

# WINEGRAPE IRRIGATION BENCHMARKING 1998-03

*Jeremy Giddings  
Irrigation Officer  
NSW Agriculture, Dareton*

## SUMMARY

Whilst the irrigators in the benchmarking study were not selected at random, a large variation in irrigation performance was still identified in the lower Murray Darling region, particularly in the initial years of the study. Over the five seasons of the survey (1998-03), however, irrigators have improved their irrigation practices. The average volume of irrigation applied over the whole sample has generally reduced over the survey period, particularly if seasonal climatic conditions are accounted for. The variation in the volume applied within the benchmarking group has also narrowed. Heavy irrigators have reduced their applications, and in many cases previously light irrigators have increased the volume applied.

The most impressive result from the study was the improvement in Application Efficiency which improved from around 77% in 1998-99 to approximately 90% in 2002-03. Drip irrigators have shown significantly higher Application Efficiencies, averaging 88.2 % over five seasons, compared to approximately 77% for low level and overhead sprinkler irrigated sites.

## OBJECTIVES

In 1998 the Murray Valley Winegrape Industry Development Committee initiated an irrigation benchmarking study for the lower Murray Darling region. The aim of the study was to;

- determine the level of irrigation performance of local winegrape growers
- monitor the change in irrigation performance over a number of seasons
- provide participating winegrape irrigators with evidence of their own performance compared to others in the industry.

The format of the benchmarking survey was adapted from a previous study (Skewes and Meissner 1997).

## INTRODUCTION

In the first year 22 irrigators nominated for the survey, providing information on seven winegrape varieties over 42 sites. These irrigators have been benchmarked for five seasons (original group). The winegrape varieties included were Sultana, Colombard, Chardonnay, Ruby Cabernet, Shiraz, Cabernet Sauvignon and Merlot. In the second year 14 additional irrigators joined the study, including nine from the Swan Hill region (total group). This resulted in 64 sites which have been generally benchmarked for four seasons except in situations when data became unavailable for reasons such as property re-development, fruit not picked due to industry oversupply or grower records not becoming available.

## METHODS

Irrigators were surveyed for their irrigation and production performance each year. Basic information only was required from irrigators. This information included yield (t/Ha), °Baume, harvest date, irrigation system, scheduling tool used and the irrigation records for the patch being surveyed.

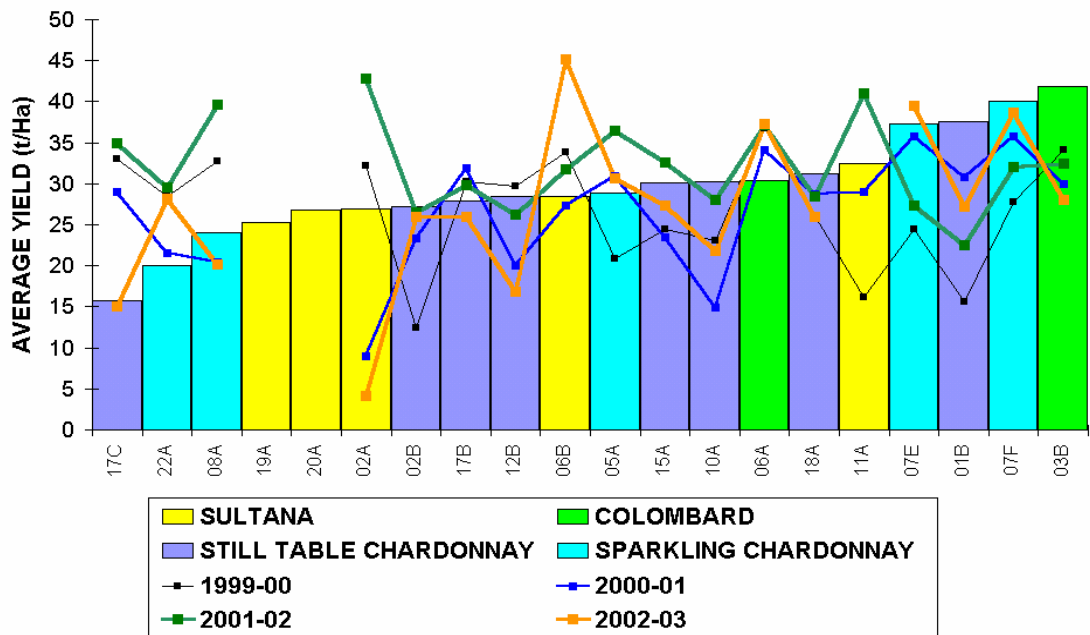
This range of performance measures from participating growers were then compared and ranked. These measures are presented below.

## RESULTS

### Yield (t/Ha)

The average yield (t/Ha) produced from each of the 42 sites (original group) over five seasons from 1998-99 to 2002-03 is presented in Figure 1 (white varieties) and Figure 2 (red varieties). The 1998-99 season is represented by the coloured bars identifying the winegrape variety, with each subsequent season represented by line graphs.

Average yield for all 64 sites (total group) when available (including original 42 sites only in 1998-99) are represented in Tables 1 (white varieties) and 2 (red varieties).



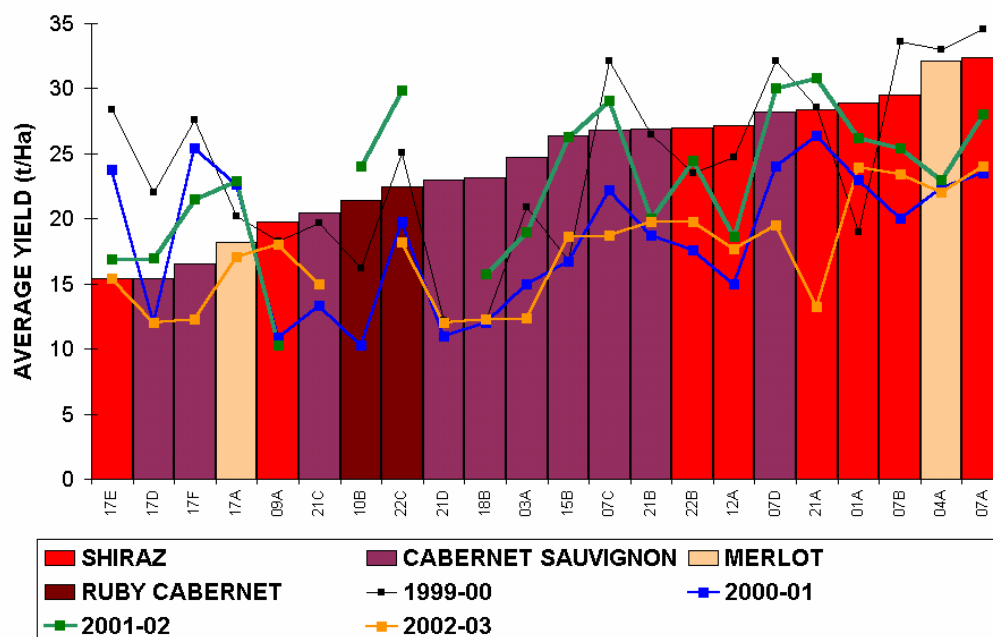
**Figure 1. Average yield (t/Ha) for white variety sites from 1998-99 to 2002-03**

Figure 1 shows that yields are highly variable from season to season, particularly with Sultana and Chardonnay. This is a reasonable reflection of district yields over the same period.

Table 1 shows that Colombard consistently crops greater than all other white varieties. It is also a very consistent cropping variety, with relatively little variation from season to season. Chardonnay harvested for sparkling produces yields higher than fruit harvested for still table Chardonnay. Fruit is often harvested for sparkling Chardonnay when heavy crops occur and concern over reaching desired maturity levels for still table Chardonnay exist.

**Table 1. Average yield (t/Ha) for white varieties from 1998-99 to 2002-03**

	AVERAGE YIELD (t/Ha)					AVERAGE
	1998-99	1999-00	2000-01	2001-02	2002-03	
<b>SULTANA</b>	28.0	26.3	21.3	31.1	24.7	<b>26.3</b>
<b>COLOMBARD</b>	36.1	36.6	34.5	40.5	36.9	<b>36.9</b>
<b>STILL TABLE CHARDONNAY</b>	28.6	23.6	23.3	28.0	21.6	<b>25.0</b>
<b>SPARKLING CHARDONNAY</b>	30.0	25.8	26.8	33.0	31.4	<b>29.4</b>
<b>AVERAGE</b>	<b>29.5</b>	<b>29.5</b>	<b>25.3</b>	<b>31.5</b>	<b>26.7</b>	



**Figure 2. Average yield (t/Ha) for red varieties from 1998-99 to 2002-03**

Figure 2 shows that lower yields were generally produced for red varieties following the initial 1998-99 season. The initially low yielding sites (in 1998-99) have, however, improved their general cropping level (sites 17E, 17D, 17F, 17A). Table 2 shows that overall yields following the initial 1998-99 season are trending down for the red varieties, reflecting industry pressure to control yield, with the perception that improved winegrape quality will result.

**Table 2. Average yield (t/Ha) for red varieties from 1998-99 to 2002-03**

	AVERAGE YIELD (t/Ha)					AVERAGE
	1998-99	1999-00	2000-01	2001-02	2002-03	
<b>SHIRAZ</b>	26.1	22.9	18.7	20.1	18.1	<b>21.2</b>
<b>CABERNET SAUVIGNON</b>	23.2	20.7	17.8	22.0	14.6	<b>19.7</b>
<b>MERLOT</b>	25.2	26.6	22.5	23.0	19.6	<b>23.3</b>
<b>RUBY CABERNET</b>	22.0	20.7	15.1	27.0	18.2	<b>20.6</b>
<b>AVERAGE</b>	<b>24.3</b>	<b>22.0</b>	<b>18.3</b>	<b>21.4</b>	<b>16.5</b>	

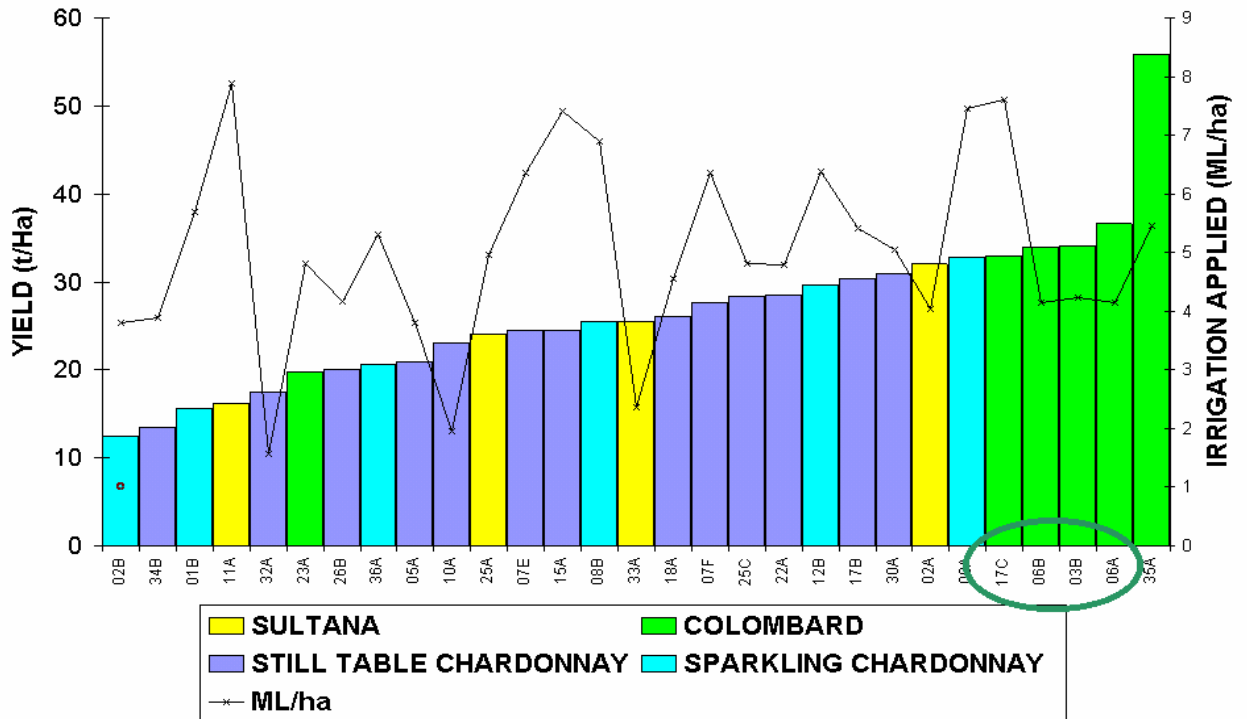
The red variety sites reasonably reflect district results with relatively low yields produced in seasons 2000-01 (blue line Figure 2) and 2002-03 (orange line Figure 2). These seasons were light cropping years throughout the lower Murray Darling.

Yield, °Baume and harvest date from all sites over all five seasons of the survey are listed in Appendix 1.

**Yield (T/Ha) and irrigation applied (ML/Ha) relationship – 1999-00 only**

***White Varieties***

Average yield for white varieties in 1999–2000 was 29.5 t/Ha, ranging from 12.4 to 55.9 t/Ha. From irrigation records collected, irrigations applied between 15 August 1999 and 31 May 2000 were totalled. Average irrigation applied was 5.1 ML/Ha, ranging from 2.0 to 7.9 ML/Ha. Rainfall is not included in any irrigation-applied figures throughout the report.

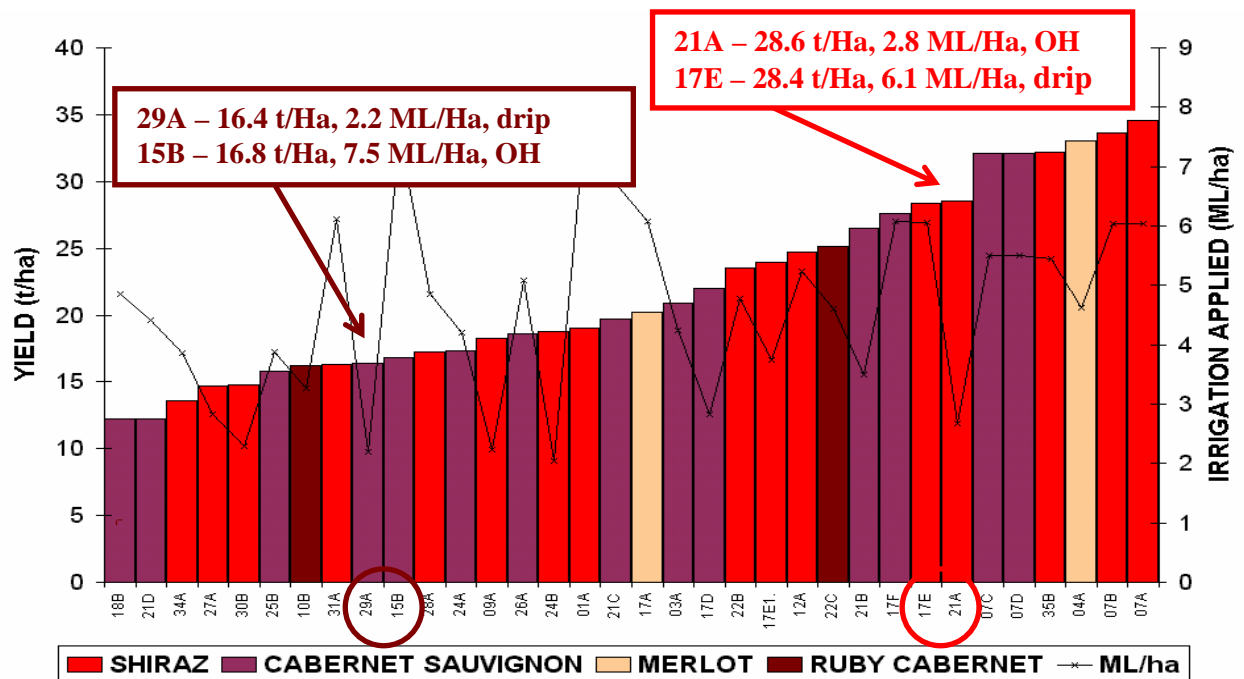


**Figure 3. Yield (coloured bars) and Irrigation Applied (line) to white winegrape varieties in 1999–2000**

Figure 3 again shows a relatively strong variety effect was seen in the yields produced in 1999-00, with Colombard ranked to the right of the graph. The amount of water applied was not strongly related to the yield produced. Enormous variation in water application existed across sites producing similar yields. Colombard site 17C, for example, produced 33.0 t/Ha using 7.6 ML/Ha, while sites 06A, 06B and 03B produced around 35 t/Ha, but applied an average of only 4.1 ML/Ha (circled). This suggests that there may be the potential to reduce annual water applications with no detriment to production in some instances. Irrigation system has a strong effect in this example, as site 17C is irrigated using overhead sprinklers, while 06A, 06B and 03B are all drip irrigated (Appendix 2).

### Red Varieties

Average yield for red varieties in 1999–2000 was 22.0 t/Ha, ranging from 12.2 to 34.6 t/Ha. Average irrigation applied was 4.6 ML/Ha, ranging from 2.1 to 7.9 ML/Ha.



**Figure 4. Yield (coloured bars) and Irrigation Applied (line) to red winegrape varieties in 1999–2000**

While reasonable conclusions from the Colombard example can be drawn in relation to the irrigation system used, this result is not consistent throughout the study. Cabernet Sauvignon sites 29A and 15B (Figure 4) are similar to the Colombard example: the overhead (OH) irrigated site (15B) had 70% more irrigation applied than the drip irrigated site 29A, with similar yields produced. However the Shiraz sites identified (21A and 17E) produced similar yields but were the reverse of the previous two examples with the overhead irrigated site applying approximately 50% less water than the drip-irrigated site (2.8 ML/Ha for overhead site 21A, 6.1 ML/Ha for drip site 17E). There are numerous examples of this ‘inconsistency’ in each season of the survey.

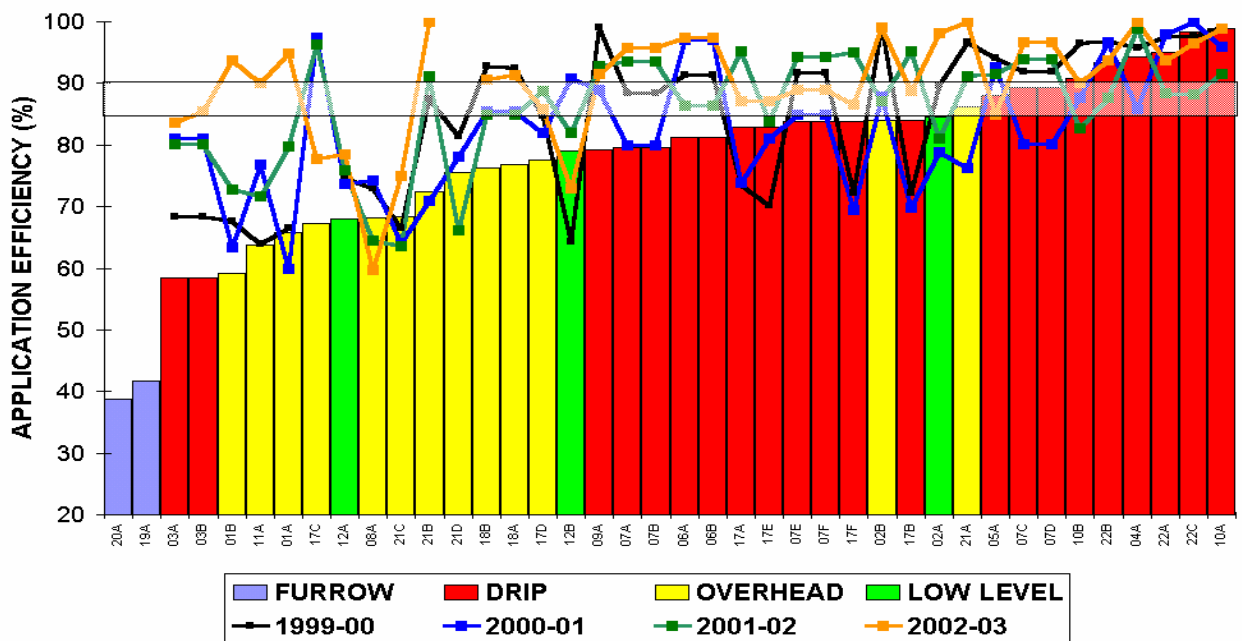
It is obvious that irrigation performance (at least in terms of ML/Ha) is not strictly driven by the irrigation system alone when related to yield. In fact no significant relationships were found in the survey between irrigation volumes applied or yield with irrigation system, scheduling tool or rootstock. The lack of significant relationships is understandable considering that the survey includes irrigators who adopt vastly different management practices with regard to pruning, nutrition and crop thinning, etc. Irrigation is one of the many management practices which contribute to production. The survey is not a controlled experiment in any way. The data is of more use in comparing irrigator performance and looking for trends over time, which were the original aims of the survey.

## Application Efficiency % (Original group)

Application Efficiency was estimated from the amount of irrigation applied and the estimated drainage over the season. Drainage was estimated from irrigators' records using the *Right Amount Right Time* computer aided irrigation scheduling program. Accumulation of soil moisture deficit between irrigation events was estimated from weather data collected at the NSW Department of Primary Industries, Dareton.

The amount of irrigation applied is compared with accumulated deficit, and any irrigation beyond this deficit is defined as drainage. Individual depths are summed to derive seasonal drainage depth. Total drainage depth is compared with total irrigation applied. From this the **relative percentage** of irrigation water applied to the crop and used by the vines for evapotranspiration is estimated. Rainfall is included in the water balance, however, estimated drainage produced by rainfall is not included in the application efficiency calculation.

High application efficiency percentages reflect low volumes of drainage produced. In the lower Murray Darling a small amount of drainage is necessary in order to leach salts from the rootzone. One hundred percent efficiency is not a recommended aim, but low values reflect excessive water wasted as drainage. For these reasons a well established and recognised benchmark of 85-90%, resulting in a leaching fraction of 10-15%, is considered sufficient to remove harmful salts from the rootzone in the lower Murray Darling without creating excessive drainage.



**Figure 5. Application Efficiency from 1998-99 to 2002-03**

Figure 5 shows that in 1998-99 (coloured bars) only 11 of the original 40 participating sites (28%) produced an Application Efficiency greater than 85%. Another 11 sites were relatively inefficient being less than 70%. In 1998-99, drip irrigation was strongly correlated to higher Application Efficiencies (drip sites concentrated to the top of the graph), however, the manner in which these irrigation systems are managed is still the strongest determinant of irrigation performance. An example of this is where two drip sites produced poor Application Efficiencies below 60% (03A & 03B), and two overhead (02B & 21A) and one low-level (02A) site produced acceptable Application Efficiencies of approximately 85%.

Thirty-eight of the original 40 sites participated in the project in the following four seasons. Average Application Efficiency improved from 77.7 % in the first year, to 90.1% in the fifth year of the study (Table 3). The Standard Deviation (a measure of the variation in the data - Table 3) has consistently dropped each year, meaning that the variation in the benchmarking group has

reduced. Irrigators who were very efficient in the first year are tending to lower their Application Efficiency at least occasionally in order to leach harmful salts from the rootzone. Likewise the irrigators who were initially poor have generally improved their performance. This results in a general ‘flattening’ of the line, and a lower standard deviation. In the final year of the survey 31 of the 40 participants (78%) produced an Application Efficiency of greater than 85%.

The originally poor performing drip sites (03A & 03B) are separate patches managed by the same irrigator and are an interesting example of how improvements can be made in a short period of time. The first year of the survey (1998-99) was also the first season that these sites were converted from flood to drip irrigation. As is often found significant adjustments are required to irrigation management once a new system is installed. In this case in the first year excessive irrigation tended to occur, both due to inexperience and lack of understanding of the new system. There is a recognised need to apply ample water to help existing vines adjust to the new wetting pattern under drip irrigation, however, extremely excessive irrigation volumes were applied in this case. This resulted in an Application Efficiency of only 53 % in the first season, by far the lowest performance by a drip irrigated site in 1998-99.

After this first season these sites significantly improved (Figure 5). In the second season an Application Efficiency of 68% was produced, and in the final three seasons around 80% occurred. This irrigator has made gradual improvements as a result of both experience and feedback gained from this benchmarking survey, allowing performance comparisons to be made with other experienced drip irrigators.

**Table 3. Application Efficiency (%) Averages From 1998-99 to 2002-03**

	<b>DRIP</b>	<b>OVERHEAD</b>	<b>LOW LEVEL</b>	<b>AVERAGE</b>	<b>STANDARD DEVIATION</b>
1998-99	84.4	72.4	77.2	<b>77.7</b>	13.6
1999-00	87.7	81.1	77.2	<b>83.9</b>	12.4
2000-01	85.7	75.4	76.2	<b>82.4</b>	10.2
2001-02	90.4	70.4	81.1	<b>86.0</b>	9.1
2002-03	92.6	85.3	77.2	<b>90.1</b>	8.8
<b>AVERAGE</b>	<b>88.2</b>	<b>76.9</b>	<b>77.8</b>		

Table 3 shows that drip irrigation had a consistently higher Application Efficiency (88.2% over five seasons) than both overhead (76.9%) and low level sprinkler irrigation (77.8%). Drip and low level sprinkler systems have generally improved their average Application Efficiency throughout the five years of the study, while the trend with overhead sprinklers has been inconsistent.

The biggest improvement in average Application Efficiency over all sites occurred between the first and second year of the survey (77.7 % in 1998-99 to 83.9% in 1999-00). One reason for this is that significant rainfall occurred in the early part of season 1999–2000. As well as reducing the amount of irrigation required, this rainfall provided good leaching of the profile. For the remainder of the season growers could more confidently apply irrigation efficiently with little concern about leaching irrigations. This results in higher Application Efficiencies.

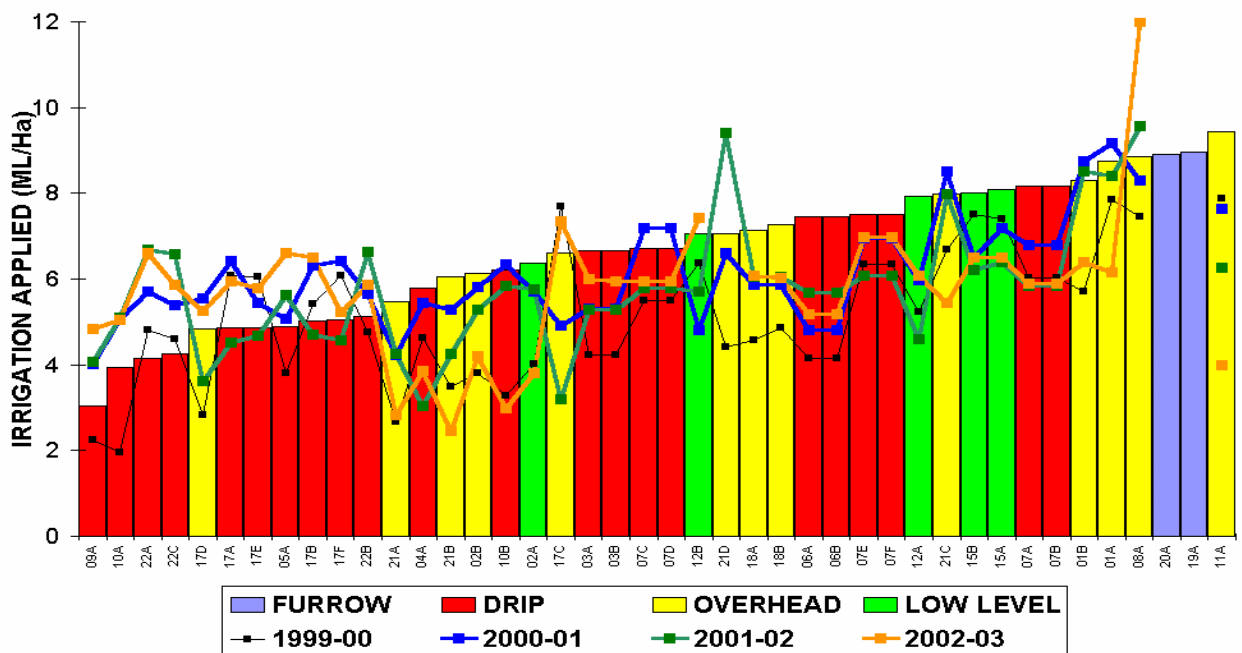
Application Efficiencies have continued to improve in latter years of the survey, even with very little rainfall recorded in these seasons (Table 3). In season 2002-03 further improvements were found as a number of overhead sprinkler irrigated sites were converted to drip irrigation, and a greater adoption of soil moisture monitoring tools occurred.

Irrigation water supply frequency and flexibility often effects individual irrigators ability to be as efficient as they would like. Of the 42 original sites surveyed, 38 of these are either private diverters, or located in a communal scheme such as Western Murray Irrigation’s Coomealla district which practically supplies water on demand. Therefore these sites have no supply issues which may influence irrigators ability to apply irrigation when they desire, therefore effecting performance measures such as Application Efficiency. From this point of view this data sample may not be considered truly representative of the lower Murray Darling Winegrape Industry.

The four remaining sites (18A, 18B, 19A & 20A) are supplied water through open channel. When surveyed these irrigators indicated that they actually receive water 90 to 100% of the time they place an order, indicating that supply issues are not a concern in these instances either. Sites 19A and 20A produced very poor Application Efficiencies in the first year of the study, however, this is a reflection of the irrigation system (furrow) rather than water supply.

**Irrigation Applied (ML/Ha)** (Original group)

Irrigation volumes applied per site were determined using irrigators' records and calculating the irrigation system theoretical application rate (100 mm = 1 ML/Ha). An assumption was made that the irrigation system was running to design specifications and that the calculated application rate (from design specifications) was actually occurring in the field.



**Figure 6. Irrigation applied in 1998-99 to 2002-03**

Figure 6 shows that although overall water use decreased following the first year, the ranked performance is similar in all seasons. The irrigators who applied higher volumes of water in the first year generally remain the highest in the following seasons, and vice versa. The lowest eleven irrigators in the first year of the study did, however, slightly increase their applications in the final years of the study (line graphs located higher than the coloured bars).

The irrigation applied was reduced by 21% in the second year of the survey (from 6.6 ML/Ha in 1998-99 to 5.2 ML/Ha in 1999-00 – Table 4). This was due to the milder first half of the 1999–2000 season, as well as higher seasonal rainfall as previously mentioned. At NSW Department of Primary Industries, Dareton, only 166mm of rainfall fell from September to May in 1998–99, compared to 295 mm in 1999–2000 (Table 4).

**Table 4. Irrigation Applied Averages (ML/Ha) from 1998-99 to 2002-03**

	DRIP	OVERHEAD	LOW LEVEL	OVERALL YEARLY AV.	STAND. DEVIATION	Evapotranspiration – mm (Sept-May)	Rainfall – mm (Sept-May)
1998-99	5.9	7.2	7.5	<b>6.6</b>	1.6	1614	166
1999-00	4.9	5.2	6.1	<b>5.2</b>	1.6	1533	295
2000-01	5.9	6.8	6.0	<b>6.2</b>	1.2	1534	150
2001-02	5.3	7.1	5.7	<b>5.8</b>	1.5	1507	126
2002-03	5.4	6.6	6.1	<b>5.7</b>	1.6	1701	159
<b>AVERAGE</b>	<b>5.5</b>	<b>6.6</b>	<b>6.3</b>				

The final three years of the study showed an average application of approximately 5.9 ML/Ha. These seasons were all very low in rainfall, however, this overall average application did not reach the average measured in 1998-99, which was also a very dry season (Table 4). This offers strong evidence that irrigation practices did improve within this benchmarking group, with irrigation volumes dropping regardless of demanding climatic conditions. Irrigation system has a strong effect on the irrigation volumes applied, with drip irrigation drip applying 15-20% less water than overheads and low levels over the five seasons of the study.

Nine of the original sites adopted high tech. scheduling tools at some stage during the five years of the survey (Appendix 3 – comments). It is expected that the adoption of such technology will result in reduced water application. This is not the case at all sites, however, particularly for sites irrigated with overhead sprinkler. In all cases when an overhead sprinkler irrigator has adopted irrigation scheduling (sites 01A, 01B, 08A & 08B), irrigation volumes applied have initially increased. In most cases adoption of scheduling enabled the irrigator to discover that subsoils were very dry and that initially significant increases in application were required to correct this. Increased volumes were also a result of the scheduling tool highlighting the possible inefficiencies of overhead sprinkler systems, with irrigators applying additional volumes to account for these inefficiencies.

The annual volume of irrigation applied provides a reasonable indication of the level of irrigation performance but does not accurately show how the irrigation was applied throughout the season. For example 03B applied only 4.2 ML/Ha in 1999-00 (Figure 6), but had a relatively low Application Efficiency of 68.4% (Figure 5). Vine vigor, crop end use, row spacing and other location effects are not taken into account when comparing the volume of irrigation applied. Location of the property in particular appears to influence irrigation volumes. Private diverters in isolated areas on the Murray and Darling River appear to have a greater water demand than irrigators inside community schemes, regardless of system type. These properties are operating at around 85% Application Efficiency. *Therefore applying a benchmark standard for irrigation volumes to which irrigators should aim does not seem appropriate. To do this would be an oversimplification.*

### **Irrigation Applied (ML/Ha) and winegrape variety** (Whole group)

High yielding Colombard and Chardonnay (Sparkling) received the highest irrigation volumes applied (Table 5). As expected the red varieties generally have the lowest irrigation volumes applied. The irrigation volumes applied to the red varieties generally decline over the period of the survey, reflecting both the improving level of irrigation management and the greater deficit that irrigators are placing on these varieties.

**Table 5. Irrigation applied and winegrape variety** (Whole group)

VARIETY	1998-99	1999-00	2000-01	2001-02	2002-03	AVERAGE
Sultana	8.4	4.8	5.3	4.8	3.8	<b>5.4</b>
Colombard	7.2	4.6	6.0	6.5	6.3	<b>6.1</b>
Chardonnay (still table)	6.5	4.8	5.7	5.5	6.1	<b>5.7</b>
Chardonnay (sparkling)	6.6	5.9	6.9	7.2	8.5	<b>7.0</b>
Shiraz	6.4	4.5	5.3	5.3	5.4	<b>5.4</b>
Cabernet Sauvignon	6.5	4.7	6.0	5.7	5.1	<b>5.6</b>
Merlot	5.8	5.3	5.9	3.8	4.9	<b>5.2</b>
Ruby Cabernet	5.2	3.9	5.9	6.2	5.9	<b>5.4</b>
<b>AVERAGE</b>	<b>6.6</b>	<b>4.8</b>	<b>5.9</b>	<b>5.6</b>	<b>5.7</b>	

### **Regulated Deficit Irrigation** (Whole group)

Regulated Deficit Irrigation (RDI) is becoming a more common management practice for red grape growers in Sunraysia. As discussed it is difficult to determine relationships between any irrigation practices and production or irrigation applied. An interesting trend, however, has been the irrigation volumes applied in relation to RDI. Table 5 describes the irrigation volumes and average yields produced from 1999-00 to 2001-02 only.

**Table 5. Irrigation Applied (ML/Ha) and Yield (t/Ha) of Red Winegrape Varieties**

	1999-00		2000-01		2001-02	
	IRRIGATION APPLIED (ML/Ha)	YIELD (t/Ha)	IRRIGATION APPLIED (ML/Ha)	YIELD (t/Ha)	IRRIGATION APPLIED (ML/Ha)	YIELD (t/Ha)
UNRESTRICTED GROWTH	5.1	21.7	6.5	16.6	6.3	22.6
RDI	4.5	23.3	5.4	20.7	4.5	20.5

Irrigators adopting RDI have consistently applied less water over all seasons than irrigators allowing unrestricted growth of their red varieties. This is expected as RDI involves restricting the amount of irrigation applied from four to six weeks in the middle of the season. In addition, for RDI to be successful irrigation must be closely monitored over the whole season, and this will also help to reduce annual irrigation volumes.

It appears that the irrigators adopting RDI have been progressively applying greater stress over each season. The differences in the average amount of irrigation applied each season between RDI and unrestricted growth has progressed from 0.6 to 0.9 to 1.8 ML/Ha over three seasons. Average yield is not significantly different between RDI and unrestricted growth over any of the seasons; however, it has taken until the final year of the survey for the average yield under RDI to fall below the average yield under unrestricted growth.

## **Conclusions**

- Application efficiencies consistently improved throughout the survey, suggesting effective adoption of better irrigation practices and management by the benchmarking group.
- Irrigation volumes have generally reduced within the benchmarking group. When seasonal climatic conditions are taken into account a strong example of reducing irrigation volumes exists.
- The adoption of irrigation scheduling does not always result in a reduction to irrigation volumes. Irrigators may have previously been under irrigating. Overhead sprinkler irrigated sites, in particular, generally had an increase in irrigation volumes applied when irrigation scheduling was adopted.
- Different varieties are receiving different volumes of irrigation. White varieties generally receive more water than red varieties, with Colombard and Chardonnay (Sparkling), receiving the largest irrigation volumes.

## **Acknowledgments**

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## **References**

Skewes, M. & Meissner, T. (1997). *Irrigation Benchmarks and Best Management Practices for Winegrapes*. Technical Report No. 259, Primary Industries and Resources SA, Adelaide, South Australia.

## **Extension**

### **Written material**

Winegrape Irrigation Benchmarking – Sunraysia 1998-99. Murray Valley Winegrapegrower. Volume 5, Issue 5, November 1999

Winegrape Irrigation Benchmarking Update. Sunraysia and Swan Hill 1999-2000. Murray Valley Winegrape Grower. Volume 6, Issue 6, November 2000

Winegrape Irrigation Benchmarking. Growers report 1999-2000.

Irrigation Survey gives snapshot of efficiency. Cooperative Research Centre for Viticulture Newsletter. Volume 7, Winter 2001

Winegrape Irrigation Benchmarking. Murray-Darling and Swan Hill 1998-2002. ASVO Proceedings. Managing Water (as above)

### **Presentations**

Victorian & Murray Valley Winegrape Growers Council field day. Lake Cullulleraine. 5<sup>th</sup> October 1999.

ASVO Seminar. Managing Water. Mildura 12<sup>th</sup> July 2002

Coomealla Grapecheque group. ARAS Dareton 23<sup>rd</sup> September 2002

Irrigation Association of Australia (IAA) conference. Improving Irrigation Efficiency in the Lower Murray Darling. Adelaide May 2004

**APPENDIX 1**

SITE	VARIETY	ROOTSTOCK	1998-99		1999-00			2000-01			2001-02			2002-03		
			YIELD (t/ha)	%Baume	YIELD (t/ha)	Harv. date	%Baume	YIELD (t/ha)	Harv. date	%Baume	YIELD (t/ha)	Harv. date	%Baume	YIELD (t/ha)	Harv. date	%Baume
01A	Shiraz	own	28.9	12.4	19	23-Mar-00	13.7	23	24-Mar-01	13.2	26.25	22-Mar-02	14.4	23.96	16-Mar-03	14.2
01B	Chardonnay	Ramsay	37.6	12.1	15.6	28-Mar-00	10.8	30.87	25-Feb-01	12.4	22.5	31-Jan-02	10.8	27.17	17-Feb-03	12.6
02A	Sultana	own	26.9	9	32.12	23-Feb-00	9.25	8.95	22-Jan-01	11.1	42.8	11-Mar-02	9.5	4.2	27-Jan-03	12.3
02B	Chardonnay	Ramsay	27.2	12.95	12.4	23-Jan-00	11.5	23.33	11-Feb-01	12.67	26.5	29-Jan-02	12	26	9-Feb-03	13.2
03A	Cabernet Sauvignon	Ramsay	24.7	13.5	20.9	27-Mar-00	13.7	15	9-Mar-01	14.3	19	25-Feb-02	14	12.4	28-Mar-03	15
03B	Colombard	Ramsay	41.8	12	34.1	20-Mar-00	12.2	30	28-Mar-01	13	32.5	20-Apr-02	13.5	28	20-Mar-03	13.6
04A	Merlot	Swarzmann	32.1	13.3	33	18-Apr-00	13.2	22.38	7-Mar-01	13.8	23	25-Feb-02	13.3	22	17-Feb-03	13.5
05A	Chardonnay CB	Ramsay	28.9	9.8	20.9	15-Feb-00	13.6	30.88	30-Jan-01	10.7	36.5	20-Feb-02	10.9	30.6	16-Feb-03	
06A	Colombard	Swarzmann	30.4	11.9	36.7	23-Mar-00	12.2	34.17	6-Mar-01	11.8	37.1	14-Mar-02	13.3	37.3	28-Feb-03	11.8
06B	Colombard	Ramsay	28.5	10.8	33.9	6-Mar-00	11.9	27.37	6-Mar-01	12.5	31.7	14-Mar-02	12.7	45.2	3-Mar-03	11.7
07A	Shiraz	own	32.4	12.6	34.6	21-Mar-00	14	23.5	5-Apr-01	13.1	28	24-Mar-02	13.8	24	17-Mar-03	13.7
07B	Shiraz	own	29.5	12.6	33.6	16-Mar-00	13.6	20	22-Mar-01	12.7	25.4	15-Mar-02	13.4	23.4	15-Mar-03	13.3
07C	Cabernet Sauvignon	own	26.8	12.9	32.1	29-Mar-00	13	22.2	21-Mar-01	12.9	29.1	2-Apr-02	13.8	18.7	24-Mar-03	15
07D	Cabernet Sauvignon	own	28.2	12.9	32.1	29-Mar-00	13	24	6-Apr-01	13.2	30	27-Mar-02	13.7	19.5	19-Mar-03	15
07E	Chardonnay CB	own	37.3	9.2	24.5	4-Feb-00	13.4	35.8	22-Feb-01	13.2	27.3	19-Feb-02	12.5	39.5	25-Feb-03	13
07F	Chardonnay CB	own	40	10	27.7	4-Feb-00	13.4	35.8	24-Feb-01	13.3	32.1	18-Feb-02	12.5	38.7	18-Feb-03	13.1
08A	Chardonnay CB	Ramsay	24	9.4	32.8	1-Feb-00	9.7	20.4	29-Jan-01	10.4	39.7	22-Feb-02	11.4	20.1	2-Mar-03	13
08B	Chardonnay CB	Ramsay			25.5	20-Jan-00	9.4	20.4	29-Jan-01	10.4	27	30-Jan-02	8.9	27.5	18-Feb-03	12.2
09A	Shiraz	own	19.8	14.4	18.3	9-Mar-00	14	10.9	6-Mar-01	14	10.3	17-Feb-02	14.4	18	10-Mar-03	14
10A	Chardonnay	Ramsay	30.3	12.5	23.1	11-Feb-00	15	14.9	25-Feb-01	13.5	28	2-Mar-02	13.5	21.8	27-Feb-03	13.5
10B	Ruby Cabernet	Ramsay	21.4	13.4	16.2	4-Mar-00	14.3	10.3	10-Mar-01	13.1	24	4-Apr-02	13.5			
11A	Sultana	own	32.5	10.3	16.2	22-Feb-00	9.95	29	29-Jan-01	10.5	40.96	25-Feb-02	10.2			
12A	Shiraz	Swarz & Teleki	27.2	13.5	24.7	30-Mar-00	12.6	15	7-Mar-01	14.1	18.6	25-Feb-02	12.8	17.7	10-Mar-03	13.5
12B	Chardonnay	Ramsay	28.4	13	29.7	28-Jan-00	10	20	9-Feb-01	13.2	26.2	1-Mar-02	13.2	16.8	5-Feb-03	13.2
15A	Chardonnay	Swarz/Teleki	30.1	13.5	24.5	9-Feb-00	13.7	23.5	23-Feb-01	13.2	32.6	28-Feb-02	13.2	27.3	28-Feb-03	13.4
15B	Cabernet Sauvignon	Rugeeri/Swarz	26.4	13.2	16.8	11-Mar-00	13.2	16.7	6-Mar-01	13.1	26.3	14-Mar-02	14.7	18.6	13-Mar-03	13.7
17A	Merlot	own	18.2	13.5	20.2	3-Apr-00	13.5	22.6	11-Mar-01	13.4	22.9	11-Mar-02	13.05	17.1	15-Mar-03	14.33
17B	Chardonnay	Swarzmann	27.9	13	30.3	14-Feb-00	13	31.9	9-Feb-01	12.65	29.8	28-Feb-02	12.5	26	28-Feb-03	13.7
17C	Chardonnay	own	15.7	13.3	33	31-Mar-00	11.5	29	20-Mar-01	11.4	35	22-Mar-02	11.2	15	3-Mar-03	13.28
17D	Cabernet Sauvignon	own	15.4	14	22	3-Apr-00	13.5	12	30-Mar-01	13.7	17	2-Apr-02	14	12	29-Mar-03	14.32
17E	Shiraz	mixed	15.4	14	28.35	27-Mar-00	13.5	23.8	30-Mar-01	13.4	16.9	20-Mar-02	13.9	15.4	11-Mar-03	14.09
17E1	Shiraz	mixed			23.99	16-Mar-00	13	17.1	12-Apr-01	13.7	16.9	20-Mar-02	13.9	15.4	11-Mar-03	14.09
17F	Cabernet Sauvignon	mixed	16.5	13.75	27.6	10-Apr-00	13.5	25.4	30-Mar-01	13.7	21.5	15-Mar-02	13.2	12.3	18-Mar-03	14.37
18A	Chardonnay	Ramsay	31.2	13.76	26.1	14-Feb-00	13.4	28.77	19-Feb-01	12.9	28.5	18-Feb-02	13	25.96	25-Feb-03	13.5
18B	Cabernet Sauvignon	own	23.2	13.6	12.2	6-Apr-00	13.3	11.99	2-Apr-01	13.6	15.8	20-Apr-02	14.2	12.31	28-Mar-03	13.9
19A	Sultana	Shiraz/own	25.3	11.5												
20A	Sultana	own	26.8	10												
21A	Shiraz	own	28.4	13	28.56	27-Mar-00	12.5	26.38	12-Mar-01	13.3	30.81	3-Apr-02	13.68	13.2	5-Mar-03	13.5
21B	Cabernet Sauvignon	own	26.9	13.1	26.5	7-Apr-00	12.9	18.7	23-Mar-01	13	20	5-Jun-02		19.86	21-Mar-03	14.5
21C	Cabernet Sauvignon	own	20.5	13.1	19.7	19-Apr-00	12.45	13.3	29-Mar-01	13.7				15	23-Mar-03	14
21D	Cabernet Sauvignon	own	23	12.98	12.2	23-Mar-00	12.6	10.99	24-Mar-01	12.5				12	3-Apr-03	
22A	Chardonnay CB	Ramsay	20	11.8	28.5	11-Feb-00	14	21.6	20-Feb-01	12.7	29.6	10-Mar-02	13.5	28.2	14-Feb-03	11.5
22B	Shiraz	Swarzmann	27	13	23.5	11-Apr-00	14	17.6	2-Apr-01	12.7	24.5	9-Apr-02	13.9	19.8	14-Mar-03	13.5
22C	Ruby Cabernet	Ramsay	22.5	13.7	25.1	16-Apr-00	13.1	19.8	5-Apr-01	14.1	29.9	29-Apr-02	14.1	18.2	2-Apr-03	14.8
23A	Colombard	Ramsay			19.7	19-Mar-00	12.6	28.2	23-Mar-01	11.85	42.5	15-Apr-02	12.8	46.25	27-Mar-03	11.3
24A	Cabernet Sauvignon	own			17.3	17-Mar-00	13.7	24.7	29-Mar-01	13.75	24.7		14	8.8	15-Mar-03	14.2
24B	Shiraz	mixed			18.8	8-Mar-00	12.7	17.3	8-Mar-01	14	16.3		14.5	14.6	24-Mar-03	13.5
25A	Sultana	own			24	15-Feb-00	11	14.8		11.5						
25B	Cabernet Sauvignon	Swarzmann			15.8	5-Apr-00	13.4	22.2		13.5	28					
25C	Chardonnay	Ramsay			28.3	13-Feb-00	13.1	23.5		13.5						
26A	Cabernet Sauvignon	Swarzmann			18.6	17-Mar-00	13.9	18.6	15-Mar-01	13	10.4	12-Mar-02	14.3	8.4	3-Mar-03	14.6
26B	Chardonnay	K5 BB			20	14-Feb-00	13	8.1	12-Feb-01	13.9	19.4	25-Feb-02	13.7	9	7-Feb-03	15.1
27A	Shiraz	own			14.7	10-Mar-00	13									
28A	Shiraz	own			17.2	17-Mar-00	14	12	11-Mar-01	14	12.3		14			
29A	Cabernet Sauvignon	own			16.4	9-Apr-00	14.4	13.12	22-Mar-01	14.3				20.24	2-Apr-03	14.1
30A	Chardonnay	Ramsay			31	18-Feb-00	13.5	30	21-Feb-01	13	37.5	1-Mar-02	13	30	13-Feb-03	13.5
30B	Shiraz	own			14.8	20-Mar-00	13.2	14	1-Mar-01	13.8	12	8-Mar-02	13.5			
31A	Shiraz	own			16.3	4-Apr-00	14.2									
32A	Chardonnay	own			17.5	15-Feb-00	12.7									
33A	Sultana	own			25.5	13-Feb-00	11	26.5	3-Feb-01	11.5	9	11-Feb-02	12.02			
34A	Shiraz	own			13.6	7-Apr-00	14.1	10	4-Mar-01	14.4	11	2-Mar-02	14.7	4.8	28-Feb-03	13.9
34B	Chardonnay	own			13.5	11-Feb-00	14.7	18.7	5-Mar-01	13.8	22.5	1-Mar-02	13.5	7	3-Mar-03	13.4
35A	Colombard	Ramsay			55.9	4-Apr-00	11.5	45.6	23-Mar-01	11.4	49.7	21-Mar-02	11.2	36.2	5-Mar-03	11.26
35B	Shiraz	own			32.2	28-Mar-00	13.5	29.7	4-Apr-01	13.7	28.4	24-Mar-02	13.6	23.3	17-Mar-03	13.97
36A	Chardonnay CB	own			20.58	13-Jan-00	9.99	16.26	19-Jan-01	10.8						

**APPENDIX 2**

SITE	IRRIGATION SYSTEM	ORIGINAL SCHEDULING TOOL	DISTRICT	APPLICATION EFFICIENCY (%)					COMMENTS
				1998-99	1999-00	2000-01	2001-02	2002-03	
01A	OVERHEAD	Gopher	DARLING	80.7	66.6	60	79.8	94.9	Installed EnviroSCAN in 2000
01B	OVERHEAD	Gopher	DARLING	73.8	67.6	63.4	72.7	93.7	
02A	LOW LEVEL	Tens	YELTA	84.7	89.7	78.8	81	98.2	
02B	OVERHEAD	Tens	YELTA	87.7	99.3	87.8	87.1	99.1	
03A	DRIP	Calender	GOL GOL	53	68.4	81	80.2	83.6	1998 first year with drip
03B	DRIP	Calender	GOL GOL	53	68.4	81	80.2	85.5	
04A	DRIP	Tens	COOMEALLA	90.1	95.7	85.8	98.9	100	Installed C-probe in 1999
05A	DRIP	Calender	COOMEALLA	89.1	94.2	92.6	91.5	74	Installed EnviroSCAN in 2001
06A	DRIP	Calender	COOMEALLA	82.1	91.3	97.1	86.3	97.5	Installed EnviroSCAN in 2001
06B	DRIP	Calender	COOMEALLA	82.1	91.3	97.1	86.3	97.5	
07A	DRIP	EnviroSCAN	DARLING	79.8	88.5	79.9	93.5	95.8	
07B	DRIP	EnviroSCAN	DARLING	79.8	88.5	79.9	93.5	95.8	
07C	DRIP	EnviroSCAN	DARLING	89.7	91.95	80.1	93.9	96.6	
07D	DRIP	EnviroSCAN	DARLING	89.7	91.95	80.1	93.9	96.6	
07E	DRIP	EnviroSCAN	DARLING	85.1	91.8	84.86	94.3	89	
07F	DRIP	EnviroSCAN	DARLING	85.1	91.8	84.86	94.3	89	
08A	OVERHEAD	Gopher	COOMEALLA	85.5	68.3	74.3	64.5	59.7	Installed EnviroSCAN in 2001
08B	OVERHEAD	Gopher	COOMEALLA		73	74.3	64.9	63.6	
09A	DRIP	EnviroSCAN	COOMEALLA	77.5	99	88.6	92.9	91.5	
10A	DRIP	Calender	COOMEALLA	91.5	99	95.9	91.5	98.9	
10B	DRIP	Calender	COOMEALLA	82.4	96.5	87.6	82.8		Re-developed in 2002
11A	OVERHEAD	Eto data	COOMEALLA	87.7	64	76.8	71.7		Re-developed in 2002
12A	LOW LEVEL	Gopher	COOMEALLA	76.6	74.7	73.7	76	78.5	Installed EnviroSCAN in 1999
12B	LOW LEVEL	Gopher	COOMEALLA	83	64.3	90.8	81.9	72.9	
15A	OVERHEAD	Calender	GOL GOL			*	*	*	
15B	OVERHEAD	Calender	GOL GOL			*	*	*	
17A	DRIP	EnviroSCAN,	COLIGNAN	82.9	73.5	73.8	95.2	87.1	
17B	DRIP	EnviroSCAN,	COLIGNAN	84	72.3	69.8	95.3	88.8	
17C	OVERHEAD	Ntn prb,	COLIGNAN	67.3	65.3	97.4	96.4	77.8	
17D	OVERHEAD	Ntn prb,	COLIGNAN	77.6	84.8	81.9	88.7	85.8	
17E	DRIP	EnviroSCAN,	COLIGNAN	82.9	70.2	81.1	83.9	87.1	
17E1.	DRIP	EnviroSCAN,	COLIGNAN	83.9	94.1	81.1	83.9	83.5	
17F	DRIP	EnviroSCAN,	COLIGNAN	79.5	72.2	69.5	95	86.6	
18A	OVERHEAD	Tens, Eto data	IRYMPLE	76.8	92.4	85.4	85	91.3	
18B	OVERHEAD	Tens, Eto data	IRYMPLE	76.2	92.8	85.4	85	90.6	
19A	FURROW	Calender	MERBEIN	41.7					
20A	FURROW	Tens	MERBEIN	38.7					
21A	OVERHEAD	Ntn prb	NANGILOC	86.2	96.7	76.2	91.1	100	Converted to drip in 2001
21B	OVERHEAD	Ntn prb	NANGILOC	72.5	87.5	70.9	91.1	100	
21C	OVERHEAD	Ntn prb,	NANGILOC	68.4	66.6	64.2	63.6	75	
21D	OVERHEAD	Gp blk, Ntn prb	NANGILOC	72.5	81.5	78.1	66.2		
22A	DRIP	Tens, Eto data	NANGILOC	84.6	97.6	97.9	88.5	93.8	
22B	DRIP	Tens, Eto data	NANGILOC	95	96.8	96.6	87.6	93.7	
22C	DRIP	Tens, Eto data	NANGILOC	94.4	97.7	100	88.3	96.5	
23A	LOW LEVEL	Tens	COOMEALLA		84	68.6	62.6	74	
24A	LOW LEVEL	EnviroSCAN	ROBINVALE		82.6	67.5		*	
24B	LOW LEVEL	EnviroSCAN	ROBINVALE		100	87.5		*	
25A	FURROW	Calender	RED CLIFFS		60				
25B	LOW LEVEL	Tens	IRYMPLE		93.8				
25C	LOW LEVEL	Tens	IRYMPLE		80.3				
26A	DRIP	Tens	LAKE BOGA		91.1	99.3	99.8	98	
26B	DRIP	Tens	LAKE BOGA		91.4	100	99.7	98.4	
27A	FURROW	Tens	WOORINEN		98.5		*		
28A	DRIP	Calender	NYAH		57.4	89.9			
29A	DRIP	Calender	KERANG		96.2	100		100	
30A	DRIP	Tens	LAKE BOGA		78.6	81.1	91.5	88	
30B	DRIP	Tens	LAKE BOGA		100	100	100		
31A	LOW LEVEL	Gopher	WOORINEN		74.8		*		
32A	DRIP	C-probe	PIANGIL		100		*		
33A	DRIP	Tens	NYAH		99	100	100		
34A	LOW LEVEL	Tens	WOORINEN		99.5	99.3	90	100	
34B	OVERHEAD	Tens	WOORINEN		95.1	88.8	82.7	83.5	
35A	DRIP	Tens	COLIGNAN		79	73.4	81	79.3	
35B	DRIP	Tens	COLIGNAN		79	73.3	79.7	82.4	
36A	DRIP	EnviroSCAN	DARLING		90.7	81.6			

**APPENDIX 3**

SITE	IRRIGATION SYSTEM	SCHEDULING TOOL	DISTRICT	IRRIGATION APPLIED (ML/Ha)					COMMENTS
				1998-99	1999-00	2000-01	2001-02	2002-03	
01A	OVERHEAD	Gopher	DARLING	8.76	7.86	9.18	8.4	6.16	Installed EnviroSCAN in 2000
01B	OVERHEAD	Gopher	DARLING	8.31	5.7	8.76	8.52	6.4	
02A	LOW LEVEL	Tens	YELTA	6.36	4.03	5.72	5.77	3.81	
02B	OVERHEAD	Tens	YELTA	6.12	3.8	5.82	5.28	4.2	
03A	DRIP	Calender	GOL GOL	6.65	4.24	5.31	5.29	6	
03B	DRIP	Calender	GOL GOL	6.65	4.24	5.31	5.29	5.95	
04A	DRIP	Tens	COOMEALLA	5.8	4.62	5.45	3.04	3.86	Installed C-probe in 1999
05A	DRIP	Calender	COOMEALLA	4.9	3.81	5.08	5.64	6.61	Installed EnviroSCAN in 2001
06A	DRIP	Calender	COOMEALLA	7.46	4.14	4.82	5.67	5.18	Installed EnviroSCAN in 2001
06B	DRIP	Calender	COOMEALLA	7.46	4.14	4.82	5.67	5.18	
07A	DRIP	EnviroSCAN	DARLING	8.17	6.03	6.79	5.85	5.89	
07B	DRIP	EnviroSCAN	DARLING	8.17	6.03	6.79	5.85	5.89	
07C	DRIP	EnviroSCAN	DARLING	6.71	5.51	7.18	5.78	5.95	
07D	DRIP	EnviroSCAN	DARLING	6.71	5.51	7.18	5.78	5.95	
07E	DRIP	EnviroSCAN	DARLING	7.5	6.35	6.94	6.08	6.99	
07F	DRIP	EnviroSCAN	DARLING	7.5	6.35	6.94	6.08	6.99	
08A	OVERHEAD	Gopher	COOMEALLA	8.85	7.45	8.29	9.57	12.2	Installed EnviroSCAN in 2001
08B	OVERHEAD	Gopher	COOMEALLA		6.9	8.29	9.26	11.6	
09A	DRIP	EnviroSCAN	COOMEALLA	3.05	2.24	4.01	4.06	4.83	
10A	DRIP	Calender	COOMEALLA	3.99	1.96	5.07	5.1	5.06	
10B	DRIP	Calender	COOMEALLA	6.22	3.27	6.34	5.85		Re-developed in 2002
11A	OVERHEAD	Eto data	COOMEALLA	9.44	7.88	7.63	6.26		Re-developed in 2002
12A	LOW LEVEL	Gopher	COOMEALLA	7.93	5.23	5.97	4.59	6.07	Installed EnviroSCAN in 1999
12B	LOW LEVEL	Gopher	COOMEALLA	7.06	6.37	4.8	5.72	7.43	
15A	OVERHEAD	Calender	GOL GOL	8.1	7.4	7.2	6.4	6.5	
15B	OVERHEAD	Calender	GOL GOL	8	7.5	6.5	6.21	6.5	
17A	DRIP	EnviroSCAN	COLIGNAN		6.07	6.41	4.52	5.96	
17B	DRIP	EnviroSCAN	COLIGNAN	4.82	5.41	6.31	4.7	6.5	
17C	OVERHEAD	Ntn prb	COLIGNAN	6.61	7.61	4.91	3.19	7.36	
17D	OVERHEAD	Ntn prb	COLIGNAN	4.84	2.83	5.56	3.61	5.26	
17E	DRIP	EnviroSCAN	COLIGNAN	4.6	6.06	5.44	4.67	5.79	
17E1.	DRIP	EnviroSCAN	COLIGNAN		3.74	5.44	4.67	5.69	
17F	DRIP	EnviroSCAN	COLIGNAN	4.77	6.07	6.41	4.58	5.24	
18A	OVERHEAD	Tens, Eto data	IRYMPLE	7.14	4.56	5.88	6.06	6.09	
18B	OVERHEAD	Tens, Eto data	IRYMPLE	7.26	4.86	5.88	6.06	6.03	
19A	FURROW	Calender	MERBEIN	8.95					
20A	FURROW	Tens	MERBEIN	8.9					
21A	OVERHEAD	Ntn prb	NANGILOC	5.48	2.67	4.23	4.26	2.83	Converted to drip in 2001
21B	OVERHEAD	Ntn prb	NANGILOC	6.04	3.5	5.28	4.26	2.46	
21C	OVERHEAD	Ntn prb	NANGILOC	7.98	6.7	8.5	9.42	5.45	
21D	OVERHEAD	Gyp blk, Ntn prb	NANGILOC	6.5	4.42	6.6	7.99		
22A	DRIP	Tens, Eto data	NANGILOC	4.16	4.8	5.7	6.7	6.61	
22B	DRIP	Tens, Eto data	NANGILOC	4.9	4.77	5.66	6.64	5.88	
22C	DRIP	Tens, Eto data	NANGILOC	4.26	4.6	5.38	6.59	5.88	
23A	LOW LEVEL	Tens	COOMEALLA		4.81	8.48	9.68	8.36	
24A	LOW LEVEL	EnviroSCAN	ROBINVALE		4.2	7.15	4.8		
24B	LOW LEVEL	EnviroSCAN	ROBINVALE		2.05	4.55	6.8		
25A	FURROW	Calender	RED CLIFFS		4.96				
25B	LOW LEVEL	Tens	IRYMPLE		3.87				
25C	LOW LEVEL	Tens	IRYMPLE		4.82				
26A	DRIP	Tens	LAKE BOGA		5.09	3.04	4.17	4.61	
26B	DRIP	Tens	LAKE BOGA		4.17	2.95	4.21	4.7	
27A	FURROW	Tens	WOORINEN		2.82				
28A	DRIP	Calender	NYAH		4.86	2.23			
29A	DRIP	Calender	KERANG		2.19	2.82		2.48	
30A	DRIP	Tens	LAKE BOGA		5.05	5.97	5.53	5.44	
30B	DRIP	Tens	LAKE BOGA		2.3	2.69	2.07		
31A	LOW LEVEL	Gopher	WOORINEN		6.11				
32A	DRIP	C-probe	PIANGIL		1.57				
33A	DRIP	Tens	NYAH		2.37	2.67	2.39		
34A	LOW LEVEL	Tens	WOORINEN		3.86	4.76	4.37	4.52	
34B	OVERHEAD	Tens	WOORINEN		3.89	4.57	5.26	6.98	
35A	DRIP	Tens	COLIGNAN		5.45	6.74	6.18	6.59	
35B	DRIP	Tens	COLIGNAN		5.45	6.7	6.36	6.16	
36A	DRIP	EnviroSCAN	DARLING		5.3	7.05			