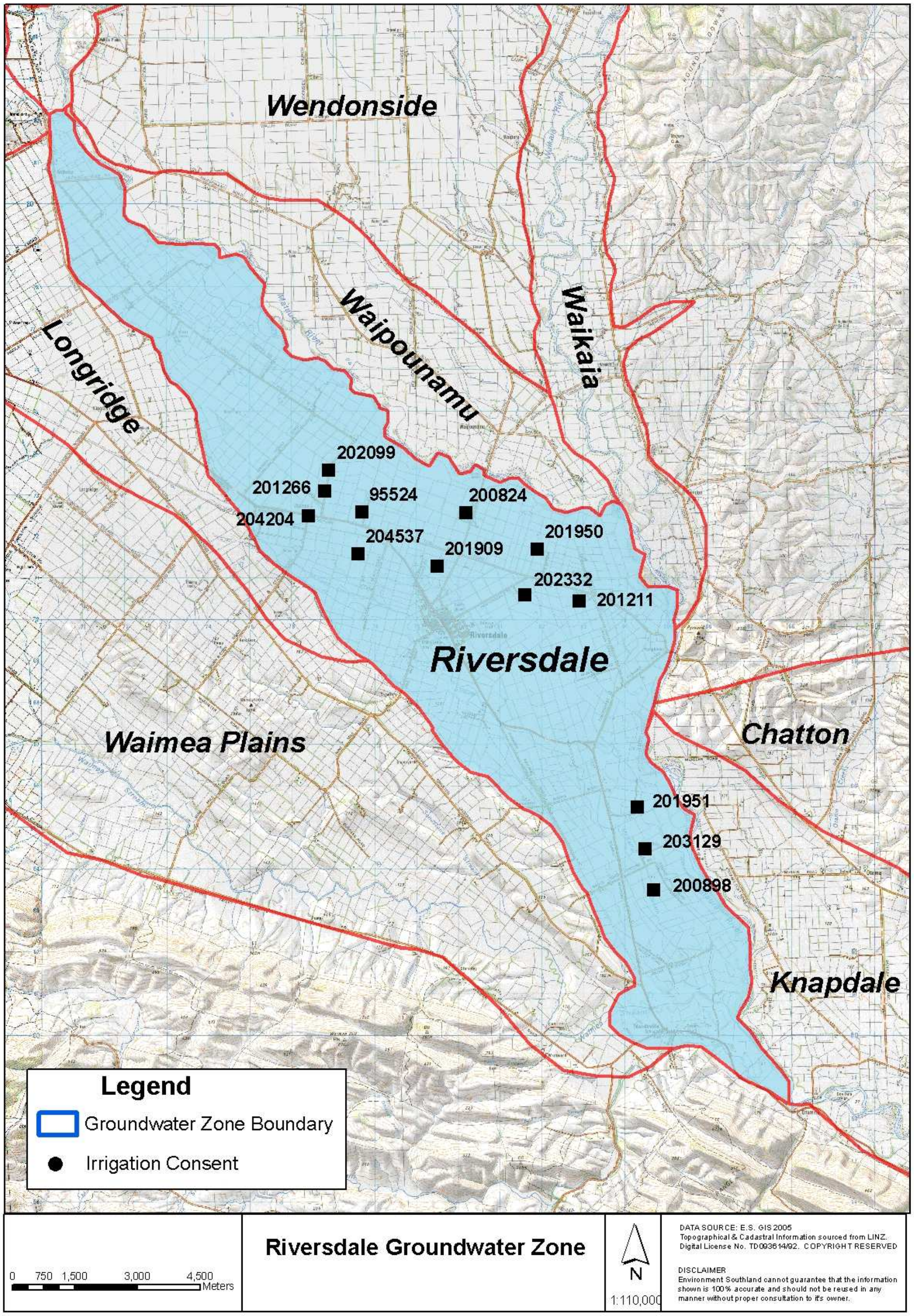

Figure 1. Riversdale groundwater zone location map showing the location of existing irrigation consents

2.0 Irrigation water use in the Riversdale groundwater zone

During and subsequent to rainfall events, moisture infiltrates from the land surface and accumulates in the underlying soil matrix. Following heavy rainfall the volume of water within the soil increases until a point (termed *field capacity*) when it can no longer be retained within the soil and gravity drainage occurs (this process results in recharge of underlying aquifers). Conversely, during periods of low rainfall the volume of moisture held within the soil matrix decreases due to the combined effects of evaporation and adsorption by plants (termed evapotranspiration). As soil moisture levels fall it becomes progressively harder for plants to access water held in the soil until a point where plant growth is impaired (termed the *wilting point*). Irrigation is utilised to maintain soil moisture levels in the optimum range for crop growth during periods of low rainfall and/or high evapotranspiration.

The following section provides a summary of temporal and volumetric water use in the Riversdale groundwater zone based on available water use data. Due to incomplete coverage and data quality issues, the primary focus of the assessment is on data collected between the 2005/06 and 2010/11 irrigation seasons.

It is recognised that some of the differences observed between irrigation use for individual resource consents will reflect differing land uses for individual irrigation operations (e.g. pasture vs crop). However, due to the lack of information available to quantify land use at a paddock-scale, such variations are not accounted for in the analysis undertaken. It is also noted that while a number of resource consents in the Riversdale groundwater zone have conditions requiring abstraction to cease when flow in the Mataura River falls below nominated rates, these minimum flow restrictions were not reached between 2005/06 and 2010/11 period. As a result, water use is not influenced by access restrictions during the analysis period.

2.1 Climatic Conditions

The following sections review historical water use records for the Riversdale groundwater. In order to provide context for these records a simple soil moisture model was established for the Riversdale groundwater zone following the methodology outlined by Scott and Thorpe (1986). This model utilises rainfall and potential evaporation (PET) data to calculate moisture deficit for a nominal soil water holding capacity. Despite being a simplistic model, it provides a useful guide to enable comparison of relative soil moisture conditions which are likely to influence irrigation demand between individual irrigation seasons.

Figure 2 plots the cumulative soil moisture deficit modelled for a 55 mm PAW soil in the Riversdale groundwater zone during the 2005/06 to 2010/11 irrigation seasons. Over the period modelled, the data indicate the 2005/06, 2007/08 and 2009/10 irrigations seasons were the driest with a cumulative soil moisture deficit of approximately 205mm. In contrast, the 2010/11 season was appreciably wetter with a modelled cumulative soil moisture deficit of less than 150mm.

Figure 3 shows a plot accumulated monthly modelled soil moisture deficit. This data provides a useful indication of the temporal variation in soil moisture likely to have influenced irrigation water use during individual irrigation seasons. These data indicate the following soil moisture conditions (modelled soil moisture deficit in brackets):

- 2005/06 - dry late September through to mid-December (170 mm), wet December and January (0 mm), dry late January to late February (87 mm);

- 2006/07 - relatively dry mid to late September (34 mm), wet through October and November (16 mm) and average to slightly wet December to March (87 mm);
- 2007/08 - relatively wet through to mid-November (0 mm) then dry through to late March (256 mm). Note: mid-November to mid-February rainfall at Mandeville close to a 1 in 10 year return low;
- 2008/09 - Average conditions to mid-January (110 mm), dry mid-January to mid-February (87 mm);
- 2009/10 - Dry to mid-December (130 mm) followed by a period of higher rainfall through to mid-January (22 mm), average to dry late January to mid-March (86 mm);
- 2010/11 - Dry November to late-December (110 mm) then relatively wet for the remainder of the season (5 mm).

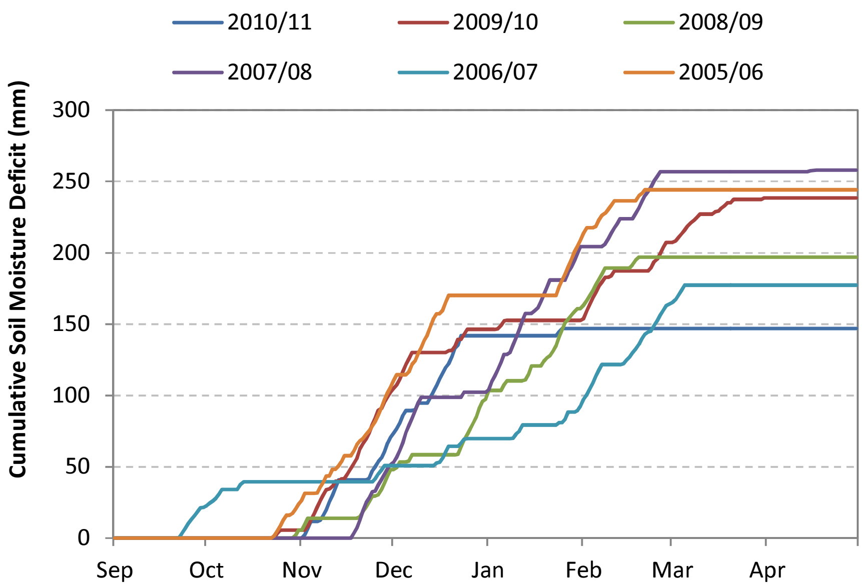

Figure 2. Cumulative soil moisture deficit modelled for the Riversdale groundwater zone for the 2006/07 to 2010/11 irrigation seasons

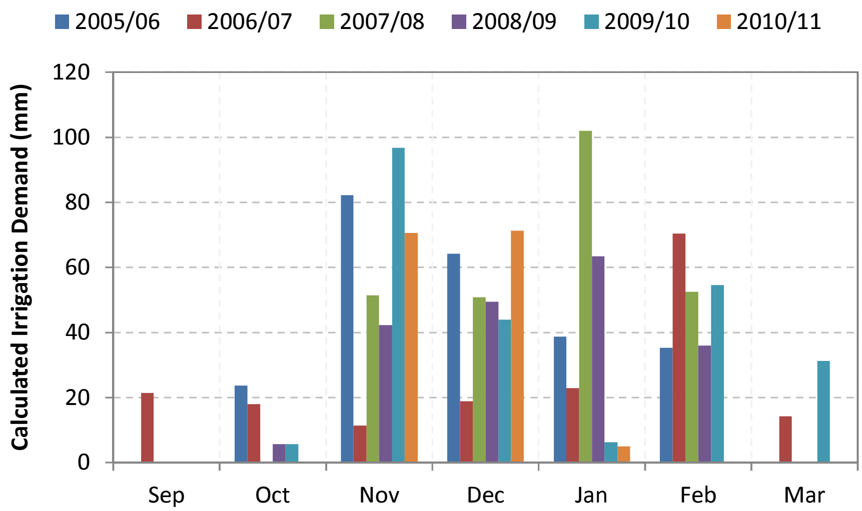

Figure 3. Modelled monthly soil moisture deficits for the 2005/06 to 2010/11 irrigation seasons

2.2 Total allocation and water use compliance monitoring

Figure 4 shows a plot of total allocation from the Riversdale groundwater zone over the period 2001/02 to 2010/11. The plot shows the significant increase in allocation which occurred between 2002 and 2005 followed by relatively stable allocation over the subsequent period. The figure illustrates water use compliance monitoring over this period in terms of three components:

- Water used - recorded water use
- Unused allocation - the volume of water unused by consents supplying water use information; and
- Unknown water use - water allocated to consents which failed to supply water use information.

Overall, the data show a significant improvement in the collection and provision of water use compliance data between 2001/02 when no water use records were provided and the 2009/10 season where there was full compliance with metering requirements[1]. The data show a steady increase recorded use from the 2002/03 season peaking at 3.13 million m^3 (or 47 percent of total allocation) in 2008/09. Water use over the past two years has remained below the 2008/09 total reflecting the above average summer rainfall conditions experienced over this period.

[1] At least at a resolution sufficient to determine seasonal water use. The resolution of data at a daily timescale varies between individual consents.

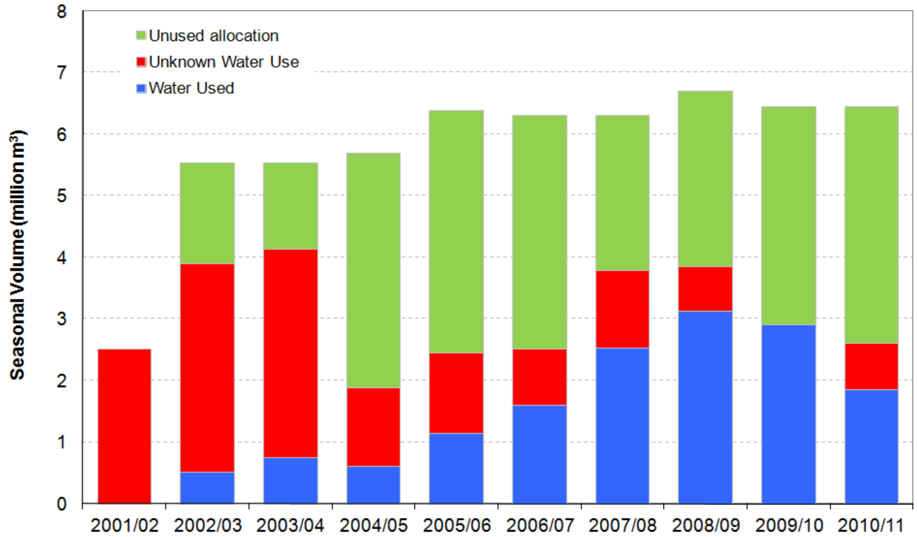

Figure 4. Water Use in the Riversdale groundwater zone, 2001/02 to 2010/11

2.2 Cumulative Abstraction

Figure 5 shows a plot of cumulative abstraction from the 2005/06 to 2010/2011 irrigation seasons[2]. The data show the highest cumulative abstraction of approximately 3.2 million m^3 during the 2008/09 season and 2.9 million m^3 in 2009/10. The 2005/06, 2006/07 and 2010/11 seasons all show significantly lower abstraction of between 1 and 1.5 million m^3. With the exception of 2005/06, the data shown in **Figure 5** generally follow the general trend of the accumulated soil moisture deficits illustrated in **Figure 2**.

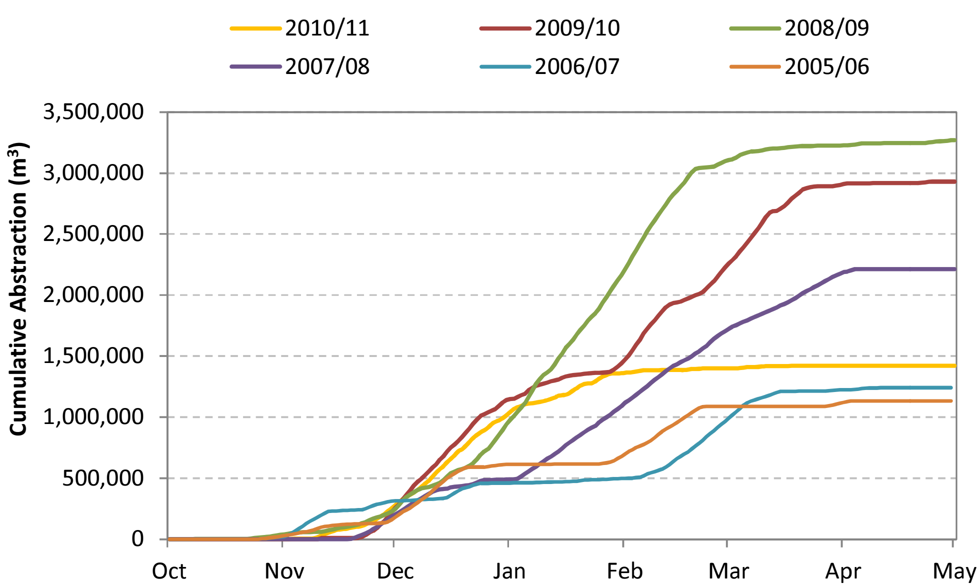

Figure 5. Cumulative abstraction over the 2007/08 to 20010/11 irrigation seasons

[2] Based on data from consents providing water use return

Figure 6 shows a breakdown of monthly abstraction expressed as a percentage of cumulative seasonal use (to normalise for seasonal differences in cumulative water use) as well as PET recorded at Gore. These data show average use of less than 2 percent of total water use during October and April, increasing to around 12 percent in November and March and 28 percent in December and February. Water use in January is generally lower than December and February reflecting the often unsettled weather experienced during this period. Overall, (with the exception of January) the monthly water shows a normal distribution which tracks seasonal variation in PET rates with a lag of around 1 month.

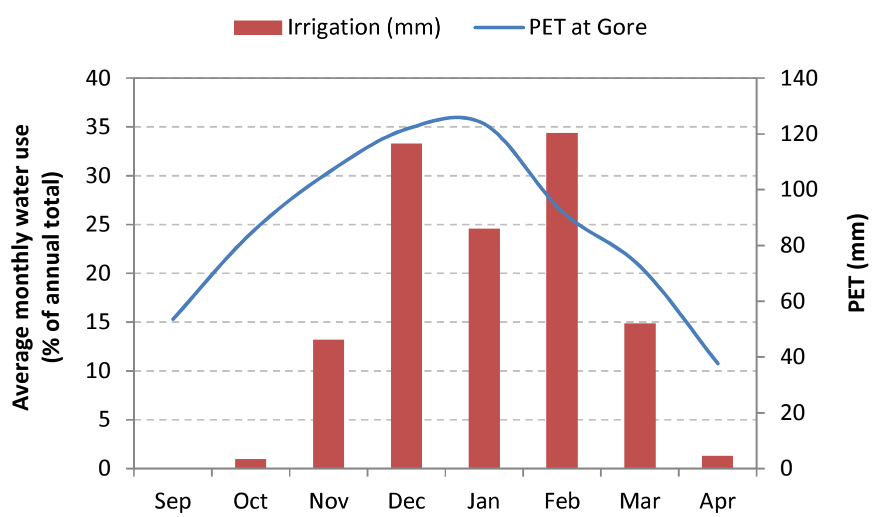

Figure 6. Monthly abstraction (expressed as a percentage of cumulative seasonal use) and PET at Gore, 2005/06 to 2010/11

In terms of actual monthly use, **Figure 7** shows a plot of cumulative monthly abstraction for the 2005/06 to 2010/11 irrigation seasons. The data show a maximum monthly abstraction of 1.2 million m^3 in January 2008, the season with the highest cumulative water use. It is noted that abstraction during January 2008 was significantly greater than the same period during any other year illustrating the potential effect of extended mid-summer dry conditions (i.e. during the period of highest PET) on total seasonal water use.

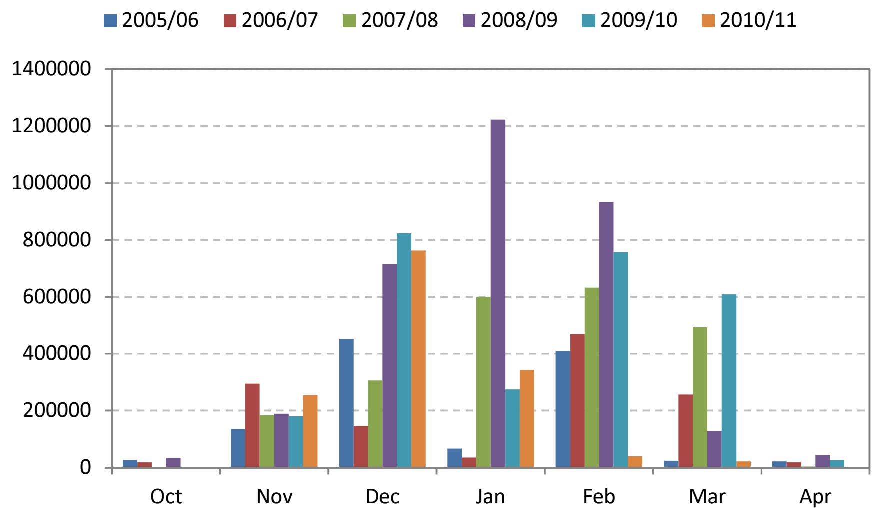

Figure 7. Cumulative monthly abstraction for resource consents in the Riversdale groundwater zone, 2005/06 to 2010/2011 irrigation seasons

Figure 8 shows a plot of the same data, this time expressed as a percentage of total seasonal water use. Shown in this form the data highlight the temporal variability of soil moisture in during individual irrigation seasons. For example, a majority of water use during the 2010/11 occurred in December 2010 reflecting the short duration of dry soil moisture conditions during this irrigation season. In contrast, water use during the 2006/07 year primarily occurred during late spring (Nov) and late summer (Feb/Mar) reflecting the relatively wet conditions during the late December/January period. Interestingly, the most consistent demand occurs in February, with use during this period in all seasons (except 2010/11) around 30 percent of the annual total, possibly reflecting the (typically) more settled weather conditions during this period.

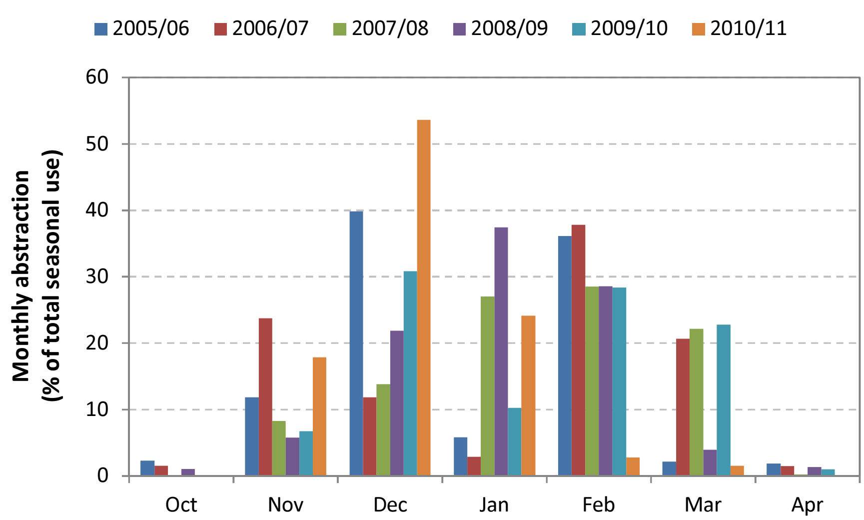

Figure 8. Monthly water use in the Riversdale groundwater zone 2005/06 to 2010/11 (expressed as a percentage of total seasonal water use)

2.3 Seasonal Use

All resource consents for groundwater abstraction in the Riversdale groundwater zone issued since 2000 have conditions which specify a maximum short-term rate of abstraction (in terms of a maximum instantaneous rate and/or daily volume) as well as a seasonal allocation. This seasonal allocation caps the total volume of water able to be abstracted in any given irrigation season (nominally established as 1 August to 31 July). Under Rule 23 of the Regional Water Plan (RWP) the cumulative seasonal allocation is established as the primary tool for managing the overall sustainability of abstraction within nominated groundwater management zones.

In the absence of specific criteria for establishing seasonal allocation, Environment Southland has typically utilised a 'rule of thumb' for establishing annual volumetric limits for irrigation takes based on continuous abstraction at the maximum rate of take over a nominal 150 day irrigation season multiplied by a factor (typically 0.6 to 0.65) to allow for reduced demand (due to lower evapotranspiration rates) during the shoulder portions of the irrigation season[3].

Table 1 provides a listing of seasonal volumes for individual resource consents in the Riversdale groundwater zone along with usage (both volumetric and calculated as a percentage of seasonal allocation) over the 2005/06 to 2010 to 2010/11 irrigation seasons. The data show considerable variation in seasonal use between individual consents and irrigation seasons.

Table 1. Seasonal allocation and volumetric use for irrigation consents in the Riversdale groundwater zone, 2005/06 to 2010/11 irrigation seasons (Note: ND indicates not data)

Consent Number	Annual Volume	2010/11		2009/10		2008/09		2007/08		2006/07		2005/06	
		m^3	%	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%
95524	267,300	124,500	53	86,001	32	ND		ND		ND		ND	
200824	875000	287,904	33	681147	78	703,823	80	624,600	71	272,140	31	ND	
200898	860,000	119,531	14	151,579	18	255,920	30	328,720	38	177,199	38	ND	
201211	589,875	216,912	37	293,628	50	72,628	12	199,889	34	340,462	58	224,080	38
201266	615,000	ND		402,118	65	543,924	88	ND		122,897	20	287,157	47
201909	152,400	78,212	51	79,496	52	95,625	63	134,973	89	61,178	40	58,512	38
201950	348,075	145,600	42	221,110	64	270,420	78	313,400	90	187,610	54	147,530	42
201951	888,225	308,690	35	425,870	48	437,720	49	656,170	74	291,310	33	296,010	33
202099	606,450	ND		215,200	35	289,000	48	ND		143,470	24	121,030	20
202332	59,400	ND		22,968	39	22,537	38	ND		ND		ND	
203129	513,825	126,872	25	1548715	30	165,541	32	222,302	43	ND		ND	
204204	210,750	93,104	44	64,991	31	ND		ND		ND		ND	
204537	379,350	180,625	48	173,757	46	268,390	71	49,030	13	ND		ND	

Figure 9 shows a box and whisker plot of seasonal use for irrigation consents in the Riversdale groundwater zone. The data show median use has ranged between 35 and 57 percent of seasonal

[3] Nominally interpreted to be Oct/Nov and March April

allocation between 2006/07 and 2010/11, with maximum usage of approximately 90 percent of seasonal allocation by two consents (201909 and 201950) during 2007/08.

Overall, seasonal usage data indicate that a significant proportion of allocation (>50 percent) is currently not utilised even during relatively dry seasons such as 2007/08 and 2009/10. This suggests that the methodology previously utilised to establish seasonal allocation consistently over-estimate actual use for a majority of resource consents.

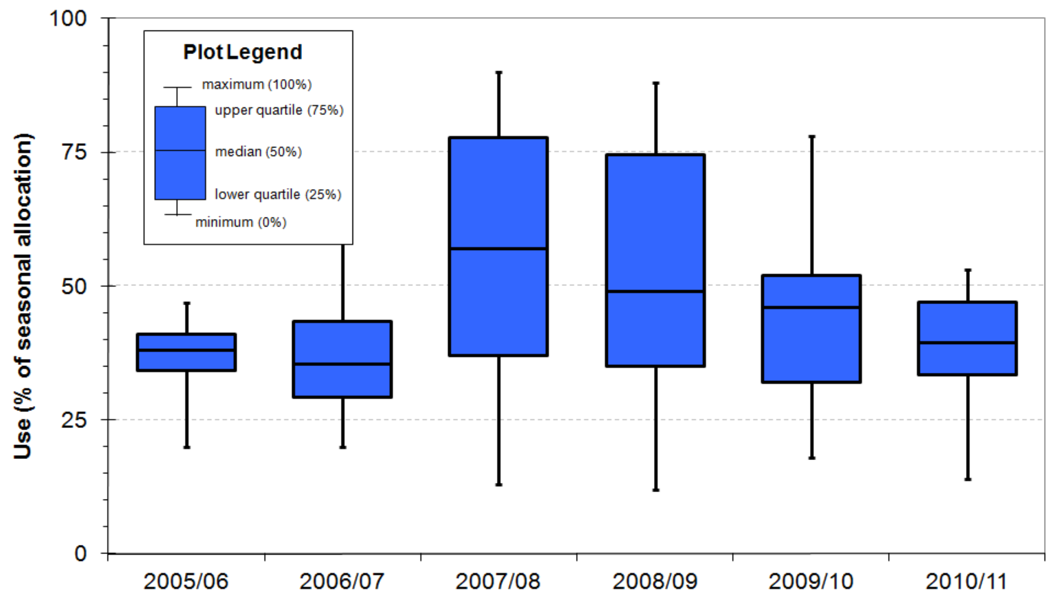

Figure 9. Box and whisker plot of seasonal use by irrigation consents in the Riversdale groundwater zone, 2005/06 to 2010/11

2.4 Seasonal application depth

Application depth describes the maximum amount of irrigation that can be applied to an irrigated area for a given seasonal allocation[4]. Application depth is an important parameter for managing allocation to ensure:

- The seasonal volume for individual resource consents are set at a level which reflects potential water demand (i.e. to optimise allocative efficiency); and,
- Reliability of supply for individual users (i.e. individual users have sufficient water to meet crop water requirements during dry conditions of a given magnitude and/or return interval).

For the purposes of this report calculation of application depth assumes that the entire area nominated for each irrigation consent is irrigated and that irrigation occurs evenly across the entire area.

Figure 10 shows application depth established by resource consent conditions for irrigation consents in the Riversdale groundwater zone range from 148 mm (Consent No 202349) through to a maximum of 430 mm (200898) with an average of 332 mm.

[4] Calculated as the seasonal allocation divided by the irrigated area for each individual resource consent

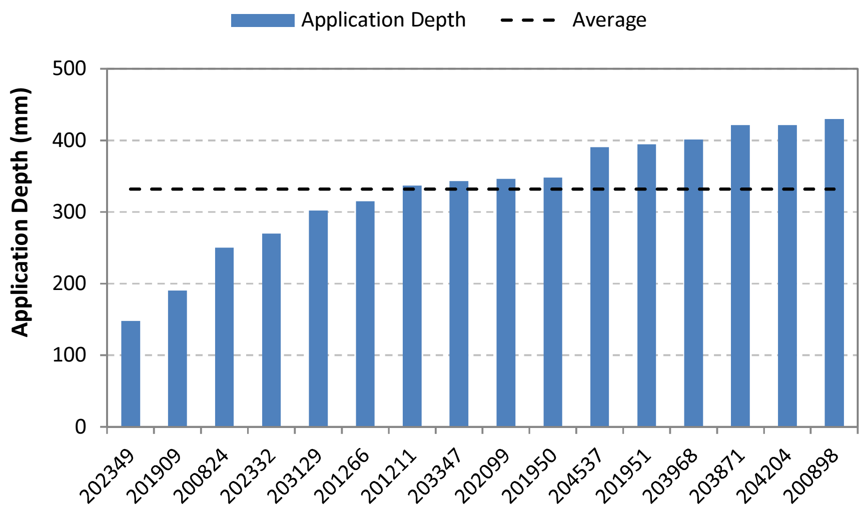

Figure 10. Application depth for irrigation consents in the Riversdale groundwater zone

Figure 11 shows a box and whisker plot of application depth for consents in the Riversdale groundwater zone between the 2004/05 and 2010/11 irrigation seasons. The median application depth over this period ranged from 56 mm in 2004/05 to a maximum of 164 mm in 2007/08, significantly lower than that provided for by existing seasonal allocations. The maximum application depth of 313 mm was recorded by a single irrigation consent (201950) during the 2007/08 irrigation season. The maximum application depth for all other seasons is approximately 280 mm, with an upper quartile (i.e. usage by 75 percent of consents) less than 250 mm.

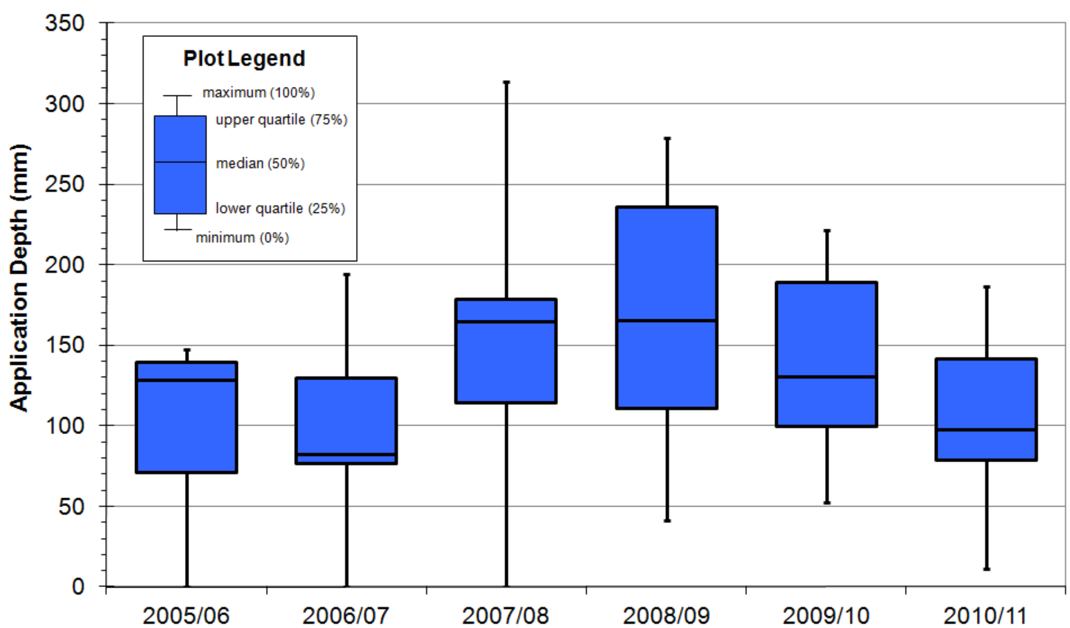

Figure 11. Box and whisker plot of application depths for resource consents in the Riversdale groundwater zone, 2004/05 to 20010/11

2.4 Application rate

The primary objective of irrigation is to essentially apply a volume of water equivalent to the crop evapotranspiration rate in order to maintain soil moisture in the optimum range for plant growth. During periods of high demand an application rate which is too low will result in a gradual decline in soil moisture levels while excessive applicant rates can result in soil moisture exceeding field capacity resulting in gravity drainage through the soil profile. Application rate is a measure of the total volume of water that can be applied to a given irrigated area each day and is therefore an important parameter to ensure the volume of water available for an individual consent is sufficient to meet short-term crop demand.

Due to the nature of the water use records available it is not possible to reliably compare irrigation rate against potential crop water demand. A major reason for this is the nature of the available water use records (particularly those manually recorded) where it is common for usage recorded on multiple or part days to be recorded against a given day.

Figure 12 shows a plot of 7-day moving average PET recorded at the Met Service Gore climate station over the period 2000-2011. These data show that while PET values occur across a wide range depending on the climate on any particular day, average values tend to follow a relatively smooth curve increasing from less 1 mm/day in August to a broad peak of around 4mm/day from November through February before declining to less than 1 mm/day by May.

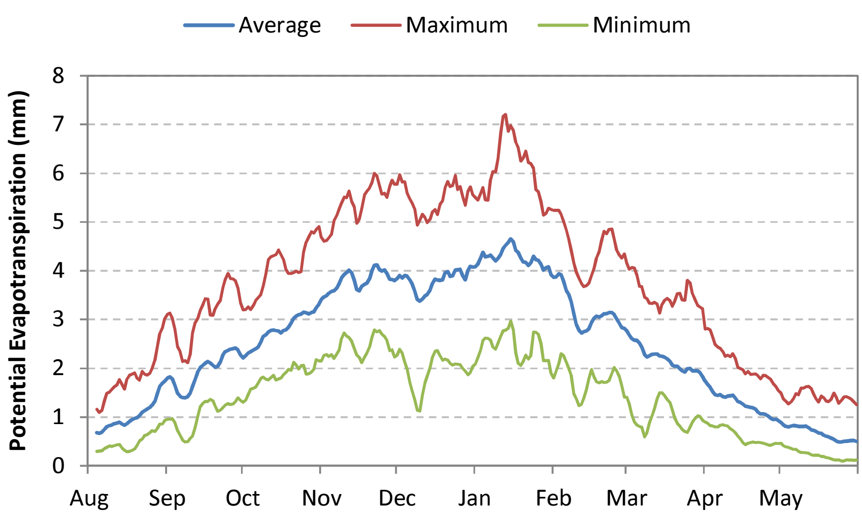

Figure 12. 7-day moving average potential evapotranspiration (PET) recorded at Gore, 2000-2011.

Peak application rate for individual resource consents is typically used to establish the maximum daily volume required for individual resource consents. In the Southland Region, a figure of 4 mm/day (essentially equal to the average mid-summer PET rate) has been used a basis for establishing peak rate for a significant number of irrigation consents. **Figure 13** shows peak application rates for consents in the Riversdale groundwater zone range from 1.6 mm/day to a maximum of 4.3 mm/day with an average of 3.3 mm/day. One consequence of these rates is that a number of individual consents at the lower end of this range are unlikely to have sufficient water to enable maintenance of soil moisture during extended periods of low rainfall, necessitating irrigation of a reduced area to meet evapotranspiative demand (i.e. to maintain technical irrigation efficiency).

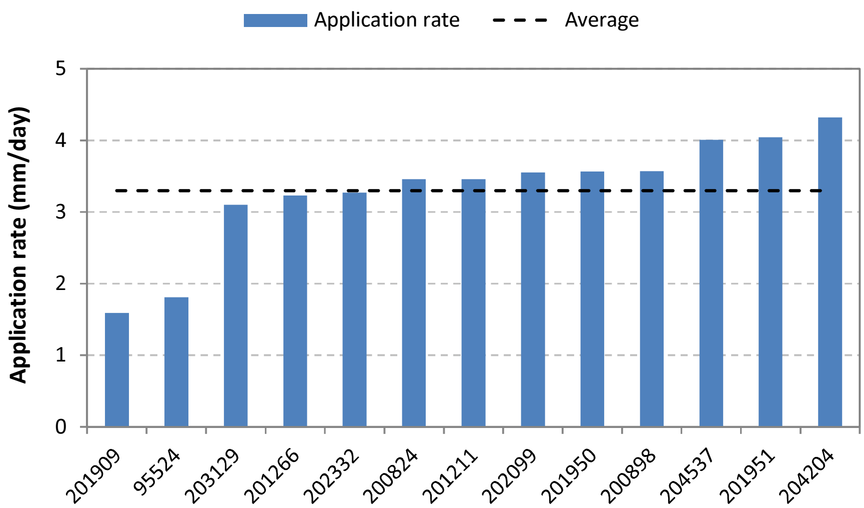

Figure 13. Peak application rates for resource consents in the Riversdale groundwater zone.

2.5 Duration of abstraction

In the Southland Region the timing and duration of irrigation is highly dependent on seasonal climate variability. **Table 2** lists the date for the first and last recorded irrigation over the 2005/06 to 2010/11 irrigation seasons. These data show irrigation typically commences between late October and mid-November (also illustrated on **Figure 2**). However, the end of the irrigation season varies considerably between both individual season and irrigation operations.

Table 2. Dates for the start and end of irrigation, 2005/06 to 2010/11 irrigation seasons

	Irrigation Season					
	2005/06	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**2010/11**
Start	20 October	22 October	18 November	23 October	11 November	3 November
Stop	23 February	11 April	3 April	25 April	25 April	13 March

Figure 14 shows a box and whiskers plot of irrigation duration for individual consents (counted as the number of days on which abstraction is recorded). These data show the median irrigation season over the period 2005/06 to 2010/11 varied between 44 days in 2006/07 through to 76 days in 2008/08. The maximum duration of irrigation was between 110 and 122 days in the 2007/08, 2008/09 and 2009/10 seasons.

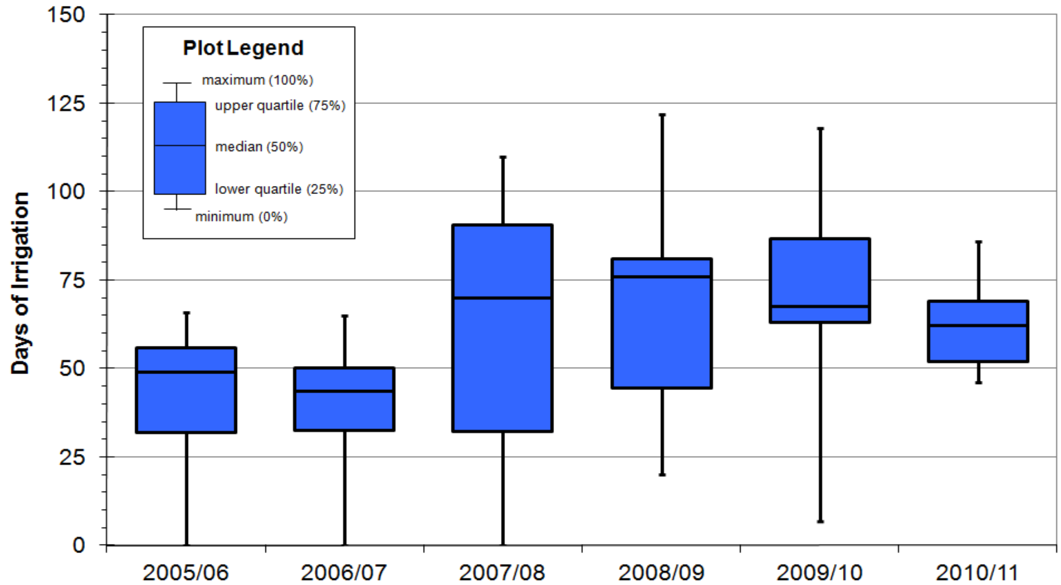

Figure 14. Box and whiskers plot of the number of days of irrigation per season, 2005/06 to 2010/11.

Figure 15 shows the annual variability in the duration of irrigation for individual resource consents. While these data show a degree of commonality in relative irrigation duration for individual consents, the overall variability between individual seasons suggests short-term management decisions may significantly affect the use of irrigation rather than more objective criteria (such as soil moisture levels which should follow a similar trend across a majority of the irrigated area).

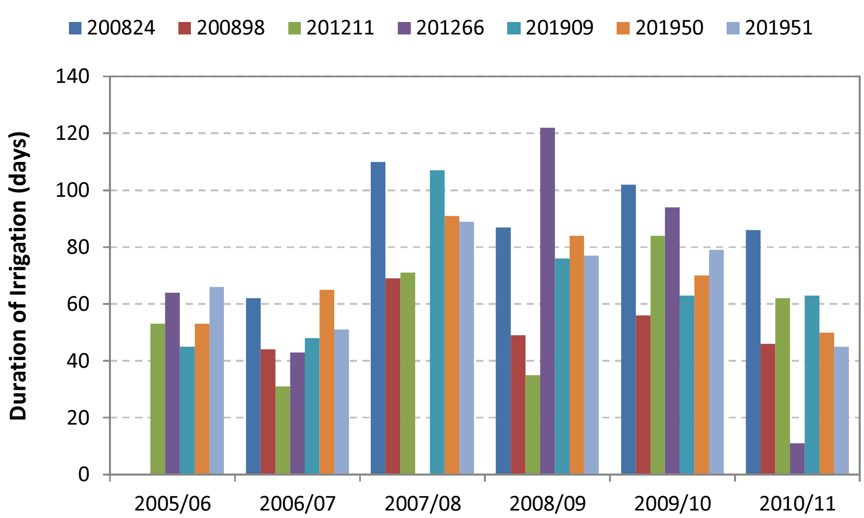

Figure 15. Duration of irrigation for individual resource consents, 2005/06 to 2010/11

Overall, water use compliance data indicate that irrigation consents in the Riversdale groundwater zone were utilised for a median duration of between 44 to 76 days between the 2005/06 and 2010/11 irrigation seasons with a maximum recorded duration of 122 days in the 2008/09 season. This observation suggests the 150 day nominal duration utilised to establish seasonal allocation is likely to exceed the actual period of irrigation under a range of climate conditions (including the 2007/08 season when 3-month rainfall totals at Mandeville[5] were close to a 1 in 10 year low return interval). The nominal 150 day duration is also utilised in the calculation of potential stream depletion effects in RWP Policy 29 and is similarly likely to result in over-estimation of potential effects associated with groundwater abstraction for irrigation supply.

2.5 Maximum pumping rate

While there is some uncertainty with regard to characterisation of the maximum pumping rate (particularly in terms of manual meter readings) the available data (particularly from recent years) are sufficient to provide an indication of current abstraction patterns in terms of maximum pumping rates.

The temporal variability observed in abstraction rates for individual consents is illustrated in **Figure 16** below which shows a plot of daily abstraction for four consents during the 2009/10 irrigation season. The data show that while the consents illustrated have relatively common times for the start and stop of irrigation, there is considerable variability in actual abstraction rates on a day-to-day basis (most likely due to operational factors on individual properties). These data suggest it may be rare for an individual consent to pump at the maximum permitted rate for an extended duration.

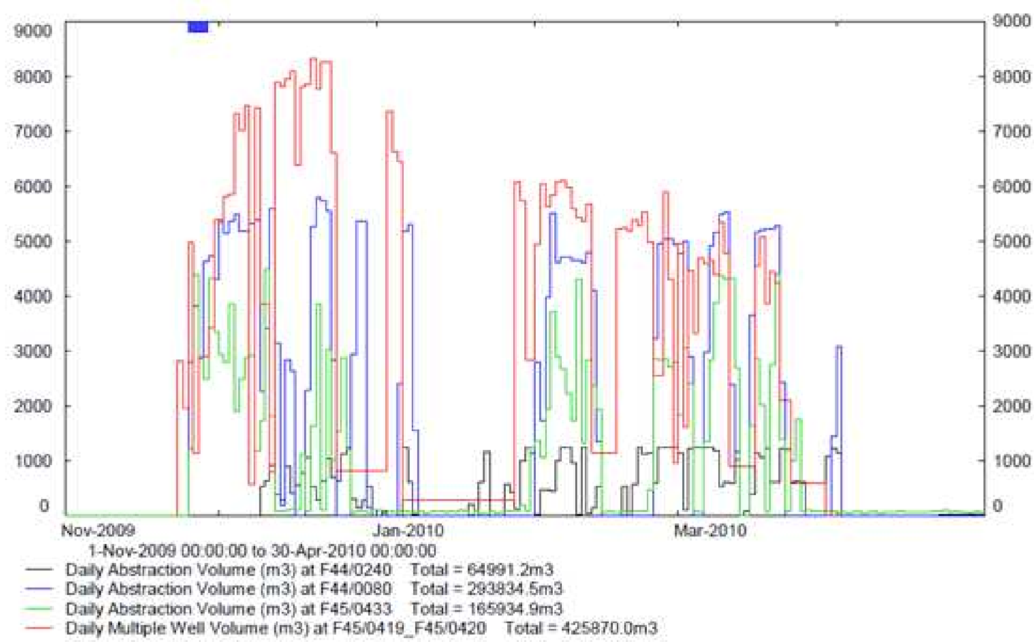

Figure 16. Daily abstraction for resource consents in the Riversdale groundwater zone 2009/10.

Figure 17 shows a plot of the daily pumping rate duration curve for seven consents in the Riversdale groundwater zone. These data indicate that for a majority of consents the recorded pumping rate is less than half of the maximum daily rate for between 60 to 80 percent of days on which abstraction is recorded. Only one consent (210950) has a recorded daily pumping rate within 10 percent of the

[5] The monitoring record is too short (<10 years) to reliably undertake similar analysis for the Riversdale Aquifer at Liverpool Street site.

daily maximum for any extended duration (in this case approximately 50 percent of days on which abstraction is recorded).

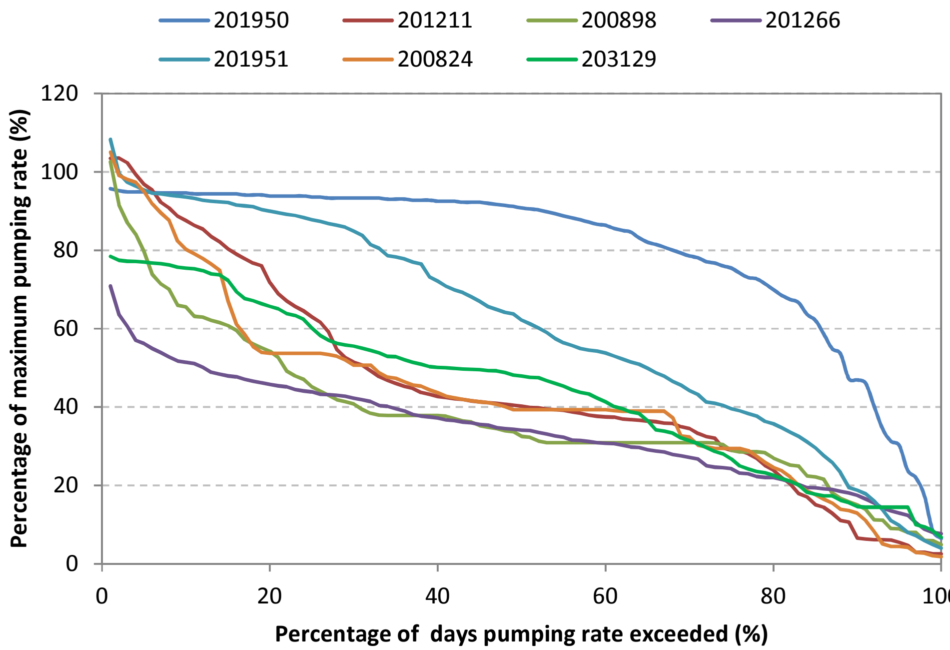

Figure 17. Pumping rate duration curve for selected resource consents in the Riversdale groundwater zone

Overall, available data indicate a majority of consents in the Riversdale groundwater zone pump at rates well below the maximum permitted for a significant portion of the irrigation season. This suggests that assessment of effects based on continuous maximum rate pumping (e.g. stream depletion or well interference assessment) are likely to over-estimate actual effects.

3.0 Characterisation of seasonal irrigation water use

A significant feature of the water use data available for the Riversdale groundwater zone is that actual water use is consistently lower than water demand calculated utilising the ES soil moisture water balance model[6]. **Figure 18** provides a comparison of actual irrigation (calculated as total abstraction divided by total irrigated area) against irrigation requirements calculated using the ES water balance model[7]. The data show actual irrigation generally tracks seasonal differences in modelled cumulative soil moisture deficit (2007/08 being the only major exception), varying between around 50 to 90 percent of the calculated total.

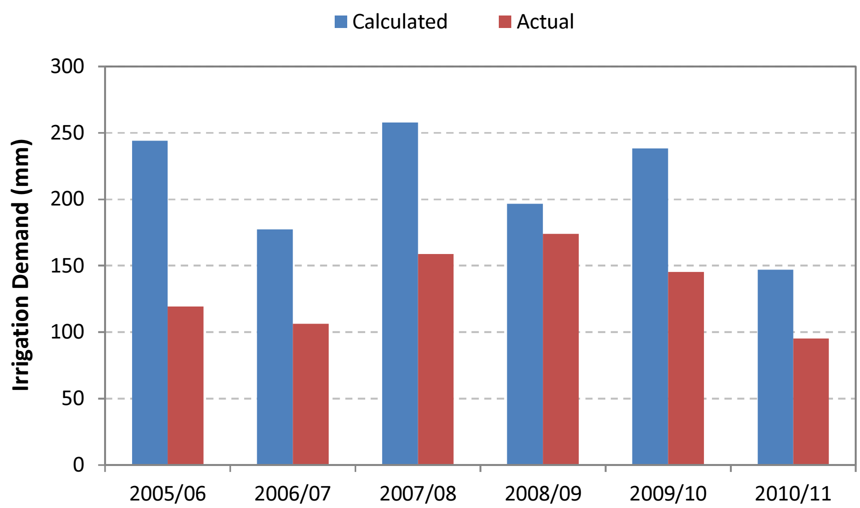

Figure 18. Comparison of annual irrigation demand and actual irrigation (averaged for all consents)

Figure 19 shows a plot of actual irrigation against calculated soil moisture deficit for a selection of six resource consents over the period 2005/06 to 2010/11. It is noted that in some years (e.g. 2006/07 and 2010/11) the volume of irrigation is relatively uniform, while in others (particularly 2007/08 and 2008/09) there is considerable variance in irrigation practice between individual consents. The only period when actual use significantly exceeds modelled soil moisture deficit is in 2007/08 when usage by two consents (201950 and 201951) was almost 50 percent greater than modelled. One possible explanation for the high usage during this season was the persistence of dry conditions through January compared to other seasons when irrigation use has been reduced due to rainfall and/or periods of unsettled weather (see **Figure 7**).

[6] And significantly lower (<50 percent) than estimates made using a specialised irrigation demand model (IrriCalc) in the Mataura Catchment Strategic Water Study (Liquid Earth *et.al*, 2011)

[7] Irrigation requirements calculated using Irricalc range between 320 and 490 mm over the same period

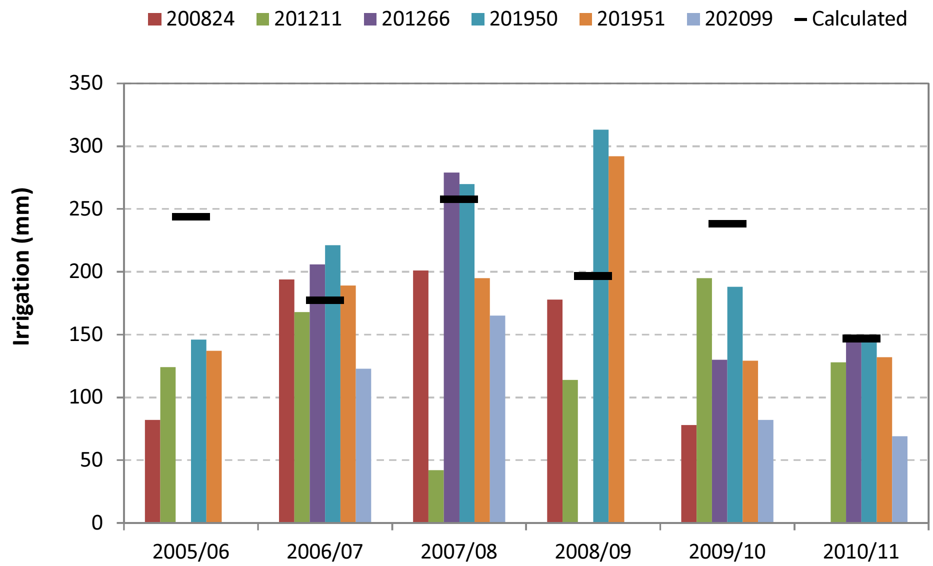

Figure 19. Comparison of modelled water demand and actual irrigation for selected resource consents, 2005/06 to 2010/11 (modelled values shown as black bars)

Figure 20 and **Figure 21** illustrate the seasonal pattern of abstraction in the Riversdale groundwater zone compared to soil moisture recorded at the Environment Southland Riversdale Aquifer at York Road monitoring site. As expected, the data show a general inverse relationship between soil moisture levels and cumulative groundwater abstraction, with abstraction peaking during the period of lowest soil moisture levels. The effect of mid-summer rainfall is particularly evident in the 2009/10 data with a significant reduction in abstraction following significant rainfall events during January and late-February.

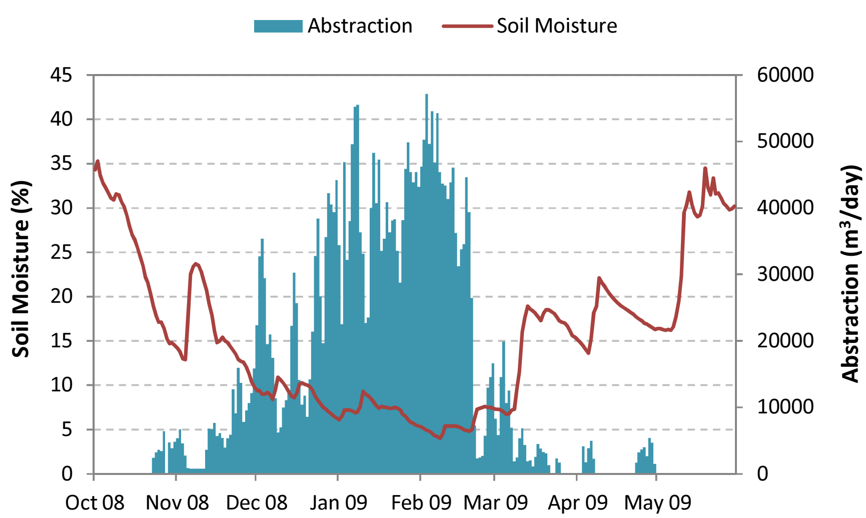

Figure 20. Soil moisture and total daily abstraction in the Riversdale groundwater zone, 2008/09

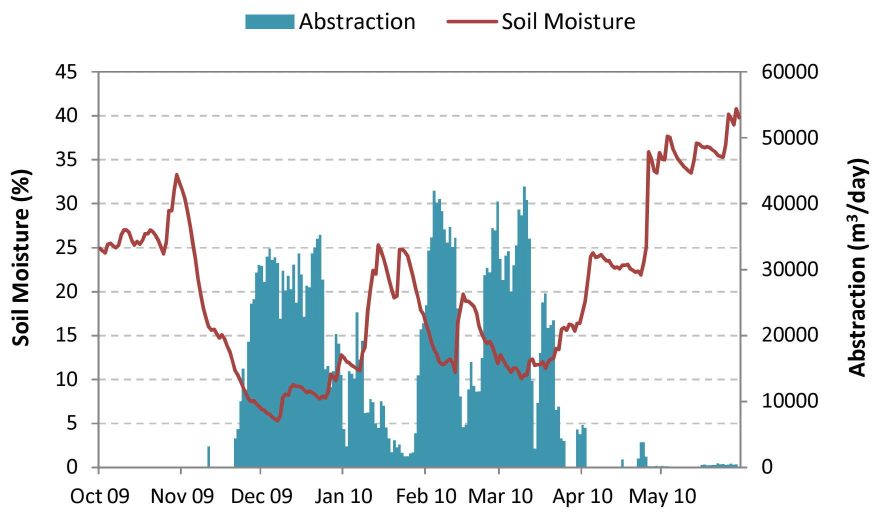

Figure 21. Soil moisture and total daily abstraction in the Riversdale groundwater zone, 2009/10

However, although following the general trend of soil moisture, when viewed at a monthly scale the discrepancy the timing of the major discrepancy between modelled and actual water use becomes more apparent. As shown in **Figure 22**, actual use (across all consents) shows a significant shortfall compared to modelled demand during the early part of the irrigation season (particularly November).

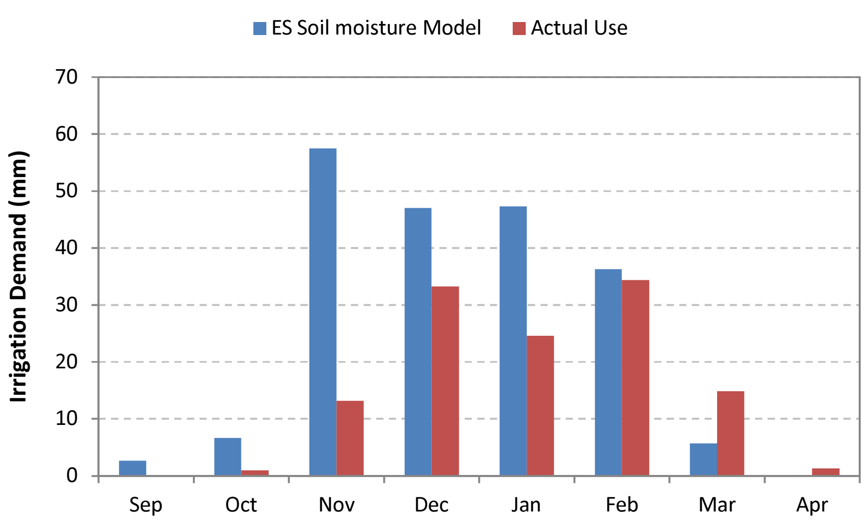

Figure 22. Discrepancy between monthly modelled soil moisture deficit and actual irrigation over the 2005/06 to 2010/11 irrigation seasons

This discrepancy between potential irrigation demand and actual use during the early part of the irrigation season is observed for virtually all consents between 2005/06 and 2010/11, regardless of temporal variability in rainfall and soil moisture characteristics during individual irrigation seasons. For example, **Figure 23** shows a plot of calculated soil moisture deficit and actual irrigation for consent

200824 for the 2008/09 irrigation season[8]. The plot clearly illustrates the delayed start to irrigation during a period of reduced soil moisture during November and December 2008. Conversely, irrigation matches or exceeds modelled demand during the latter part of the season.

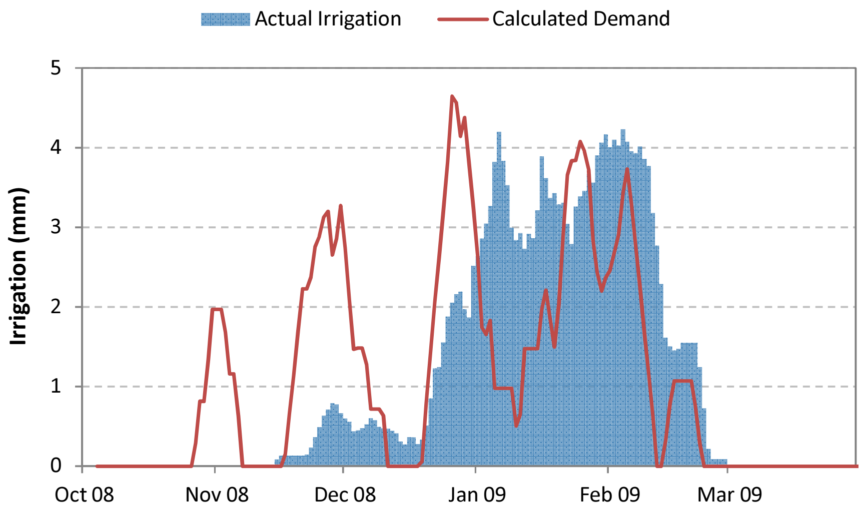

Figure 23. 7-day average calculated irrigation demand and actual irrigation for consent 200824, 2008/09

Figure 24 and **Figure 25** show a similar pattern of shortfall during the initial portion of the irrigation season with irrigation matching or exceeding calculated demand during the late-summer/autumn period for other resource consents during the 2009/10 and 2010/11 irrigation seasons.

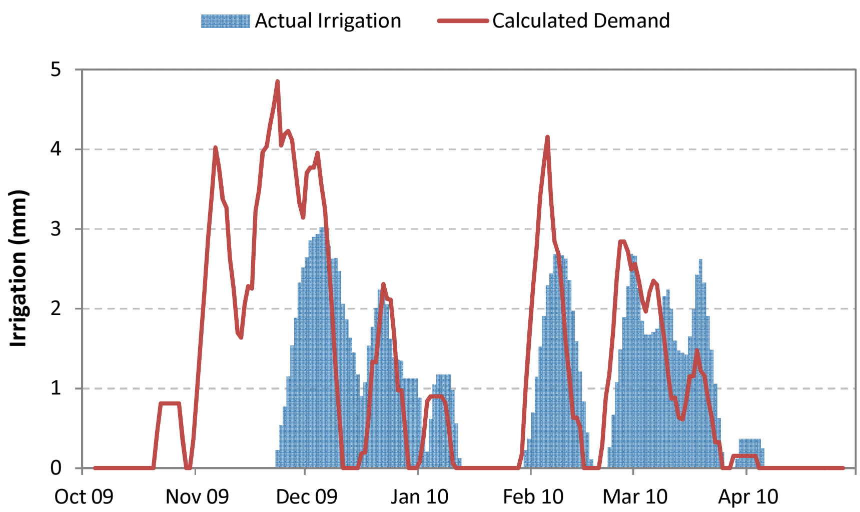

Figure 24. 7-day moving average calculated irrigation demand and actual irrigation for consent 201211, 2009/10

[8] Data are presented as 7-day moving averages to remove daily variability and better illustrate short-term trends

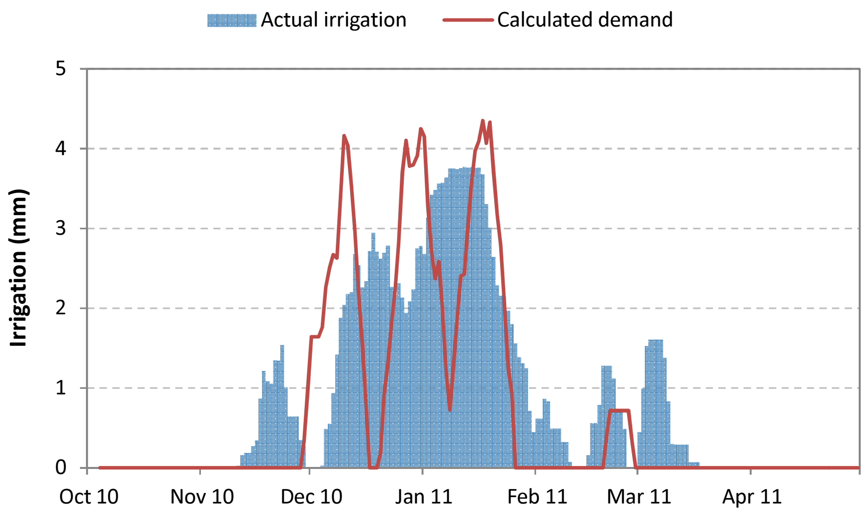

Figure 25. 7-day moving average calculated irrigation demand and actual irrigation for consent 204537, 2009/10

The best match between calculated irrigation demand and actual irrigation was observed for consent number 201950 during the 2008/09 season. As shown in **Figure 26** below, the timing and magnitude of irrigation for these consents matched calculated soil moisture deficit with a seasonal application depth of 270 mm compared to the 260 mm modelled.

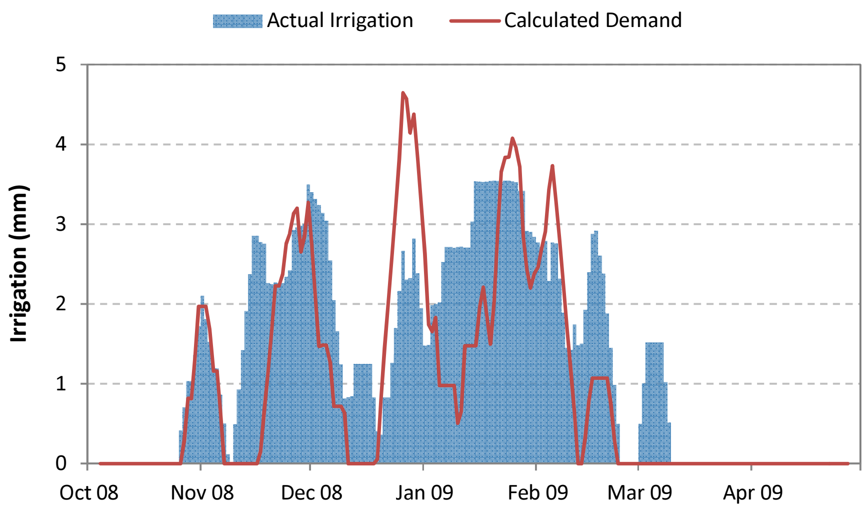

Figure 26. 7-day moving average calculated irrigation demand and actual irrigation for consent 201950, 2008/09

As previously noted periods of rainfall and/or unsettled weather frequently occurred during the mid-summer period in the Riversdale area between 2005/06 and 2010/11. The effect of such conditions on the management of irrigation appears to have a significant influence on cumulative seasonal water demand. As described in Liquid Earth *et al*. (2011)[9], anecdotal evidence suggests that as a result of periods of unsettled weather over the New Year period (rainfall, low air temperatures, overcast conditions) limited irrigation occurs over this period despite soil moisture conditions remaining below optimum.

To illustrate this point, **Figure 27** and **Figure 28** show plots of actual irrigation and calculated water balance (rainfall minus PET) for selected consents for the 2007/08 and 2009/10 irrigation seasons. During the extended dry 2007/08 summer irrigation application during the January period was between 40 to 95 mm with a corresponding water deficit of between 30 to 50 mm. In contrast, the more limited irrigation (30 to 50 mm) occurred during January 2010 due to unsettled weather conditions resulting in a higher moisture deficit of between 40 to 60 mm.

While relatively simplistic, this analysis suggests that current irrigation practice (and consequently irrigation water use) is significantly influenced by climate rather than soil moisture conditions, during the mid-summer period. Combined with the delay in irrigation during the early part of the irrigation season, management of irrigation in response to rainfall events during the mid-summer period may account for a significant proportion of the discrepancy between actual and modelled irrigation.

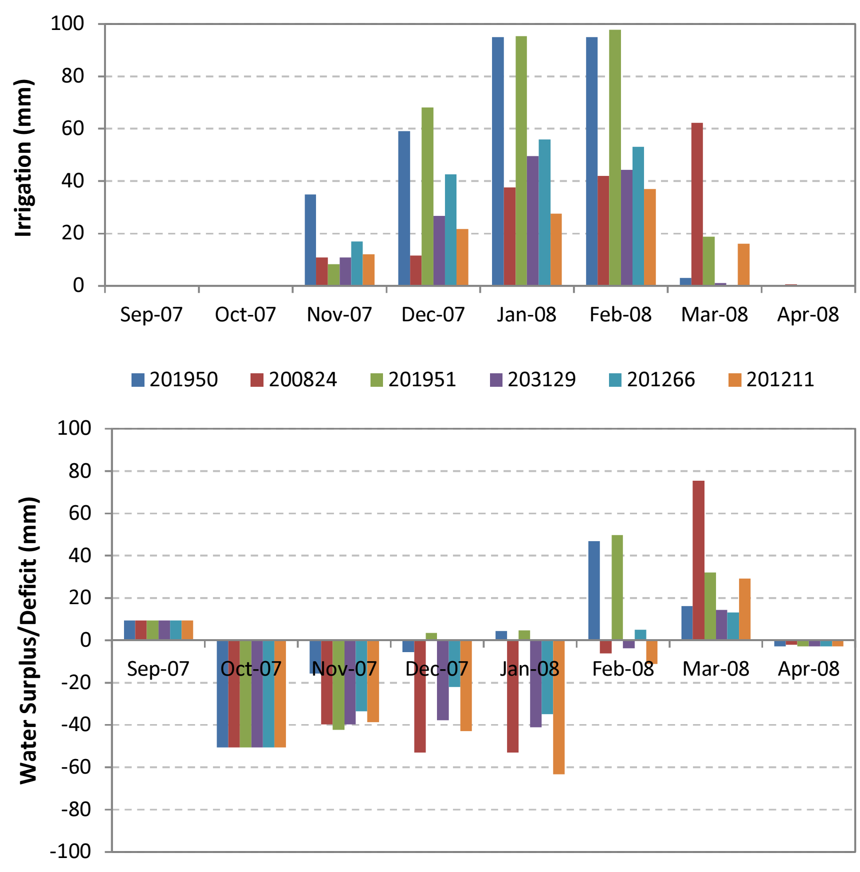

Figure 27. Irrigation and estimated water surplus/deficit for selected consents over the 2007/08 irrigation season

9 Liquid Earth, Aqualinc Research, Harris Consulting (2011) *Mataura Catchment Strategic Water Study*. Report prepared for Environment Southland, May 2011.

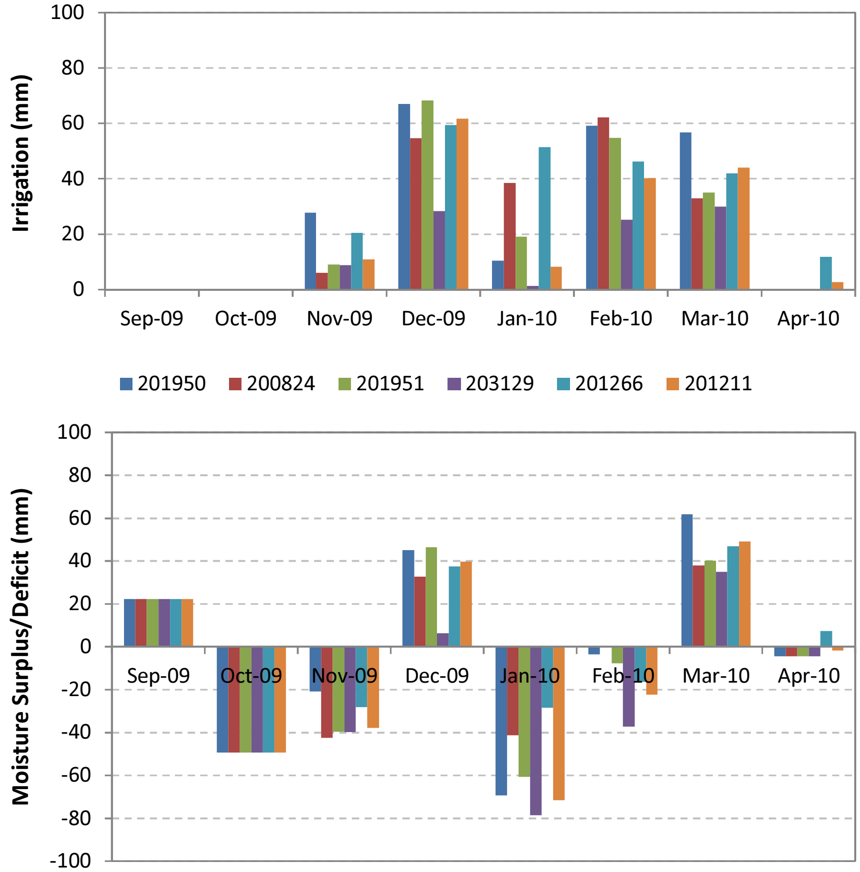

Figure 28. **Irrigation and estimated water surplus/deficit for selected consents over the 2009/10 irrigation season**

4.0 Summary

Measurement and recording of water use data is a standard condition for all irrigations consents in the Riversdale groundwater zone. Over the past ten years both the rate of compliance with water use monitoring requirements and the quality of data has improved significantly. Although there are some issues with the quality of historical information, the overall data set provides a valuable resource to quantify the rate and nature of irrigation water use in the Riversdale groundwater zone.

This report summaries various aspects of the available water use data including the volume, rate and timing of irrigation abstraction and provides analysis of various aspects of irrigation water use that may assist future water resource management.

Table 3 and **Table 4** provide a summary of irrigation water use data for the Riversdale groundwater zone for the 2009/10 and 2010/11 irrigation seasons respectively.

Table 3. Summary of irrigation water use in the Riversdale groundwater zone, 2009/10

Consent No	Allocation (m^3)		2009/10 Irrigation Season						
	Daily	Seasonal	Start Date	Finish Date	Maximum Daily Use (m^3)	Cumulative Volume (m^3)	% of seasonal allocation	Application depth (mm)	Days of Irrigation
95524	2,970	267,300				86,001	32.1	52.4	
200824	12,100	875,000	24/11/09	13/3/10	11,983	680,291	77.7	194	96
200898	7,143	860,000	22/11/09	21/3/10	2,710	151,575	17.6	76	65
201211	6,050	589,875	25/11/09	2/4/10	5,782	293,943	49.8	168	72
201266	6,305	615,000	11/11/09	7/4/10		402,118	65.4	206	121
201909	1,270	152,400	20/11/09	4/3/10		79,497	52.2	99	104
201950	3,750	348,075	20/11/09	20/3/10	3,570	221,110	63.5	221	71
201951	9,110	888,225	22/11/09	23/3/10	8,330	425,870	47.9	189	89
202099	6,220	606,450	21/11/09	19/3/10		215,200	35.5	123	118
202322	720	59,400	21/11/09	15/3/10	667	22968	38.7	104	62
203129	5,270	513,825	25/11/09	25/3/10	3,570	154,715	30.1	91	80
202349	988	88,920				No data			
204204	2,160	210,750	8/12/09	2/4/10	1,253	64,991	30.8	130	80
204537	3,890	379,350	2/2/10	25/4/10	3,722	173,757	45.8	179	56

Table 4. Summary of irrigation water use in the Riversdale groundwater zone, 2010/11

Consent No	Allocation (m^3)		2010/11 Irrigation Season						
	Daily	Seasonal	Start Date	Finish Date	Maximum Daily Use (m^3)	Cumulative Volume (m^3)	% of seasonal allocation	Application depth (mm)	Days of Irrigation
95524	2,970	267,300	25/11/10	7/2/11		124,129	46.4	75	61
200824	12,100	875,000	11/11/10	8/2/11	6,229	287,903	32.9	82	81
200898	7,143	860,000	8/11/10	20/3/11	5,527	119,702	13.9	60	46
201211	6,050	589,875	4/11/10	30/1/11	6,011	216,706	36.7	124	57
201266	6,305	615,000				Data incomplete			
201909	1,270	152,400	8/11/10	29/1/11	1,270	78,212	51.3	98	63
201950	3,750	348,075	10/11/10	30/1/11	3,550	145,600	41.8	146	55
201951	9,110	888,225	30/11/10	27/1/11	8,848	308,690	34.8	13	52
202099	6,220	606,450				No data			
202332	720	59,400				No data			
201329	5,720	513,825	20/11/10	27/1/11	4,484	127,527	24.8	75	52
202349	988	88,920				No data			
204204	2,160	210,750	10/12/10	19/3/11	2,244	93,104	44.2	186	69
204537	3,890	379,350	14/11/10	14/3/11	3,711	180,680	47.6	186	77

Observations from a review of available allocation and irrigation water use monitoring information from the Riversdale groundwater zone include:

- The current seasonal allocation of approximately 6.4 million m^3 per year has remained relatively static since 2005/06;
- Seasonal water use increased steadily from 2002/03, peaking at approximately 3.2 million m^3 in the 2008/09 irrigation season. Recorded use over the 2005/06 to 2010/11 period ranged between 18 to 47 percent of total allocation, indicating a significant proportion of current allocation is not utilised even under relatively dry periods such as the 2007/08 summer (when 3-monthly rainfall at Mandeville was close to a 1 in 10 year return low);
- Average monthly water use tracks seasonal variation in potential evapotranspiration (PET) with a lag of approximately 1 month. Monthly water use peaks in December and February at around 30 to 35 percent of seasonal use. Average use during January was significantly lower than December and February (despite being the period of peak PET) over the 2005/06 to 2010/11 irrigation seasons reflecting the frequent occurrence of wet and/or unsettled weather conditions over this period;

  However, peak monthly use of approximately 120,000 m^3 was recorded in January 2009 reflecting the low rainfall occurring over this period. The high volumetric usage in January 2009 resulted in the 2008/09 season recording the highest cumulative water use, suggesting climate variability (and associated effects on irrigation management) during the mid-summer period may exert a significant influence on seasonal water use;

- Nominal application depths for irrigated properties in the Riversdale groundwater zone range from 148 to 430 mm. Water use data show median application depth ranging from 56 to 164 mm between 2005/06 and 2010/11 with an individual maximum of 313 mm recorded during the 2007/08 season;
- Maximum application rates for a majority of consents in the Riversdale groundwater zone range between 3 to 4 mm/day. Comparison with PET at Gore (as well as maximum water use) suggest this application rate is adequate to maintain soil moisture under a range of climate conditions;
- Water use data indicate the timing and duration of abstraction is highly dependent on seasonal climate variability. While irrigation typically commences within a relatively narrow window between late-October and mid-November, the end of the irrigation season varies considerably between both individual seasons and irrigation operations;

  The median duration of irrigation for consents in the Riversdale groundwater zone between 2005/06 and 2010/11 ranged between 44 and 76 days with a maximum of between 110 and 122 days recorded during the 2007/08, 2008/09 and 2009/10 seasons. Given the range of climate conditions experienced over this period, this observation suggests the nominal 150 day irrigation season previously utilised to establish seasonal allocation (and assess potential environmental effects) is likely to significantly exceed the duration of actual use;
- Data on maximum pumping rates is affected by the nature of data recording (particularly where manual measurements are recorded at irregular intervals). However, available data indicate that a majority of consents rarely operate at rates approaching the maximum daily limit for any extended period with the median daily abstraction rate typically less than 50 percent of maximum. Again, the assumption of continuous maximum rate abstraction is likely to result in over-estimation of actual environmental effects (particularly in terms of stream depletion).

One significant feature of water use data from the Riversdale groundwater zone is that irrigation use is consistently lower than water demand calculated using standard soil moisture or irrigation scheduling models. Two factors that appear to contribute significantly to this apparent discrepancy are:

- The commencement of irrigation during the early part of the irrigation season typically lags the onset of reduced soil moisture conditions; and,
- Period of rainfall and/or unsettled weather during mid-summer (i.e. the period of highest PET) commonly reduce the rate of irrigation below that required to maintain optimum soil moisture.

These factors appear to be related to management of individual irrigation operations and may reflect considerations such as the presence of surplus feed from the ‘spring flush’ during October/November and a reluctance to utilise irrigation during periods of cold or unsettled weather.

However, given the increasing application of soil moisture monitoring to manage irrigation operations, it is suggested that future water use for irrigation may increase as individual operations seek to maximise pasture production (and reduce costs through irrigation when soil moisture levels are sufficiently high). It is therefore suggested that historical water use is not necessarily the best guide to likely future irrigation water use for individual consents.

4.1 Recommendations for future irrigation management

Based on analysis of modelled and actual water use in the Riversdale groundwater zone, it is suggested the following parameters may be utilised as a guide to future management of irrigation consents in this area:

- Daily allocation should be consistent with an application rate of between 3 to 4 mm/day. Where appropriate consents should be managed in terms of both an maximum instantaneous pumping rate as well as a maximum daily allocation, particularly where abstraction is not continuous;
- Seasonal allocation should be based on a nominal irrigation depth over the proposed irrigated area rather than calculated from an empirical formula;
- An application depth of the order of 320 mm should be utilised as a guide for setting seasonal allocation in the Riversdale groundwater zone (based on water use the 1 in 10 year low rainfall during the peak PET period in 2007/08)[10]. Detailed description of farm-scale irrigation management practice should be required for all applications seeking amounts in excess of this figure;
- A maximum duration of abstraction of approximately 120 days. Where daily application rates are significantly below the recommended range, seasonal volumes should be established on the basis of pumping duration rather than seasonal application depth; and,
- A long-term (seasonal) abstraction rate of approximately 50 percent of the maximum daily should be applied to assessment of environmental effects at a seasonal timescale.

Observations from a review of irrigation water use data in the Riversdale groundwater zone that also potentially have application at a more regional scale include:

- Monitoring and recording of water use data is a critical element to enable effective water resource management. Environment Southland should continue efforts to improve both levels of compliance and the quality of data in line with the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010;
- Consent applications should define irrigated areas to a reasonable degree of accuracy (at least to the paddock scale);
- Historical water use practice may not always provide a reliable guide to future use, particularly with the more widespread utilisation of soil moisture monitoring as the primary basis for management of irrigation systems;
- Application of soil moisture modelling can provide a guide to assess potential irrigation water use requirements (at least at a monthly or seasonal scale). In combination with records of actual use, such assessment could be utilised to provide guidelines for ‘reasonable’ seasonal allocation in different parts of the Southland Region;
- Assessment of environmental effects should be cognisant of actual irrigation practice to avoid over-estimation of potential effects.

[10] It is however also noted that this volume is consistent with that calculated using the existing empirical formula (i.e. maximum pumping rate x irrigation season length x 0.65) assuming a 120 day irrigation season duration