MANAGING VINEYARD VARIABILITY FOR A TARGETED WINE OUTCOME

FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **CSU 03/05**

Principal Investigator: **Professor Geoffrey Scollary**

Research Organisation: **National Wine and Grape Industry Centre**

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MANAGING VINEYARD VARIABILITY FOR A TARGETED WINE OUTCOME

Luke Rolley[1], Patrick Iland[2], Allen Hart[3], Peter Morath[4], Emily Rouse[5], John Blackman[5] and Geoffrey Scollary[5]

1. Blaxland Vineyards Limited, PO Box 737, Maitland, NSW, 2320.
2. Patrick Iland Wine Promotions Pty Ltd, PO Box 131 Campbelltown, SA, 5074
3. Foster's Group, 116 Main Street, Great Western. Vic. 3377
4. Gundagai Vineyards, Chandlers Road, Nangus, NSW, 2722
5. National Wine and Grape Industry Centre, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW, 2678.

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ABSTRACT

Variability in vine growth and berry composition always exists in a vineyard. This project has established procedures to evaluate the effects of vineyard variability as measured by vine characteristics and berry composition on the resulting wine composition and wine sensory properties. A 'how-to' guide has been developed that describes a protocol for quantifying vineyard variability using precision management techniques, vine characteristics assessment, berry sensory analysis, small lot winemaking and wine sensory analysis. The guide has been created to assist vineyard managers and winemakers assess whether the wine produced from fruit within different sections of a vineyard is sufficiently different to other sections or the whole vineyard as a basis for decision making with respect to employ differential harvesting techniques or changing management strategies to improve fruit consistency. A model has been developed that will allow vineyard managers to evaluate the potential impact on vineyard financial returns based on a differential harvesting approach to managing variability.

EXECUTIVE SUMMARY

1. A three-year study (2004, 2005 and 2006 vintages) relating vine vigour to final wine sensory assessment has been completed. The project focus was on managing vineyard variability for a specific wine outcome. The vineyards used in this study produce grapes that are directed towards the 'popular premium' category ($10 - $14 price point). This represents approximately 35% of the current Australian market.

2. Two vineyards in warm regions (Central Victoria (Vineyard 1) and Southern NSW (Vineyard 2)) were used in all years of this study. A third vineyard (Western Victoria, cooler region (Vineyard 3)) was added in the second year.

3. Vine vigour zones were established based on plant cell density maps. Three vigour zones were identified in 2004: lower, higher and moderate vigour. Two zones were used in 2005 and 2006: lower and higher vigour. In 2005 and 2006, a sample representing the entire vineyard ('combined') was also used. There were three sampling sites per zone in all years.

4. The approach to locating vigour zones and sampling sites with these zones evolved over the three years. The *k*-means clustering methodology was applied in the final year.

5. Vine and grape parameters were assessed using assessment sheets provided by the Foster's Group (known as Southcorp when the project commenced), the company supporting this project.

6. The sites were harvested for small lot winemaking and berry analysis on the same day (or as close as possible) to the same day for the commercial harvest. The suitability of the fruit for harvest was assessed by the winemaker from the Foster's Group who participated in this project.

7. Small lot winemaking was carried out using a standard protocol determined by the project team. Triplicate ferments were used per vigour zones and assessed for consistency of winemaking to eliminate any influence from the winemaking of the interpretation of the impact of vineyard variability. In 2004, two wines (lower vigour and higher vigour) from one vineyard were made on a commercial 20-tonne scale.

8. The wines were analysed for a suite of chemical parameters in each year and related to the sensory assessment for each wine.

9. Sensory assessment, using both a team of winemakers and a trained sensory panel, was used in each year. Where differences occurred between the winemaker scoring and the trained panel scoring, preference was given to the results for the winemaker team as this reflected the potential clients for the grapes.

10. There was no significant difference in wine descriptors of wine scores for either Vineyard 1 or Vineyard 2 in 2004. There was also no significant difference in the sensory analysis for the small lot and commercial scale wines made in this year.

11. There wee some significant differences between wine scores for wine made from different vigour zones in Vineyard 2 only in 2005. For Vineyard 3, there were noticeable differences in berry sensory parameters at harvest that were not reflected in significantly different wine scores.

12. Significant difference in wine scores for wines made from the different vigour zones in 2006 for both Vineyard 1 and Vineyard 2. Although a more rigorous approach was used to

define the vigour zones by *k*-means clustering, it is more likely that the wine score differences relate to vintage/climatic influences rather than zonal definition.

13. Grapes from the lower vigour zones always had a higher berry colour value (measured at harvest) than those from the higher vigour zones or the combined zones. However, the difference in colour between the two vigour zones did not show any direct relationship with the difference in the score for the wines from the two zones.

14. An approach to modelling the financial impact of vineyard variability has been developed. Using wine scores for the wines from the different vigour zones and the combined, whole of vineyard, sample as indicators of potential different values for grapes, several scenarios are evaluated in terms of returns for single whole of vineyard harvest versus differential harvesting of the two vigour zones.

15. The potential for increasing the productivity of the lower vigour zones through soil amelioration of changed irrigation management was identified as a possible factor to be investigated for increased financial benefit in place of differential harvesting. The need for more research in this area was identified.

16. The project has developed a general protocol that will allow vineyard managers and winemakers to assess if advantages may accrue from zonal analysis and differential harvesting.

17. A "How to' guide, developed as a web resource, and the empirical model for assessing increased revenue from differential harvesting will allow individual managers to apply the methodology for specific vineyard situations.

Communications

1. The results of this project have been presented at wine industry forums in each year.

2. A full project presentation was given to the winemakers from the Foster's Group in 2007.

3. One technical article has been published (Australian Viticulture) and as second will appear in 2008

4. A detailed 'How to' guide has been prepared s a web document for general access by vineyard managers and winemakers

Finances

In-kind contributions totalling $233,360 over the three years of the project were provided by the participants in this project.

BACKGROUND

The fundamental issue addressed in this project was an analysis of the impact of variability in a vineyard on the final wine product. Variability exists in all vineyards. Variation occurs within and between vines, for example in shoot length, berry size and in berry composition. The variability that this research project focuses on is the natural variability across a vineyard block where some vines tend to be more vigorous and fertile than others, most likely due to impacts of difference in soil, elevation and aspect of the vineyard site.

New vineyard management technologies, sometimes collectively referred to as precision viticulture technologies, have recently become more prolific in vineyard management. What this technology has really highlighted is the significant variation of vine vigour and yield in a vineyard. This variation can be spatially mapped with the use of precision viticulture techniques. Obviously as the technology advances and we understand the effects of the variation, the possibility arises to manage the variability within a vineyard to increase revenue for vineyards and wineries.

Following Shiraz benchmarking work in 2002 and 2003(Rolley, 2002, 2003) one of the interesting results, particularly from the 2003 study was the relationship between the variability of grape colour (from 3 sample sites) within a block and the wine score of wine made from the vineyard. Vineyards with the greatest variability in colour levels did not have high wine scores. The hypothesis was formulated that the large variability contained within these vineyards was leading to detrimental wine composition and quality. Therefore it seemed sensible to have a detailed look at how vineyard variability is influencing wine quality and whether there are options for separating the potentially 'better' fruit from the potentially 'poorer' fruit or if there are alternatives for managing the variability, for example to reduce the net variability across a vineyard and simultaneously increase net cropping levels to result in a larger more uniform parcel of fruit with a potentially higher revenue per hectare.

This report outlines our findings from three vineyard sites where we measured plant cell density (PCD), vine characteristics, berry composition, wine composition and wine sensory characteristics in order to determine the influence of vineyard variability on the wine. The aim was to understand what are the effects of this variation in the vineyard on wine sensory characteristics and wine score, so that we could commence to address questions such as: 'how much variation is required in the vineyard to produce a detrimental influence on wine quality?' or 'what can be done in a highly variable vineyard to influence the financial return by either differential harvest techniques or alternatively reducing the variation in the vineyard to improve fruit consistency?'

The focus of this project has been on commercial vineyards that supply fruit for the 'popular premium' category of Australian wine[1] representing approximately 35% of the Australian wine market in the $8 to $14 price point. This differs from several previous studies that examined variation in smaller vineyards that tend to have higher management costs and generally higher returns in terms of the value of the fruit.

The results of this project have allowed a model to be developed that can be used by vineyard managers to evaluate the potential impact on vineyard financial returns based on a differential harvesting approach to managing variability.

[1] Terminology from 'The Marketing Decade' (https://www.awbc.com.au/winefacts/data/free.asp?subcatid=110) with price point upgrades.

PROJECT AIMS AND PERFORMANCE TARGETS

This project formally commenced in calendar year 2004 as project CSU 03/05. By agreement with the GWRDC, the mid-year progress report for CSU 03/05 became part of the application process for the longer term project in vintage years 2005 and 2006.

The project aims as described in the original detailed submission for CSU03/05 are:

1. To link remote sensing, vine assessment, berry analysis, wine composition and sensory data in such a way that the results of this project can be used as a template for broad industry adoption of management tools aimed at quantifying and managing variability within vineyards for winemaking outcomes.

2. To communicate the results to industry through technical and scientific publications and through workshops.

3. To hold winemaker and grapegrower debriefing seminars in the final year to communicate the outcomes of the project.

The Outputs and Performance Targets for each year of the project, as set out in the original project application, are listed in the following table. These outputs and performance targets are tabulated for all three vintage years.

January to June 2004

Outputs	Performance Targets
1. Precision Viticulture tools applied	Remote sensing completed, analysed and used to define distinct regions of variability within the experimental vineyards
2. Vineyard trial design finalised	Design completed using information produced after analysis of remote sensing data
3. Fruit harvested	50kg batches of fruit harvested and transported appropriately for each trial site and experiment
4. Small lot and commercial wines produced	21 small lot wines produced at each location (x2). 3 commercial wines from the Central Victorian site produced.

July to December 2004

Outputs	Performance Targets
1. Sensory Analysis	Small lot and commercial wines analysed and statistically evaluated
2. How-to guide	How to guide produced to demonstrate how the principles demonstrated in the project can be broadly applied
3. Statistical Analysis	Correlations made between vineyard, berry and wine quality attributes

January to June 2005

Outputs	Performance Targets
1. Remote sensing tools applied	Remote Sensing Imagery data collected for the three vineyards and interpreted by Feb 2005
2. Vineyard trial design finalised	Design completed using information produced after analysis of remote sensing data and winemaker assessment and berry analysis.
3. Fruit assessed and harvested	Berry Samples taken for analysis. High and Low quality wines made on small scale and large scale (20T).
4. Small lot and commercial wines produced	27 small lot wines made (3 replicates of each of high and low quality and 3 replicates of combined quality) for the 3 vineyards
5. Preliminary Evaluation	Initial sensory evaluation of the wines by Southcorp.

July 2005 – June 2006

Outputs	Performance Targets
1. Sensory analysis of small lot and commercial wines	Full Sensory analysis of small lot and large scale wines and spectral analysis of wines completed by Oct 2005.
2. Review of 2005 results	Review completed by December 2005
3. Remote sensing tools applied for 2006 vintage	Remote Sensing Imagery data collected for the three vineyards and interpreted by Feb 2006
4. Vineyard trial design finalised	Design completed using information produced after analysis of remote sensing data and winemaker assessment and berry analysis.
5. Fruit assessed and harvested	Berry analysis completed by March 2006. 50 kg of fruit harvested (at optimum Baume) at each sampling site.
6. Small lot and commercial wines produced	27 small lot wines made (3 replicates of each of high and low quality and 3 replicates of combined quality) for the 3 vineyards
7. Preliminary Evaluation	Initial sensory evaluation of the wines by Southcorp.

July 2006 – July 2007

Outputs	Performance Targets
1.Sensory analysis of small lot and commercial wines	Full Sensory analysis of small lot and large scale wines and spectral analysis of wines completed by Oct 2005.
2. Statistical analysis of data	Statistical analysis completed by Nov 2006
3. Communication outputs	Two technical publications by June 2007; One scientific publication by May 2007.
4. Industry communication	Project debriefing and presentation of results to Southcorp and other company winemakers: minimum of 3 presentations by June 07
5. Final project review	Review completed by Feb 2007
6. Final report	Final report submitted by June 2007*

*Extension granted until 16 November, 2007.

Comment on the performance targets

The performance targets set out in the original submission used 'wine quality' as the potential differentiator for the study. As the project evolved, it became clear to the project team that 'wines from sites of high and low vigour' was a more appropriate descriptor. The report therefore uses 'high and low vigour' from this point.

The performance targets were achieved with the following exceptions:

In 2006, only two of the three vineyards were harvested. The third vineyard was commercially harvested due to rapidly approaching inclement weather, without the full number of project samples being collected from the vineyard. Two out of the three sites were collected for small lot winemaking but the decision was made not to proceed with winemaking as there would be no comparison sample for analysis.

Only one and not three project debriefings were carried out. The project team, however, has prepared a "How to" guide which will be made available on the web. This guide will make the results more widely available to industry.

One technical article has been published and another will be prepared for early 2008. One (and possibly 2) scientific papers will be written in 2008.

METHOD

The Methods section provides an overview of the general methodology used over the three years of the project. Specifics relevant to any particular year are presented in the Results and Discussion section.

Vineyards used in this study

Three vineyards were used in this study:

- Vineyard 1: Lake Marmal Vineyard in 2004, 2005 and 2006
- Vineyard 2: Gundagai Vineyard in 2004, 2005 and 2006
- Vineyard 3: Seppelt's Great Western McKenzie Block in 2005 only (the commercial harvest took precedence over the harvest of the trial in 2006).

Each block selected for this trial showed variability and each was of sufficient size to allow the possibility of differential harvesting, if required.

a) Vineyard 1: Lake Marmal Vineyard

The Lake Marmal vineyard is situated at Boort in Central Victoria (36.12^{o}S). A 14 hectare vineyard was used in this trial that was planted to Shiraz (clone PT 23) on own roots. The Shiraz vines were six years old at the commencement of the trial in the 2004 season; the planting date was 1998. The vineyard is drip irrigated and the planting density is 1666 vines per hectare. The vines were trained on a Ballerina trellis with spur pruning. The block aspect is flat and the row orientation is North-South. The climatic conditions of the site can be described as warm with a mean January temperature of 22.6^{o}C.

b) Vineyard 2: Gundagai Vineyard

The Gundagai vineyard is situated near Nangus in Southern New South Wales (30.06^{o}S). A 13 hectare vineyard was used in this trial that was planted to Shiraz (clone PT23) on own roots. The Shiraz vines were six years old at the commencement of the trial in the 2004 season; the planting date was 1998. The vineyard is drip irrigated and the planting density is 1666 vines per hectare. The vines were trained on a 2-wire vertical trellis with spur pruning. The block aspect is north and the row orientation is East-West. The climatic conditions of the site can be described as warm with a mean January temperature of 23.3^{o}C.

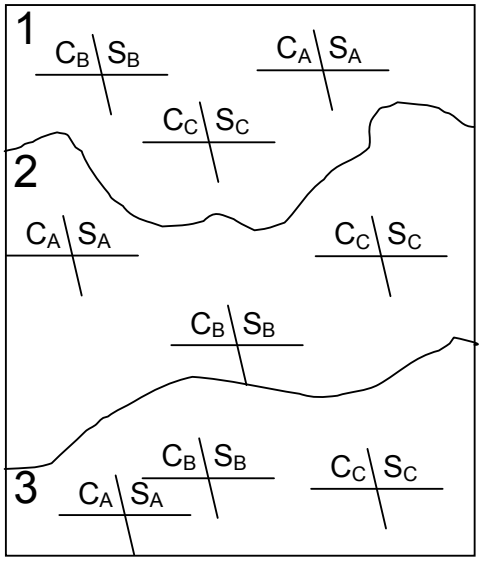
c) Vineyard 3: Seppelt's Great Western

The Mckenzie Block vineyard at Seppelt's Great Western is situated at Great Western in Western Victoria (37^{o}9'South). A 7.25 hectare vineyard was used in this trial that was planted to Shiraz (clone unknown) on own roots. The Shiraz vines were 15 years old in vintage year 2005. The vineyard is drip irrigated and the planting density is 1666 vines per hectare. The vines were trained on a single wire trellis with spur pruning. The block aspect is easterly and the row orientation is north-south. The climatic conditions of the site can be described as cool with a mean January temperature of 19.1^{o}C. The dates for veraison and harvest in 2005 were 17 February (veraison) and 30 March (harvest).

Trial Design

The concept of the trail was based is shown schematically in Figure 1. This schematic assumes three zones delineating grapevine vigour (1, 2, 3) with three sites within each zone. Initially it was assumed that there would be two samplings per site within each zone: a sampling at 13 Baumé (represented by S_A, S_B and S_C) and a second sampling at the time chosen for the commercial harvest (represented by C_A, C_B and C_C)

Figure 1. Schematic of trial design



In 2004 and 2005, each vineyard was divided into zones of different vine vigour using remotely sensed imagery (vigour mapping via plant cell density monitoring) at 0.5 m resolution by Terrabyte Services. Yield mapping of each vineyard was also conducted via yield monitors mounted on a machine harvester at harvest. In 2004, three vigour zones were identified from the imagery; these being relatively low, medium and high vigour zones. In 2005, six vigour zones were identified from the imagery; these being relatively very low, low, low-medium, medium, medium-high and high vigour zones. The six zones were grouped to give two by combining the very-low, low, low-medium zones into a relatively lower vigour zone and by combining the medium, medium-high and the high zones into a relatively higher vigour zone. In 2006, two zones were determined based on the pattern of the vigour and yield distribution data obtained in 2004 and 2005 using a technique termed *k*-means clustering analysis (Proffitt et al., 2006). The original plant cell density imagery of 2004 and 2005 was smoothed so that it could be projected onto the same grid as the respective yield map and thus, clustered with the yield data to determine 2 clusters zones. The 2 cluster zones suggest that the zones are significantly different with respect to vigour and yield.

In each year, three sampling sites were positioned within each zone. These sites were used to assess vine characteristics, sample berries for berry sensory analysis and chemical analysis and to sample fruit for small-lot winemaking.

Collection of vineyard vigour maps and yield maps

Vineyard remotely sensed imagery was obtained by Terrabyte Services of Wagga Wagga. The data were collected each season at or just after veraison according to industry standard practice. (Proffitt et al., 2006). The imagery was then processed according to standard industry protocol (Proffitt et

al., 2006) as plant cell density (PCD) imagery and uploaded onto mobile GPS units for ground truthing in the field and location of sampling sites.

Yield data were collected with Farmscan yield monitors, upgraded with load cells from Advanced Technology Viticulture technology on either a Pellenc or Braud harvesters. The data were processed according to standard industry protocol. (Proffitt et al., 2006).

K-means clustering analysis was performed on all the PCD maps and yield data collected in 2004 and 2005 in order to obtain 'zones' which were significantly different in terms of higher yield and vigour and lower yield and vigour. The zones were uploaded onto mobile GPS units for location of sampling sites within the vineyard trial areas.

Vine characteristics assessment

By arrangement with staff of Southcorp (now Foster's Group), the project industry partner, the Southcorp vineyard assessment sheet was followed for assessing vine characteristics at each trial site. The following characteristics were monitored at each trial site:

- Shoot length
- Shoots trimming
- Shoot periderm development (only assessed if shoots have not been trimmed)
- Internode length
- Leaf condition
- Leaf layer number
- Bunch exposure
- Overall assessment

The group involved in the vineyard assessment is shown in Figure 2.

Figure 2. Getting ready for the vineyard assessment

Grape berry sensory evaluation

The Southcorp berry sensory evaluation sheet was followed, by arrangement with staff of Southcorp (now Foster's Group). Figure 3 demonstrates part of the berry sensory assessment procedure.

The parameters evaluated were:

- Deformability
- Degree of berry shrivel
- Flesh texture
- Sugar/acid balance
- Aroma descriptors
- Skin thickness
- Skin integrity/feel
- Skin astringency
- Seed colour
- Seed hardness
- Seed aroma
- Seed astringency
- Overall assessment

Figure 3. Vineyard berry assessment

Harvest criteria and harvest procedure

a) Harvest criteria
There are a number of options for harvest criteria, including harvesting fruit representing each zone and the whole vineyard at the same time or when the fruit from each zone is at a predetermined ^{B}aumé or when the fruit of each zone is at a predetermined flavour ripeness as assessed by berry sensory assessment. The last two approaches may require harvesting fruit from each zone and the whole vineyard on separate days.

In this project, the first option was used because the commercial reality of picking an entire vineyard in a single event is preferable to picking out sections of a vineyard block on different days. The harvest criteria decided upon by the project group was that the harvest date for small lot winemaking and berry analysis would be the same day when the vineyard block was commercially harvested. The suitability of fruit for harvest was determined by berry analysis and berry sensory assessment by the company winemaker. In this approach the sugar ripeness (^{B}aumé) as well as the flavour ripeness of fruit from the two zones and the whole vineyard may be different and thus any differences in sugar ripeness and flavour ripeness of the fruit at harvest form part of the experimental design.

b) Harvest procedure
For each zone within each vineyard in the study, 150 kg of bunches were collected across the three sites for that zone. The bunches from each site within a zone were collected in approximate proportion according to the estimated yield for that site. The procedure for calculating the proportional contribution from each site is described below. A separate sampling of 150 kg from the whole vineyard proportionally across all sites in all zones was also made. Harvested bunches were placed in polyurethane boxes, each holding approximately 12 to 15 kg. The boxes were labelled with vineyard name, zone descriptor and harvest date. Potassium metabisulfite (PMS) was added to each box in sufficient amount to achieve an approximate sulfur dioxide concentration of 50 mg/L This was achieved by dissolving 12 gram of PMS (1 x 10g tablet + 1 x 2g tablet) in 600 ml of water and then pouring 50 ml of this solution into each box containing 12.5 kg of fruit. When harvesting was complete, the boxes were transported without refrigeration to the NWGIC Experimental Winery in Wagga Wagga.

The following procedure was used to calculate the proportional contribution of fruit from each site to the 150 kg collected from the three sites within a zone.

> For each site, the number of bunches per vine were counted on 20 vines across the site (every 4th vine) and one bunch was collected from each of these vines (20 bunches). An average number of bunches per vine and an average bunch mass were calculated. An estimated yield (Y) for each site was calculated as follows:
>
> Y = average number of bunches per vine x average bunch mass x 80 vines.
>
> The % mass contribution of each site to the 150 kg zone sample was calculated separately for each site using the formula following. For example, for site 1 of zone 1:
>
> the % contribution of site 1 = Y1 x 100/(Y1 + Y2 + Y3)
>
> where Y1, Y2 and Y3 are the calculated yield estimates for each site within the zone, respectively.
>
> This % contribution data was then used to calculate the number of bunches to be collected from each site for proportional harvesting for the 150 kg of fruit for small-lot winemaking. For example, the mass of bunches required from each site is equal to the % contribution x 150 kg, and the number of bunches required from each site is equal to the % contribution x 150/average bunch mass.

The bunches were collected from all the 80 vines across the site and placed into the respective boxes. The same 80 vines were also used to collect bunches for the small-lot winemaking sample from the respective zone and then again for the collection of bunches for the small-lot winemaking sample representing the whole vineyard. In the whole vineyard sample, the proportional contribution was calculated using data from the 6 sites; that is, sites 1, 2 and 3 of zone 1 and sites 1, 2 and 3 of zone 2 similar to the method described above.

Grape berry chemical analysis

On the date of harvest for the small lot winemaking, a set of berry samples were collected at each sampling site. In 2004 and 2006, two zones were selected and the samples were labelled according to the following:

- Zone 1, Site 1; Zone 1, Site 2; Zone 1, Site 3
- Zone 2, Site 1; Zone 2, Site 2; Zone 2, Site 3

In 2005, six zones were initially selected, but this was reduced to two zones for winemaking and subsequent analysis.

A random sample of 50 bunchlets (part of the bunch containing 6 to 10 berries) across the 80 vines at the site were collected. Generally, one bunchlet per every second vine was collected plus an additional 10 bunchlets for the remaining vines.

Once collected, the bags were placed in a box for protection of the berries during transport to Myrrhee Consulting for analysis.

The following analyses were performed on the berry samples

- Juice degrees Baumé
- Juice pH
- Juice titratable acidity
- Average seed mass
- Average berry mass
- Average skin mass
- %seeds per berry
- %skin per berry
- Anthocyanins per unit mass of berry
- Skin anthocyanins
- Skin flavonols
- Skin phenolics
- Phenolics extracted from the surface of the seeds

In 2006, colour analyses were also performed by Vintessential.

Small lot winemaking

Small lot winemaking was performed at the NWGIC Experimental Winery in Wagga Wagga. The harvested grapes (see above; Harvest criteria and harvest procedure) were transported to the NWGIC and stored overnight in a cold room at 4^{o}C. Before processing, grapes were sorted into three replicates and the mass of each replicate recorded.

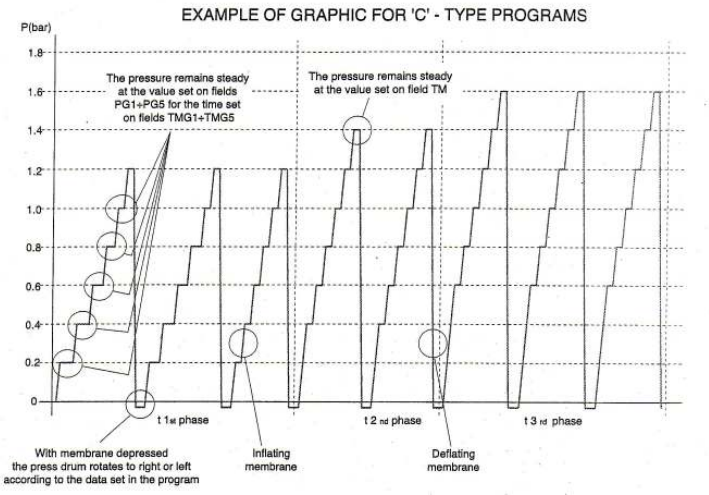
Fermentations in triplicate were carried out in 100 litre variable capacity stainless steel tanks (Figure 4) sourced from ALGOR (Italy) via Australian Winemakers in Epping, Victoria. The

fermented wines were pressed off using a Velo 600 litre fully enclosed tank press (Figure 5) that allowed a programmable press cycle. For consistency, press cycle C2 (Figure 6) was used for all pressings.

Figure 4. Variable capacity stainless tanks with lids showing seals

Figure 5. The Velo 600 Litre tank press used for pressing wine

Figure 6. Press cycle C2 for the Velo tank press used in pressing the wine



Grapes (150 kg) from each site were sorted into three replicates of approximately 50 kg. The mass of each replicate was recorded. In addition, a sample of 100 berries was collected from each replicate and stored frozen in a plastic bag for subsequent analysis.

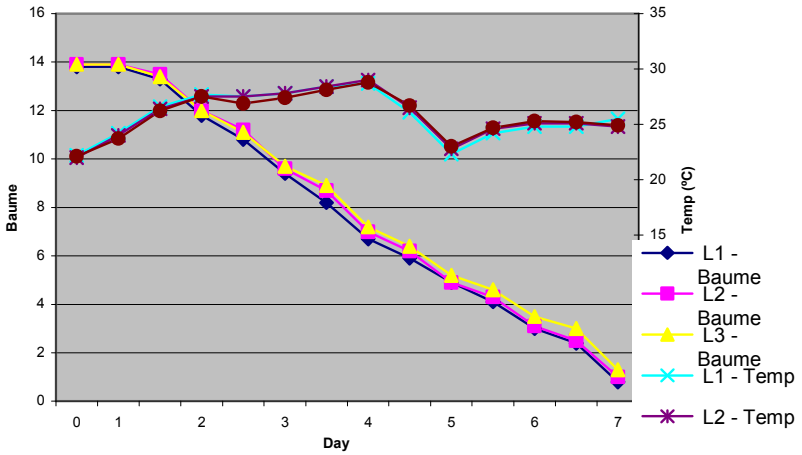
The grapes were crushed and de-stemmed using a 2 tonne/hour crusher/destemmer (Figure 7). A sample of the must was taken and the pH, TA and ^{B}aumé recorded. Sulfur dioxide (20 mg/litre), and diammonium phosphate (DAP) (200 mg/litre) were added to the must. The must was adjusted to between pH 3.6 and 3.7 with tartaric acid with the aim of keeping the TA value to between 6.0 and 7.0 g/litre tartaric acid equivalents.

Figure 7. Crusher/destemmer used for processing grapes

The must was warmed to 20^{o}C and inoculated with AWRI 796 (rate of 0.20 g/litre) in Vintages 2004 and 2005. EC1118 (0.25g/litre) was used in Vintage 2006.

Fermentation was carried out on skins for six days. The cap was plunged 4 times each day at approximately 07h00; 12h00, 16h00 and 21h00. The ferments were monitored twice daily for ^{B}aumé and temperature. Figure 8 presents a typical fermentation plot for three replicate ferments. The ferments were also monitored for the presence of hydrogen sulfide. An extra addition of DAP at 0.2 g/litre would have been made, but this was never required.

Figure 8. Fermentation plot for three replicate ferments from Vineyard 1 in Vintage 2006.



The ferments were pressed off (as described above) and the fermentation continued to dryness. In the final stages of the ferments, the residual sugar was monitored by the Rebelein method (see Iland et al, 2004).

The primary ferment was considered complete when the measured residual sugar was less than 2 g/litre. An addition of sulfur dioxide (60 mg/litre) was made at this point.

The wines were cold stabilised at 4^{o}C for three weeks. The wines were racked twice in this period. Sulfur dioxide was measured weekly and adjusted to approximately 30 mg/litre free sulfur dioxide as required.

Following cold stabilisation, the pH of the wines was adjusted to between 3.5 and 3.6, while maintaining the TA values around 6.0 to 7.0 g/litre as tartaric acid.

Prior to bottling, the wines were analyses for pH, TA, alcohol and sulfur dioxide. The wines were also tasted by a panel of at least three to check for faults (*eg*: acetaldehyde, hydrogen sulfide) and for variation between replicates. If one wine of a replicate showed marked differences from the others, it was removed. A sample of each wine was collected and retained for subsequent colour and phenolic analysis. The wines were bottled unfiltered into Punted Burgundy (French Green) BVS bottles and sealed with Plain Gold Supervin (35 x 60 mm) Stelvin closures (Figure 9). Once bottled, the wines were stored in an air-conditioned room at 12^{o}C until required for sensory analysis.

Figure 9. Screw capper used in sealing wine in bottles

In the 2004 Vintage, the wines were put through malo-lactic fermentation. However, this increased the number of wines with oxidation faults and, as a consequence, the research team determined not to use malo-lactic fermentation in 2005 and 2006.

Wine chemical analysis

The following parameters were measured and/or calculated from measured parameters on each wine replicate:

- pH
- Titratable acidity
- Wine colour density
- Wine colour hue
- Degree of red pigment colouration

- Estimate of sulfur dioxide resistant pigments
- Total red pigments
- Total red phenolics
- Modified wine colour density
- Modified wine colour hue

The methodology used to measure these parameters was as described in Iland et al, 2004

Wine sensory analysis

Two important approaches were taken to assessing the sensory characteristics of the wine produced in this project. A winemakers' tasting panel using winemakers from Southcorp was used for the 2005 and 2006 wines. A trained panel was used at the NWGIC to generate descriptive sensory data for the wines in all years. Wines were assessed when they were approximately 6 months of age, except for the winemaking tasting session in 2006 when they were assessed at approximately two months of age and repeated at 14 months of age.

Winemaker sensory analysis was carried out on the following dates at the specified venues.

- 18 May 2005, Seppelts Great Western with 10 participants;
- 4 July 2006, Wolf Blass Winery, Nuriootpa with 11 participants;
- 5 June 2007, Penfold's Winery, Nuriootpa with 12 participants.

Descriptive sensory analysis and panel training was initiated at the NWGIC in 2004. Professor Ann Noble of UC Davis led a sensory training program at the NWGIC for 25 October to 5 November, 2004. Training focused on specific aroma attributes. Fifteen people (the 'trained panel') participated in this 2004 aroma evaluation of the project wines. In addition, six members of the trained panel plus three winemakers re-assessed the wines for aroma attributes and additionally for specific mouthfeel attributes and wine quality. The three replicate ferments were presented to the panel.

The dates for the descriptive sensory analysis at the NWGIC were:

- 25 October to 5 November 2004, with Professor Ann Noble (aroma profiling)
- 01 December 2004 with 9 panel members
- 13 February 2007 with 10 panel members (2005 wines)
- 13 February 2007 with 10 panel members (2006 wines)
- 13 June 2007 with 10 panel members (repeat analysis of 2006 wines)

In 2005 and 2006, the replicate wines were assessed informally by a panel of three (one winemaker and two people with extensive sensory evaluation training) and it was determined that there were no differences between the sensory attributes of the replicate wines. Therefore only one replicate of each wine was presented to the panel for training and formal sensory evaluation.

A preliminary training session was conducted prior to the formal sensory session. In 2005 ten winemakers from the company involved with the trial assessed the wines for aroma attributes, specific mouthfeel attributes and wine quality. A preliminary training session was conducted prior to the formal sensory session.

In 2006, two approaches were again used; these being the NWGIC trained panel and a winemaking panel. In both approaches the panel assessed the wines for aroma attributes, specific mouthfeel attributes and wine quality. For both panels, a preliminary training session was conducted prior to the formal sensory session

For all years, a set of selected wines were presented to all panellists in the preliminary training sessions. Following this, participants discussed the attributes of the wines and a set of descriptors was collated and discussed until a clear definition of each term was determined and a final

consensus list was made. A practice rating session was also conducted. Terms varied slightly from year to year as decided by the panel. For the formal assessment session, tasters were given replicate samples (30 ml) of the wines in coded tasting glasses. Tasters carried out independent ratings of the attributes in isolated booths (2004) or on an individual bench space (2005 and 2006). All samples were presented to tasters in a completely randomized order. Wines were tasted in duplicate and the duplicates were poured from the same bottle.

Rating of the attributes in 2004 was carried out using a 10 cm long scale divided into 9 segments. Panelists marked a line on the scale corresponding to the intensity of their perception of the sensory attribute being assessed. Most attributes were anchored as 'weak' and 'strong' and tannin ripeness was anchored from green to ripe. In 2004, a computerised data acquisition software system was used to collect all sensory data. In 2005 and 2006 the sensory attribute ratings were scored out of a maximum of five points; tasting sheets were filled out manually and the data subsequently transferred to the computerized system. Wine quality in each year was rated out of 20 according to the criteria of the Australian Wine Show System. The data of the ratings of each sensory attribute and of the wine score was analysed using an ANOVA.

Statistical analysis

The wine descriptive sensory analysis and wine score data obtained through the tasting trials were analysed using a factorial analysis of variance with factors for the tasters and the different wines (lower vigour, higher vigour and combined zones). A full factorial model was fitted. Where a significant main effect was found for the differences between the wines, a Tukey HSD procedure was used to compare the means of the three wines and classify them into groups where wines in the same group are not significantly different and those in different groups are judged to be significantly different. The labels a, b and c are used to indicate group membership in the tables of results.

The data collected on the vine and berry characteristics have been summarised in various tables which are included in the Appendix 5. Due to the very small sample sizes in these data, formal statistical analysis is not appropriate.

RESULTS AND DISCUSSION

The approach adopted in this project to measuring variability evolved over time, due in part to some advances in technology and also from lessons learnt during each year of the project. Part of the intention of the research team was to carry out the research in a commercially-applicable way so that vineyards and wineries might be able to make sensible decisions on how to view vineyard variability.

The experimental aspects of this project spanned vintages in 2004, 2005 and 2006. Each vintage is discussed in turn followed by a comparison across vintages.

The three vineyards for this study were located in:
Vineyard 1: Central Victoria (warm region)
Vineyard 2: Southern NSW (warm region)
Vineyard 3: Central Victoria (cool region)

The same methodology was applied to all vineyards, but there was no attempt to make across-vineyard comparisons. The purpose of this project was to examine factors affecting the potential for zonal harvesting and/or the value of different strategies being employed to manage variation in vigour. The three vineyards were selected to give insight into regionality effects and vine age effects: vineyard 3 was considerably older than vineyards 2 and 3 (see Methods section for a full description of the vineyards).

Terminology: Vigour and Quality

In designing this project, the terms 'high quality' and 'low quality' were used to describe outputs for the project. As the project evolved, it became apparent that the use of 'quality' was too subjective to be of value. Consequently, and as the vineyard measures focussed on vigour assessment, we have selected to use the terms 'higher vigour' and 'lower vigour' as descriptors of the zones identified in each vineyard. Figure 10 present images of the different vigour levels in one of the vineyards used in this study.

All parameters and results in this project are given in terms vigour of each zone. Where the high and low vigour sites are combined, as would occur in a single harvest operation, this zone is labelled the 'combined' zone.

The data obtained in the 2005 season highlighted the vigour/quality issue in some detail. Initially, each vineyard block was split into six vigour regions of: Very Low, Low, Medium Low, Medium High, High and Very High. These vigour zones were then assessed by a winemaker to determine which sites offered potentially higher fruit quality sensory characters than the other sites within the vineyard.

For one vineyard, the Very Low, Low and Medium High vigour zones were assessed to be of superior quality and Very High, High and Medium Low vigour sites of lesser quality. For a second vineyard 2, the High and Very High vigour sites were assessed of potentially lower grape and wine quality and the remaining vigour zones were deemed to be superior. For the third vineyard, the Low, Medium High and Medium Low sites were assessed to be of superior quality and the other sites of less quality. This lack of relationship between observed vigour and quality perceived in the vineyard reinforced our intention of using 'vigour', rather than 'quality' as the descriptor of each zone.

Figure 10. An example of a high vigour zone and a low vigour zone

Establishing the Zones

Vineyard zones were established in each vineyard black using the PCD imagery alone in 2004 and 2005. This approach was adopted to represent and also evaluate the commercial application of PCD as an indicator of the potential for differential harvesting according to vine vigour. The methodology of *k*-means clustering was only applied in 2006 and is discussed later.

In 2004, three vigour zones were derived from the PCD imagery: higher, medium and lower vigour.

In 2005, six vigour zones were initially identified, but after the field sensory assessment of the berries, this was reduced to two zones: higher and lower vigour. A third 'whole of vineyard zone' (or combined zone) was also used in 2005.

The PCD images used for this zone identification are shown in Figure 11.

Figure 11. PCD and yield (t/ha) for Vineyard 1 in 2004 and 2005

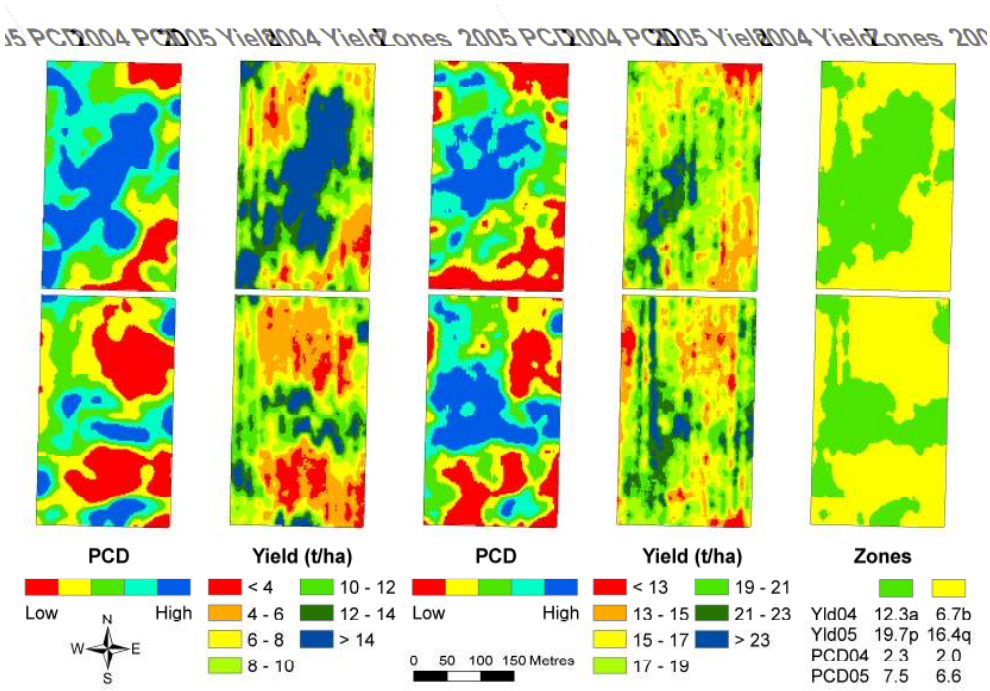
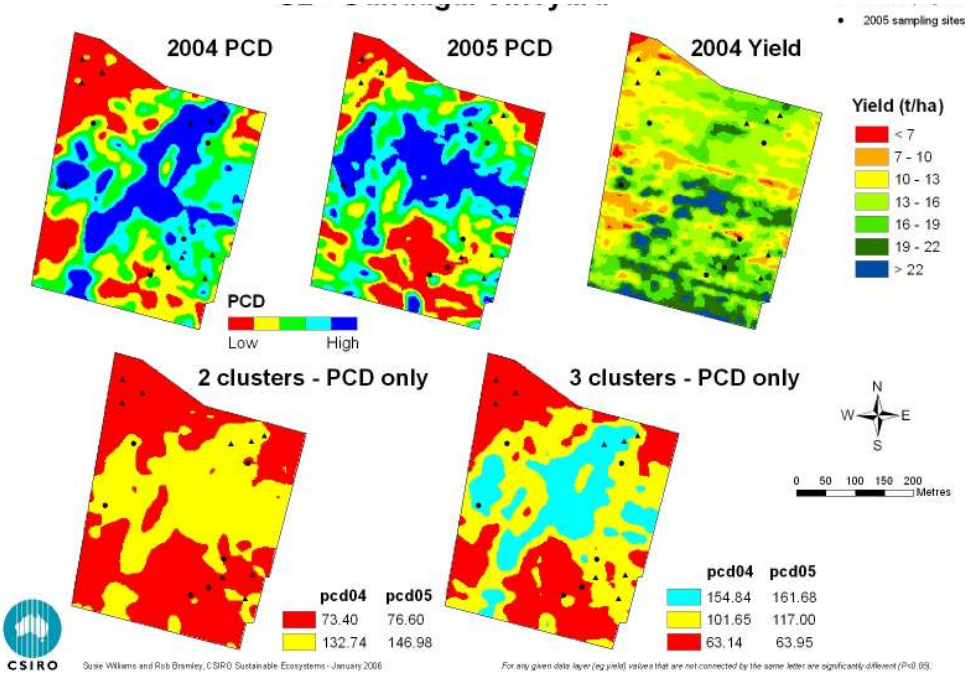


Figure 12. PCD and yield (t/ha) for Vineyard 2 in 2004 and 2005



Vintage 2004 – Testing the concepts

Methodology followed

The project aim in this year was to quantify the variability of fruit and wine quality by assessing the quality of wines produced from three levels of vine vigour within a vineyard block. Wines were made from low, medium and high vigour regions to understand the impact of the vineyard variability on the resulting wine quality.

Once the vigour zones were established, three sampling sites were defined in each zone to give a total of nine sampling sites per vineyard: three sites of low vigour, three sites of medium vigour and three sites of high vigour. Each site consisted of 40 vines (10 vines across 4 rows), so that there was sufficient fruit for berry sampling and small-lot winemaking.

The decision of the timing of the 2004 harvest for the different sections of each vineyard was based on a winemaker's recommendation after sensory assessment of berries from each site. The harvest was carried out at approximately 13 Baumé. In addition to the samples taken for small lat (50 kg) winemaking, two 20 tonne lots of grapes were picked at the vineyard in Central Victoria, according to a GPS mounted on a harvester as 'low' and 'medium-high' vigour samples and fermented commercially.

The aroma descriptive sensory analysis of the small lot wines from the 2004 were assessed by a trained panel at the NWGIC under the training and supervision of Professor Ann Noble, formerly of University of California (Davis). An additional mouthfeel descriptive sensory analysis was performed by members of the trained panel together with a group of winemakers,

2004 Results for Vineyard 1

The following list of results is not comprehensive, but simply focuses on some of the interesting vine and berry characters from the vineyards to highlight the variation that was evident within the vineyards, and the results of the tasting of the small-lot wines. All results are tabulated in Appendix 5.

Table 1. Vine Characteristics, berry composition and yield of Vineyard 1

Vigour Site	Shoot Length (cm)	Fruit Exposure (%)	Shoot Lignification (%)	Berry mass (g)	Baumé	Berry Colour (mg/g)	Yield (t/ha)
Lower	50-80	80-100	90	0.72	13.6	2.2	5
Medium	80-120	80-100	90	0.78	14.2	2.1	9
Higher	120-160	40-60	70	1.03	13.5	1.7	14

There was a high level of variability in vine characteristics (Table 1). The yield almost tripled across the three levels of vigour. Differences in berry colour however were not great, ranging from 1.7 to 2.2 mg/g berry mass.

The sensory analysis of the wines from Vineyard 1 was interesting. There were no significant differences between the higher vigour wine, the lower vigour wine, the moderate vigour wine and the combined wine from across the entire vineyard in any of the individual aroma and tannin characteristics and in the overall wine scores except one wine scoring higher in 'green olive'. Wine scores ranged from 12.7 to 13.3, but were not statistically significant. In this year, all wines were put through malo-lactic fermentation. Malo-lactic fermentation on small lot winemaking is often difficult to complete in the cooler to cold months following vintage with the consequence that acetaldehyde production can occur. Several of the wines in this year were affected by acetaldehyde and in the review of the 2004 results, the project team decided to remove malo-lactic fermentation from the winemaking protocol for the 2005 and 2006 vintages.

There were also 20 tonne commercial wines made from Vineyard 1 that yielded the same sensory result. Although there were very slight variations in some sensory characteristics, no significant difference was found between the overall wine scores for these wines. Further, there was no significant difference between the wine scores for the commercial and small lot ferments. At harvest, there appeared to be evidence of variable fruit quality in that, once picked, the bins from the lower yielding/vigour site contained smaller berries; whereas the bins from the higher yielding sections contained larger berries and also some poorly coloured fruit. These differences could not be detected in the final wines from these separate lots of fruit.

2004 Results for Vineyard 2
As with Vineyard 1 above, the following table (Table 2) presents some of the interesting results. All data are collected in Appendix 5.

Table 2. Vine characteristics, berry composition and yield of Vineyard 2.

Vigour Site	Shoot Length (cm)	Fruit Exposure (%)	Shoot Lignification (%)	Berry mass (g)	Baumé	Colour (mg/g)	Yield (t/ha)
Lower	80-120	60-80	80	0.95	13.9	1.3	11
Medium	80-120	60-80	80	1.12	13.4	1.2	15
Higher	120-160	40-60	100	1.13	12.6	1.1	15

This vineyard showed some variability in vine characteristics although the yield was reasonably consistent across the vigour zones of this vineyard. Once again, following a detailed sensory analysis of the wines (as described above for Vineyard 1), there were no significantly different characters in the wines that were made from the different sections of the vineyard, except one wine which showed a higher cherry/berry score. Wine scores fell in the narrow range of 13.1 to 13.6. No commercial ferments relating to the different vigour sites were carried out for Vineyard 2 in this season.

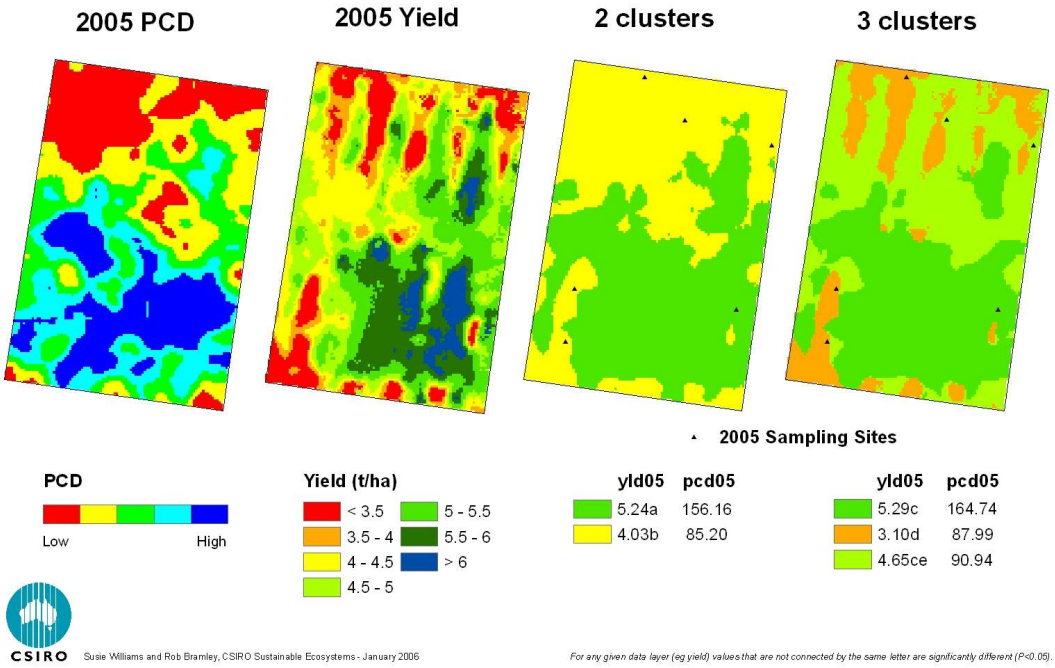
Vintage 2005 – The quest for difference

Following the results in 2004 a number of changes were made to the experimental design in 2005 to try and enhance the measurement and assessment of the variation within the vineyard.

An older vineyard in a cooler region of Victoria (Vineyard 3) was added to the experiment in an effort to determine variability in older vines. In this cool climate site, it was thought that any observed variability may have been more apparent in its impact on wine composition. The existing vineyards from 2004 were used again and the same blocks were measured as in the 2004 vintage. Each vineyard was remotely sensed for Plant Cell Density (PCD) imagery on a 50cm resolution by Terrabyte. Figure 13 presents the PCD and yield for Vineyard 3 in 2005. Figures 11 and 12 show the relevant data for Vineyards 1 and 2.

Using the PCD data, each vineyard block was subsequently split into six vigour regions of Very Low, Low, Medium Low, Medium High, High and Very High. This was done to try and increase the opportunity to find a region of vines that had higher potential wine quality. Each of the six sites was assessed for shoot length, shoot trimming, lateral growth, shoot periderm development, leaf condition, fruit exposure, leaf layer number, berry size, berry shrivel, description of pulp, flavour of berries, flavour intensity, sugar/acid balance, skin thickness, intensity and type of tannins and field colour of berries. In addition to the field analysis, samples were analysed Baumé, pH, TA, average skin mass, average seed mass, average berry mass, skin anthocyanins, skin flavonols, skin phenolics and phenolics extracted from the surface of the seeds.

Figure 13. PCD and yield (t/ha) for Vineyard 3 in 2005



Once these measurements were taken, the sites were assessed by a winemaker to determine which sites offered potentially higher fruit quality sensory characters than the other sites within the vineyard. Sites that appeared to have higher fruit quality were grouped together for small-lot winemaking and sites that were perceived as of a lower quality were grouped together for small-lot winemaking. As a result three wines (replicated three times) were made from each vineyard: perceived higher quality fruit, perceived lower quality fruit and a proportionally combined fruit sample from across all sites in the vineyard. In essence, this involved reducing the original six zones to two zones. Vine discrimination into two zones is more realistically related to the possible commercial practice of differential harvesting.

So, for 2005, the original six zones were combined as follows:

Vineyard 1 Combine Very Low, Low and Medium High to give **Lower Vigour**
Combine Very High, High and Medium Low to give **Higher Vigour**

Vineyard 2 Combine Very Low, Low, Medium Low and Medium High to give **Lower Vigour**
Combine High and Very High to give **Higher Vigour**

Vineyard 3 Combine Low, Medium Low and Medium High to give **Lower Vigour**
Combine Medium Low, High and Very High to give **Higher Vigour**

In the field these assessments made sense and could loosely be correlated with 'vine balance' as giving better fruit qualities. Vineyard 2 showed the least amount of variation in fruit quality in the field followed by Vineyard 1 and finally Vineyard 3 appeared to display the greatest variation in berry sensory characteristics of all the vineyards assessed.

As noted above, the small-lot winemaking protocol was altered in this year to try and remove the number wines that were being affected with acetaldehyde. The main modification was the decision to remove the malo-lactic fermentation step from the 2004 wine production protocol. Once the

small-lot wines were fermented through to dryness (completed primary ferment), they were racked off lees and stored in a fridge at 4°C until tasting when they were returned to room temperature for bottling. The low storage temperature and regular daily checking of the seals on the variable capacity tanks ensured that acetaldehyde production was essentially eliminated. The pre-bottling tasting did not detect any difference between the replicate ferments, validating this approach to small lot winemaking.

Sensory and spectral analysis of the wines was conducted in August following vintage. Sensory analysis was completed by a team of winemakers from Southcorp (now the Foster's Group) at the Great Western winery, where wines were scored on fruit and tannin characters as well as a total wine score.

2005 Results for Vineyard 1
Tables 3 and 4 present summary data for Vineyard 1. Appendix 5 contains all collected data for this site.

Table 3: Vine characteristics, berry composition and yield of Vineyard 1, 2005.

Vigour site	Shoot Length (cm)	Fruit Exposure (%)	Lignification (%)	Berry mass (g)	Baume	Colour (mg/g)	Yield (t/ha)
Lower	50-80	60	60	1.16	13.8	1.1	16
Higher	80-120	70	40	1.19	13.7	0.9	20
Combined	80	60	50	1.18	14.1	1.0	18

Vineyard 1 had a large crop in 2005. Many of the differences between higher vigour and lower vigour sites that were evident in 2004 were diminished. Berry size, colour and yield were similar across the zones of vigour. Sensory analysis of the fruit suggested that there were some differences that could potentially be seen in the wines.

Table 4: Descriptive sensory analysis results for Vineyard 1, 2005.

Vigour site	Fruit Flavour concentration	Flavour Complexity	Tannin Type	Lolly Flavour	Cherry Flavour	Wine Score
Lower	2.83 ns	2.47 ns	2.93 ns	2.57 ns	2.30 ns	14.6 ns
Higher	2.43 ns	2.23 ns	2.96 ns	2.33 ns	2.40 ns	14.2 ns
Combined	2.87 ns	2.57 ns	3.11 ns	2.30 ns	2.57 ns	14.6 ns

(ns = no significance)

Sensory assessment of the three wines showed no significant differences in individual characters or in overall wine scores, which ranged from 14.2 to 14.6.

2005 Results for Vineyard 2
Data summaries for Vineyard 2 are presented in Tables 5 and 6 with all data in Appendix 5.

Table 5: Vine characteristics, berry composition and yield of Vineyard 2, 2005.

Vigour site	Shoot length (cm)	Fruit exposure (%)	Lignification (%)	Berry mass (g)	Baumé	Colour (mg/g)	Yield (t/ha)
Lower	80-120	60	50	1.25	14.0	1.5	10
Higher	120-160	50	60	1.23	13.0	1.3	17
Combined	120	55	50	1.28	13.5	1.6	12

Vineyard 2 displayed more variation than in the 2004 season with some small differences in yield and berry colour level evident. Sensory analysis of the berries in this vineyard suggested that much of the fruit was similar. It was necessary to exaggerate differences in order to classify the zones into higher and lower vigour batches.

Table 6: Sensory analysis results for Vineyard 2, 2005

Vigour site	Fruit flavour concentration	Flavour complexity	Tannin type	Spice flavour	Dark fruit flavour	Wine score
Lower	3.13a	2.70a	3.05ns	2.30a	3.00ns	15.1a
Higher	2.65b	2.10b	2.95ns	1.37b	2.85ns	14.2b
Combined	2.95ab	2.47ab	3.05ns	2.10a	2.63ns	14.5b

Sensory analysis of the wines showed some differences. The allocated higher quality sites achieved a higher quality wine. It is interesting in that the variation between the sites was not clearly evident in the berry sensory analysis in the field.

2005 Results for Vineyard 3
Tables 7 and 8 present relevant data for Vineyard 3 with all data collected in tables in Appendix 5.

Table 7: Vine characteristics, berry composition and yield of Vineyard 3, 2005.

Vigour site	Shoot length (cm)	Fruit exposure (%)	Lignification (%)	Baumé	Berry mass (g)	Colour (mg/g)	Yield (t/ha)
Lower	80-120	50	100	14.4	1.03	2.4	6
Higher	120-160	50	100	14.0	1.20	2.1	6
Combined	120-160	50	100	14.2	1.18	2.4	6

Vineyard 3 displayed some variation in vine and berry sensory characteristics with generally the bigger canopies with highly shaded fruit showing less desirable berry characteristics. These field results suggested optimism in terms of subsequent differences in wine flavours.

Table 8: Sensory analysis results for Vineyard 3, 2005

Vigour site	Fruit flavour concentration	Flavour complexity	Tannin type	Plum flavour	Pepper flavour	Wine score
Lower	3.37 ns	2.85 ns	2.65 ns	2.67 a	2.03 ns	15.6 ns
Higher	3.07 ns	2.63 ns	2.83ns	2.23 b	1.67 ns	15.2 ns
Combined	3.26 ns	2.57 ns	2.72 ns	2.67 a	1.83 ns	15.2 ns

Despite initial optimism from the berry assessment in the vineyard, the wine sensory analysis showed that the only difference was the 'plum' descriptor for the lower vigour and combined sites. Wine scores were not significantly different.

Vintage 2006 – Putting it all together

Some variation in wine assessment was seen in 2005, especially in Vineyard 2. A tentative conclusion that the project team discussed at this stage was that the results from 2004 and 2005 might suggest that some variability in the vineyard may not always generate a negative influence on final wine composition, especially for wines in the popular premium category. If this were to be reflected in the 2006 results, the focus of the project could be shifted from differential harvesting to making vineyards more profitable by ameliorating the zones of the vineyards so that each zone is managed to yield its optimum.

An alternate explanation of the 2004 and 2005 results may be that the remote sensing of vigour that was used to identify the vineyard zones was not the most effective means of zonal classification. This is especially the case, given the recent emphasis on precision management techniques as described in Proffitt et al. (2006).

To address these issues, a more rigorous spatial analysis of the PCD and yield maps was performed for the 2006 season, including the *k*-means clustering approach described in Proffitt et al. (2006). Two zones were then established with three sampling sites per zone, as in the two previous seasons.

Figures 14 and 15 show the PCD maps for Vineyards 1 and 2. A PCD map was also collected for Vineyard 3, but not shown as (for reasons described above), sampling did not occur in this vineyard in 2006.

Figure 14. PCD map for Vineyard 1 in 2006

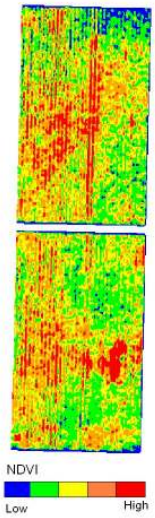
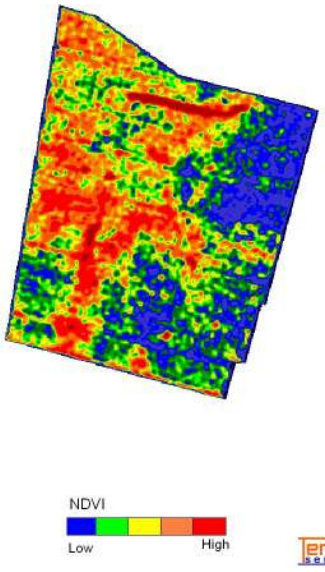


Figure 15. PCD map for Vineyard 2 in 2006



Zones of lower and higher vigour were then established and these are shown in diagrammatic format for the two vineyards in Figures 16 and 17.

Figure 16. Schematic representation of vigour zones and sampling sites for Vineyard 1, 2006.

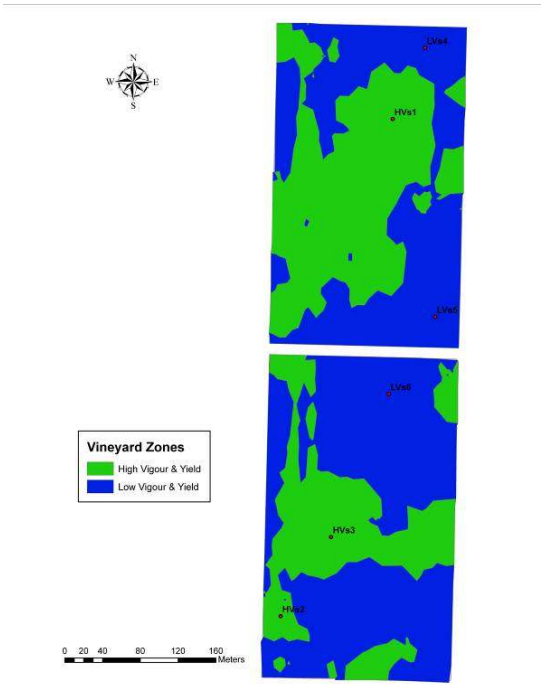
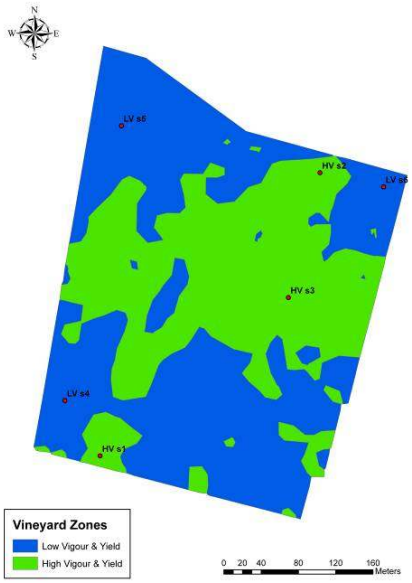


Figure 17. Schematic representation of vigour zones and sampling sites for Vineyard 2, 2006.



2006 Results for Vineyard 1.
Tables 9 and 10 present summary data for Vineyard 1. Appendix 5 contains all data collected for this site.

Table 9. Vine characteristics, berry composition and yield of Vineyard 1, 2006.

Vigour site	Shoot Length (cm)	Fruit Exposure (%)	Lignification (%)	Berry mass (g)	Baumé	Colour (mg/g)	Yield (t/ha)
Lower	80-110	40-60	100	1.34	13.8	1.5	7
Higher	120-160	20-40	90	1.43	12.9	1.1	9
Combined	90-140	40-60	95	1.39	13.4	1.3	8

The yield difference across the 2 vigour zones is reasonably small, particularly in comparison with 2004. The total yield per hectare is much lower than observed in 2005. Berry mass, Baumé at harvest and colour (mg anthocyanins/g) are higher for the lower vigour zone. This is discussed in more detail later.

Table 10. Winemaker tasting terms and scores for Vineyard 1 in the 2006 season. Maximum score per descriptor is 9.00. Tasting held at Wolf Blass Winery on 04/07/2006.

	Fruit descriptors							
Vigour zone	Leafy	Light fruit	Dark fruit	Stewy	Fruit complexity	Fruit concentration	Tannin expression	Wine score/20
Lower	2.77b	4.23b	5.20b	4.66a	5.00a	5.20a	5.41a	14.98a
Higher	4.93a	5.00a	3.02a	2.95c	3.39c	3.30c	3.73c	13.11c
Combined	3.00b	4.16a	4.50b	3.86b	4.64b	4.64b	4.82b	14.30b

It is clear from Table 10 that there are significant differences in the fruit descriptors, tannin expression and wine scores. The wines made from grapes harvested from the lower vigour sites show higher scores for the positive attributes of fruit complexity, fruit concentration and tannin expression as well as the wine score.

When the tasting using a trained panel was carried out, surprisingly no significant differences were found for any term listed in Table 10. As the trained panel tasting was carried out six months later than the winemaker tasting, it was agreed to repeat the two tastings to identify the reasons for this apparent lack of compatibility.

The winemaker tasting was repeated almost one year after the first on 5 June, 2007. Results from this tasting are given in Table 11.

Table 11. Repeat winemaker tasting for Vineyard 1 in the 2006 season. Maximum score per descriptor is 9.00. Tasting held at Penfold's Winery on 05/06/2007.

	Fruit descriptors							
Vigour zone	Savoury	Light fruit	Dark fruit	Lolly	Fruit complexity	Fruit concentration	Tannin expression	Wine score/20
Lower	4.79ns	3.40c	5.81a	2.83a	5.54a	5.58a	5.21a	14.88a
Higher	3.60ns	4.94a	2.54c	4.54a	3.71b	3.85c	3.54b	13.01b
Combined	4.04ns	4.15b	4.85b	3.25a	4.90a	4.96b	5.21a	14.31a

The two winemaker tastings showed considerable similarity, with the exception that there were changes in two of the fruit descriptors. Importantly, the wines from the lower vigour zone scored

significantly higher on the positive wine descriptors and the wine score. The wine from the higher vigour zone was generally lower in positive descriptors and also had a lower wine score. The wine from the combined zone, representing the entire vineyard, received scores between those for the lower vigour and higher vigour zones.

Intriguingly, the trained panel repeat tasting again did not find any significant difference. It was not possible to resolve the different results from the two tasting groups, although there is some evidence (more anecdotal than validated) that winemakers and trained panels approach the assessment of wines in different ways. Irrespective, the project team decided that the winemaker represented the 'client' for the grapes that underpinned the concept of this project and all subsequent interpretation is based on the sensory results from the winemakers.

Following the observation of different wine scores, additional wine and berry parameters were measured. Wine composition scores are presented in Table 12 and berry and wine tannin concentrations are given in Table 13.

Table 12. Compositional analysis of small lot wines from Vineyard 1 in 2006

Vigour zone	pH	TA (g/L)	Free SO_2 (mg/L)	Alcohol (% v/v)	Modified wine colour density (au)	Estimate of SO_2 resistant pigments (au)	Total red pigments (au)	Total phenolics (au)
Lower	3.61	7.3	29	14.4	14.2	1.9	29	39
Higher	3.64	6.7	27	13.5	10.6	1.3	23	31
Combined	3.61	7.0	32	13.5	12.2	1.6	25	34

Table 13. Berry and wine tannin concentration for Vineyard 1 in 2006.

Vigour zone	Berry skin tannin (mg/g berry mass)	Berry seed tannin (mg/g berry mass)	Berry total tannin (mg/g berry mass)	Wine tannin (mg/litre)
Lower	1.9	3.1	5.0	1203
Higher	1.5	2.4	3.9	789
Combined	1.8	2.9	4.7	1060

The modified wine colour density (Table 12) follows the same trend as the wine scores (Table 11) and berry anthocyanin values. The final alcohol concentration on the lower vigour wine is 0.7% higher than the values for the higher vigour and combined wines which suggest that the berries for this zone were slightly riper when the trial was harvested. The wine tannin value (Table 13) reflect tannin expression and wine score (Table 11)

2006 Results for Vineyard 2.
Tables 14 and 15 present summary data for Vineyard 2. Appendix 5 contains all data collected for this site.

Table 14. Vine characteristics, berry composition and yield of Vineyard 2, 2006.

Vigour site	Shoot Length (cm)	Fruit Exposure (%)	Lignification (%)	Berry mass (g)	Baumé	Colour (mg/g)	Yield (t/ha)
Lower	80-110	60-80	70	1.1	12.7	1.3	12
Higher	120-160	40-60	70	1.3	12.8	1.2	16
Combined	80-110	60-80	70	1.2	12.8	1.2	14

Reasonably consistent parameters were found for the vine and berry parameters measured in 2006. The Baumé at harvest is essentially the same for the two vigour zones and the combined sample (representing the whole of vineyard), although there was some variation is both berry colour and yield per hectare.

Table 15. Winemaker tasting terms and scores for Vineyard 2 in the 2006 season. Maximum score per descriptor is 9.00. Tasting held at Wolf Blass Winery on 04/07/2006.

	Fruit descriptors							
Vigour zone	Herbal	Light fruit	Dark fruit	Savoury	Fruit complexity	Fruit concentration	Tannin expression	Wine score/20
Lower	3.50	4.05b	5.75a	4.95a	5.07a	5.41a	5.52a	15.05a
Higher	4.20	4.45a,b	4.39b	4.20b	4.20b	4.25b	4.30b	13.84b
Combined	4.05	4.68a	4.64b	3.36b	4.27b	4.55b	4.57b	14.09b

The results for Vineyard 2 also showed significant differences with the wine from the lower vigour zone receiving higher scores for positive attributes and wine score. When the results of the trained panel were analysed, no significant differences were found. This was the same outcome as described above for Vineyard 1. Again, the project team determined to repeat the two tastings.

Table 16. Repeat winemaker tasting for Vineyard 2 in the 2006 season. Maximum score per descriptor is 9.00. Tasting held at Penfold's Winery on 05/06/2007.

	Fruit descriptors							
Vigour zone	Lolly	Light fruit	Dark fruit	Savoury	Fruit complexity	Fruit concentration	Tannin expression	Wine score/20
Lower	3.46b	4.48ns	5.23a	4.44ns	5.54a	5.71a	5.98a	14.83a
Higher	4.67a	4.88ns	3.83b	3.83ns	4.58b	4.83b	5.06b	13.92b
Combined	3.90b	4.46ns	4.42ab	3.88ns	5.00ab	5.04b	5.38ab	14.10b

The repeat tasting showed similar outcomes to those of the first tasting, although the original fruit descriptor of 'Herbal' became 'Lolly' in the second tasting. Not all descriptors showed the extent of difference observed in the first tasting, but importantly the wine scores show significant difference. The wine scores are in the order of lower vigour zone> combined >higher vigour zone.

Similar to that noted above for Vineyard 1, preference for subsequent discussion and interpretation of the results was given to the winemakers' tasting over the trained panel on the basis that the winemakers represent the client for the grapes.

Additional wine and berry parameters were measured on these wines and the results are presented in Tables 17 and 18.

Table 17 Compositional analysis of small lot wines from Vineyard 2 in 2006

Vigour zone	pH	TA (g/L)	Free SO_2 (mg/L)	Alcohol (% v/v)	Modified wine colour density (au)	Estimate of SO_2 resistant pigments (au)	Total red pigments (au)	Total phenolics (au)
Lower	3.73	6.3	29	13.0	15.0	2.1	30	42
Higher	3.74	6.7	29	13.2	12.1	1.6	27	38
Combined	3.78	6.2	30	12.9	12.0	1.7	27	39

Table 18. Berry and wine tannin concentration for Vineyard 2 in 2006.

Vigour zone	Berry skin tannin (mg/g berry mass)	Berry seed tannin (mg/g berry mass)	Berry total tannin (mg/g berry mass)	Wine tannin (mg/litre)
Lower	2.0	3.7	5.7	952
Higher	1.7	3.6	5.3	972
Combined	1.7	3.6	5.3	900

There is general consistency in the measured parameters, although the wine from the lower vigour zone tends to have slightly higher numbers. The values for the wine from the combined sample fall between those for the two vigour zones. The modified wine colour density is higher for the lower vigour wine. Surprisingly, the wine tannin value for the higher vigour zone is higher than the other numbers, but the spread (72 mg/litre) is within the precision of the measurement.

Comparison of years

This project has attempted to minimise the use of the term 'quality', as it has more subjective rather than objective characteristics. However, wine score is one tentative approach to determining what some might regard as a 'preferred' wine. That is, when two or more wines that are fault free are compared and one receives a higher score, this can be taken as an indicator of a wine with 'preferred qualities' to the taster: the plural use of qualities is more appropriate that the singular.

The small lot wines made in this project in 2005 and 2006 were fault-free and, as noted earlier, the fermentation replication was such that only one of the replicates needed to be tasted for any one site.

It is also important to note that, although some of the 2004 wines showed oxidation faults (acetaldehyde), there was no significant difference between the sensory assessments of the small lot (50 kg) wines with unreplicated 20 tonne commercial ferments. Commercial ferments were not carried out in 2005 and 2006. However, the similar sensory description of the wines in 2004 between the small lot and commercial ferments is an indicator of the usefulness of small lot winemaking for this type of evaluation of parameters in the vineyard that could influence wine composition and its qualities.

In this project over the three vintages examined, a difference in some wine descriptors between the vigour zones was observed for Vineyard 2 in 2005 only. In 2006, significant differences were observed in several parameters and also wine scores for the vigour zones in both Vineyard 1 and Vineyard 2. Intriguingly, in several cases where differences in berry sensory characters were observed in the vineyard (for example, Vineyard 3 in 2005), no significant differences were found in subsequent scores for the wines made from the grapes collected from the different vigour zones. The approach taken in 2006 to define the vigour zones followed the *k*-means clustering technique, a more rigorous approach to zonal delineation than that used in 2004 and 2005. Figures 18 and 19 present schematic representations of the zones for 2006 with the sampling sites used in each of the three years identified. There is considerable similarity in the sampling sites per vigour zone in each of the three years, suggesting that there is reasonable consistency in the sites used throughout this study. It is, however, recognised that some sampling sites are located closer than preferred to zonal boundaries. In essence, the outcomes of this project indicate that three years are needed in the first instance to define the zones with a high degree of reliability.

Figure 18. Schematic representation of vigour zones and sampling sites for Vineyard 1 in all years.

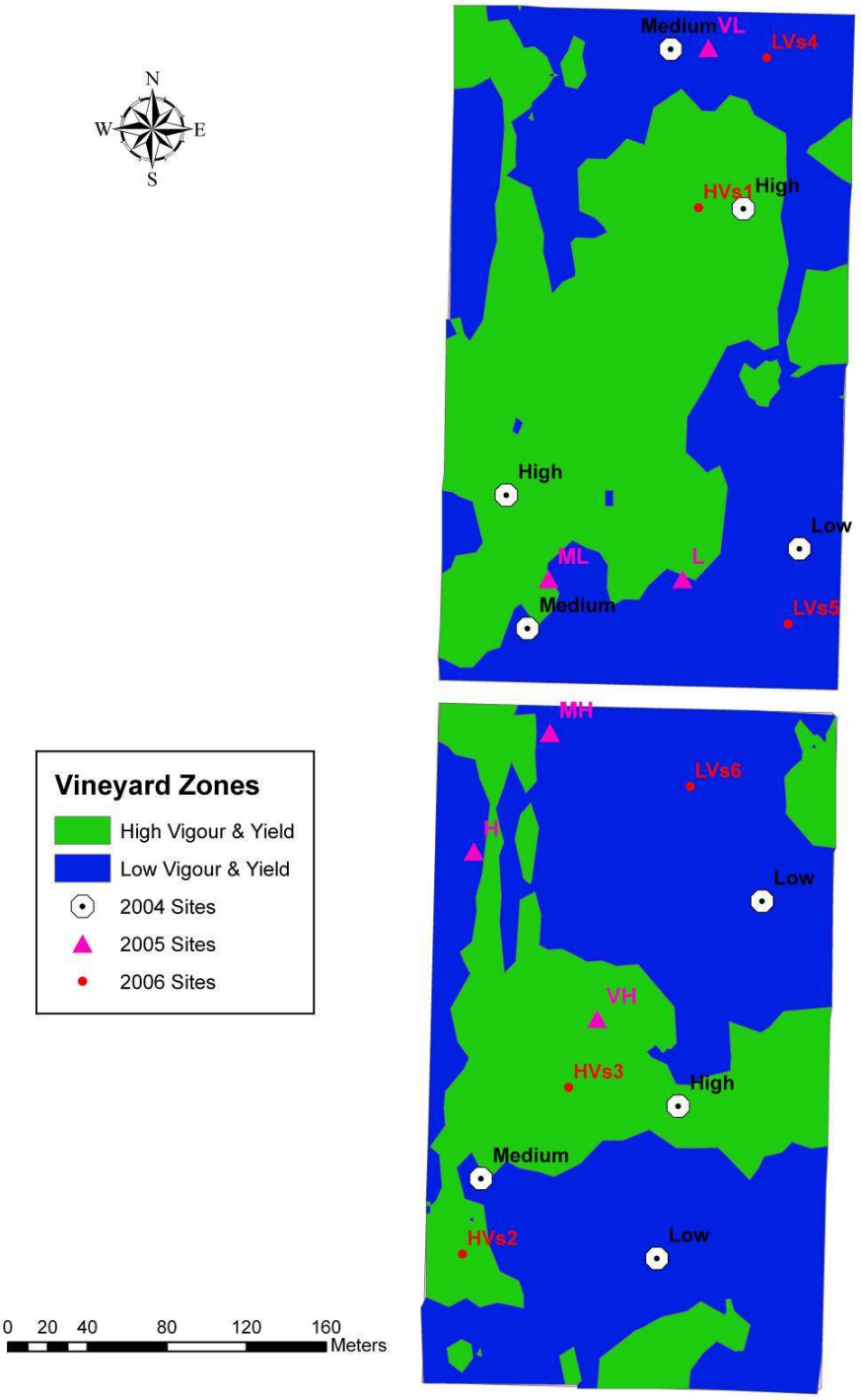
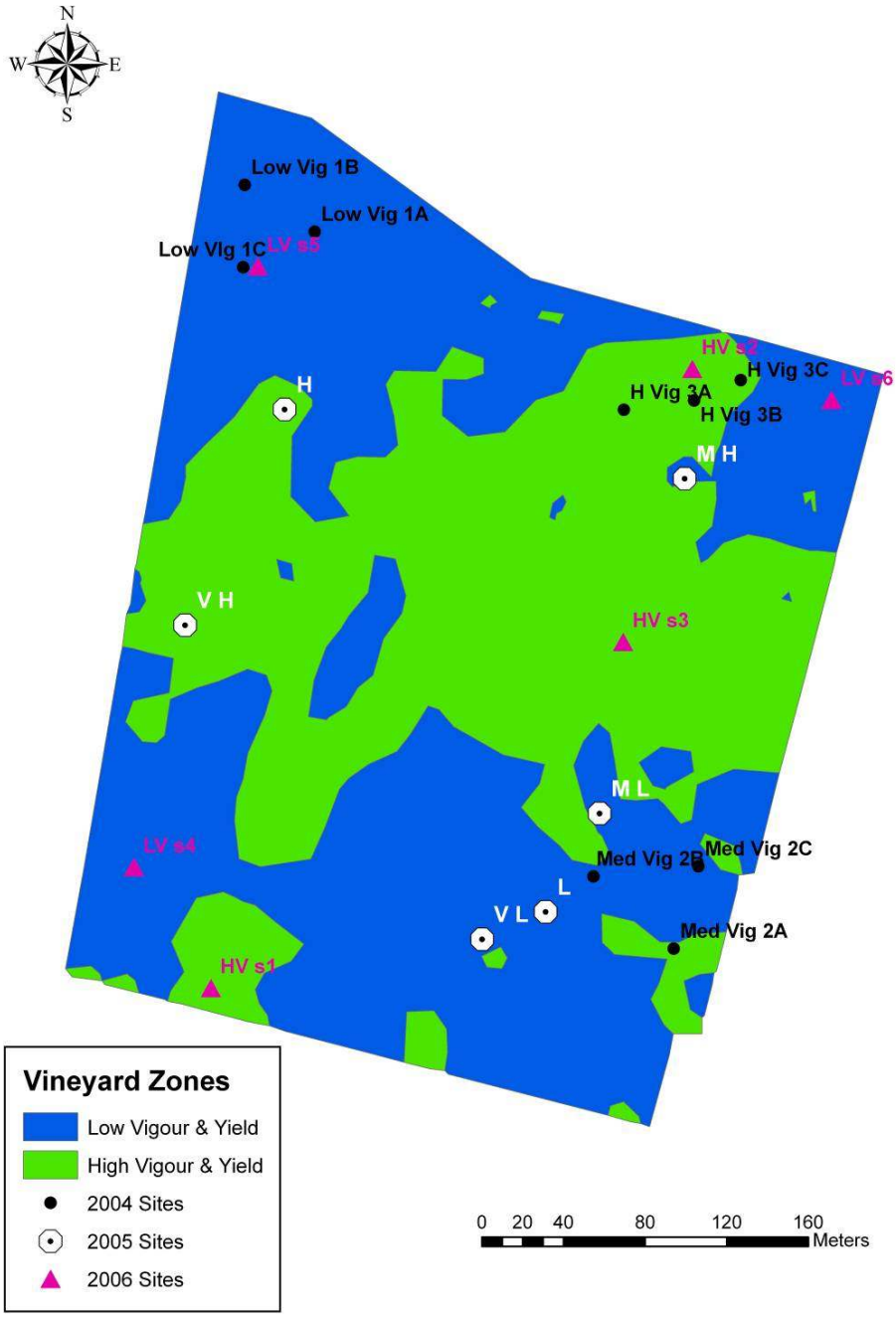


Figure 19. Schematic representation of vigour zones and sampling sites for Vineyard 2 in all years.



Colour is sometimes used to assess the relationship between grapes and subsequent wine characteristics. Tables 19 and 20, extracted from data in Appendix 5, present the mean anthocyanin values for berries collected at the time of harvest for each zone at Vineyards 1 and 2.

Table 19 Mean berry anthocyanin values (harvest samples) for Vineyard 1. Data for Tasting 1 in 2006

	Mean anthocyanin values (mg/g)	Difference between higher and lower zones	Percent difference	Wine score/20
2005				
Lower vigour	1.05	0.13	14	14.63ns
Higher vigour	0.92			14.22ns
Combined	1.01			14.58ns
2006				
Lower vigour	1.48	0.42	40	14.98a
Higher vigour	1.06			13.11c
Combined	1.27			14.30b

Table 20 Mean berry anthocyanin values (harvest samples) for Vineyard 2. Data for Tasting 1 in 2006

	Mean anthocyanin values (mg/g)	Difference	Percent difference	Wine score/20
2005				
Lower vigour	1.47	0.21	17	15.05a
Higher vigour	1.26			14.18b
Combined	1.55			14.50b
2006				
Lower vigour	1.33	0.18	11	15.05a
Higher vigour	1.15			13.84b
Combined	1.24			14.09b

It is apparent for both Vineyard 1 and Vineyard 2 in the 2005 and 2006 seasons that grapes from the lower vigour zones always had a higher berry colour value (measured at harvest) than those from the higher vigour zones or the combined zones. In 2004, for Vineyard 1, the difference in berry colour between the higher and lower vigour berries was 0.5 (30%) while the wine scores varied from 12.7 to 13.3 while for Vineyard 2, the colour difference was only 0.19 (17%) with wine scores varying between 13.1 and 13.6.

The difference in colour between the two vigour zones did not therefore show any direct relationship with the difference in the score for the wines from the two zones. Clearly, a range of berry parameters must influence the final wine composition that in turn influences the wine scores. It must be noted that the fermentations followed a standard protocol, so that any effect of the fermentation on the final wine score would be minimal. That is, the different wine scores are a reflection of vineyard influences on berry composition and hence wine composition.

OUTCOMES AND CONCLUSIONS

The purpose of this project was to try and exploit opportunities created with the knowledge of vineyard variability to maximise the value of the grapes harvested. Variability in the vineyard may lead to significant changes in grape compositional parameters that in turn may lead to grapes being allocated to wines that reach the higher price point in the market place. This is turn may be reflected in a higher financial return to grapegrowers. In the following modelling exercise, wine score was taken as the indicator of a possible higher price point for the finished wine.

Modelling the financial impact of vineyard variability.

This model has restricted the vineyards to two vigour zones: one of higher vigour and one of lower vigour. Options that might be available from differential harvesting are

- Harvest grapes from one zone that are allocated to a higher classification, while the grapes from the other zone mover to a lower classification in comparison the classification that would have been achieved if the vineyard were harvested as a single unit.

- Harvest grapes from one zone that are allocated to a higher classification, while the grapes from the other zone remain in the same classification as the allocation for the entire vineyard

For the first option, the additional cost of differential harvesting may negate the price benefit received from the zone with grapes that receive the higher classification, especially if the zone which is classified downwards is a larger component of the vineyard.

With both options, any slight benefit that might arise through differential harvesting might be outweighed by a larger financial return that could be obtained by increasing the vine capacity, especially in the lower vigour zone, with vineyard remedial work.

The following calculations have been carried out in a relatively empirical way to test the above options with respect to returns to the grower. With only three years of data, it has not been possible to test the proposal with respect to increasing productivity through amelioration of the lower vigour zone. This is one area of research that needs to be followed up from this project.

In developing the model, the following management assumptions were use

- $35/ha cost for remote sensing (Bramley, 2007)
- $40/ha for yield monitoring.
- $95/ha for differential harvesting.

In addition, the following indicative prices were used in the calculations:

- $1000 / tonne for ‘normal’ grade of fruit.
- $1200 / tonne for ‘normal + 1’ grade of fruit.
- $800 / tonne for ‘normal – 1’ grade of fruit. #

where ‘normal + 1’ refers to fruit which has been classified to a higher grade and ‘normal – 1’ refers to fruit which has been classified to one grade lower than the norm for the vineyard. The prices used do not reflect any specific company pricing policy. A vineyard manager would be able to use actual prices relevant to his or her vineyard and insert these prices into the calculations below.

For ease of presentation, the following procedure assumes that each zone within the vineyard is equal is size. The calculation procedure can be readily adapted for a specific vineyard which may have, for example, 20% per hectare allocated to one vigour zone and 80% per hectare allocated to the other vigour zone.

2004 Data – Vineyard 1.
There were no significant differences evident in the resulting wine scores from Vineyard 1. It is interesting to note, however, that on Vineyard 1 the yield differences from the clustering analysis were:

- 6.7 t/ha on lower vigour vines and
- 12.3 t/ha on higher vigour vines.

With no significant difference recorded in wine scores, there was no benefit to utilise differential harvesting of the grapes.

It must be noted that there is a $5,600 difference in revenue per hectare between the 'higher vigour' and 'lower vigour' zones within the vineyard using the 'normal' price of $1,000 per hectare. If the yield on the 6.7 t/ha 'lower vigour' zone were increased with soil amelioration or irrigation management changes, there could be a significant benefit to the revenue achieved per hectare, assuming that the amelioration did not alter the resulting wine score on this zone.

2004 Data – Vineyard 2.
As with Vineyard 1, no significant differences were evident in the resulting wine scores for Vineyard 2.

Yields between the different vigour zones were much closer than for Vineyard 1 at 14 t/ha for 'lower vigour' and 16.3 t/ha for 'higher vigour' zones. It is therefore reasonable to assume that this vineyard is reasonably uniform, in the way it expressed itself in compositional parameters in this year, and little financial benefit could be derived from alternate management techniques.

2005 Data – Vineyard 1.
Again, no significant differences were evident in the resulting wine scores for wines from the different vigour zones of Vineyard 1. The discussion above for this vineyard in 2004 is applicable here for 2005.

2005 Data – Vineyard 2.
The 'lower vigour' zone produced a wine with a significantly better score than both the 'higher vigour' zone and the 'combined' vineyard sample. This suggests that by differentially harvesting the 'lower vigour' region, the financial benefit could be derived for each hectare of the vineyard as set out below. The benefit is calculated as the difference per hectare between the revenue for single harvest versus revenue for differential harvest.

1. Vineyard yields
   - 'lower vigour' zone yielding 9 t/ha.
   - 'combined' vineyard area yielding 12 t/ha.
   - 'higher vigour' zone yielding 15 t/ha.

2. Single harvest of whole vineyard
   - Revenue achieved from 1 hectare would be 12 tonne x $1,000/t = $12,000, using the 'normal' price.

3. Differential harvesting, assuming one zone increased in value with the other zone remaining at the 'normal' price
   - Differential Harvesting would result in a benefit of 0.5 ha x (9t x $1,200 + 15t x $1,000) = $12,900
   - Operating costs for differential harvesting and remote sensing (see above) = $170/ha
   - Return per hectare would be $12,730.

A net benefit of $730 per hectare would then result from differential harvesting

2006 Data – Vineyard 1.
There were two winemaker sensory studies completed for these wines approximately one year apart with slightly different results. In the first tasting soon after vinification, the score for the 'lower vigour' wine was significantly higher than that for the 'combined vigour' wine which was also significantly higher than the 'higher vigour' wine. The later tasting showed the same trend, but the difference between the 'combined' and 'higher' vigour wines was not significant.

1. Vineyard yields
- 'lower vigour' zone yielding 7 t/ha
- 'combined vigour' zone yielding 8 t/ha
- 'higher vigour' zone yielding 9 t/ha

2. Single harvest of whole vineyard
- Revenue achieved from 1 hectare would be 8tonne x $1,000/t = $8,000 using the 'normal price.

3. Differential harvesting.
a) assuming one zone increased in value with the other zone decreased in value
- Differential harvesting would result in a benefit of 0.5 ha x (7t x $1,200 + 9t x $800) = $7,800
- Operating costs for differential harvesting and remote sensing (see above) = $170/ha
- Return per hectare would be $7,630

Net loss of $370 per hectare would result from differential harvesting.

b) if Tasting 2 is a more realistic reflection of the wines from the two zones, one zone would increase in value and the other zone would remain at the 'normal' price
- Differential harvesting would result in a benefit of 0.5 ha x (7t x $1,200 + 9t x $1,000) = $8,700
- Operating costs for differential harvesting and remote sensing (see above) = $170/ha
- Return per hectare would be $8,530

Net benefit of $530 per hectare would result from differential harvesting.

This calculation clearly shows that where a specific parcel of fruit can be picked out from the vineyard and the remaining parcel achieves the same wine score as if the whole vineyard were picked together then there is a clear benefit.

There is actually a financial loss where the vineyard is picked in two equal halves with the fruit from one zone increasing by one fruit grade and the fruit from the other zone decreasing by one grade.

2006 Data – Vineyard 2.
The two winemaker sensory studies completed for these wines showed the same result: the 'lower vigour' wine had a significantly higher wine score than that for the 'combined' and 'higher' vigour wines.

1. Vineyard yields
- 'lower vigour' zone yielding 12 t/ha
- 'combined vigour' zone yielding 14 t/ha
- 'higher vigour' zone yielding 16 t/ha

2. Single harvest of whole vineyard
- Revenue achieved from 1 hectare would be 14 tonne x $1,000/t = $14,000 using the 'normal price.

3. Differential harvesting.
- Differential harvesting would result in a benefit of 0.5 ha x (12t x $1,200 + 16t x $1000) = $15,200
- Operating costs for differential harvesting and remote sensing (see above) = $170/ha
- Return per hectare would be $15,030.

Net benefit of $1030 per hectare would result from differential harvesting.

Summary of financial modelling.
Where a vineyard is divided into two equal zones based on area, then a reasonable financial benefit of the order of $560 to $1,030 per hectare can be achieved by differential harvesting, provided that one zone increases in value and the other zone remains the same as the total vineyard block.

In the case where one zone increases by one grade and one zone decreases by one grade; then there is not likely to be a benefit as illustrated above with a net loss of $370 per hectare for differential harvesting.

If a vineyard were to be differentially harvested and, for example, only a 1/5th of the vineyard area taken for the increased classification of fruit, the risk of causing the fruit from the remaining zone to fall by one grade may be negated.

If the value of the fruit were to increase or decrease by more the one grading point, the same modelling procedure used above would still apply, except that the financial benefit would be increased or decreased accordingly. Obviously, the modelling process described here would increase in accuracy with respect to calculating financial returns if actual prices were related to purchaser grape assessment of the fruit from different zones were used. However, this pricing assessment is under commercial in confidence for individual growers and companies.

One interesting issue that will bear heavily on the calculated financial return of the differential harvesting will be the yield across the vineyard. Where lower yielding vineyards might increase by one grade point for one zone, the financial benefit will be small as the multiplication effect by yield is diminished. However the opportunity exists for lower yielding blocks to increase in value by more than one grade point, hence increasing the multiplication factor through an increase in grape price.

More research would be extremely beneficial in the area of applying remedial management techniques to the 'lower vigour' regions of the vineyard with the view to increasing yield. If the yield could be increased on these areas and no effect was evident on the resulting wine score, then the financial benefit on a per hectare basis should be evaluated against the value of differential harvesting.

RECOMMENDATIONS

This project has examined the relationship between vineyard variability and the potential cost advantages of differential harvesting zones based on vigour. The focus has been on vineyards producing grapes for the 'popular premium' category of wines that represent approximately 35% of Australia's current wine sales.

The project has developed a general protocol that will allow vineyard managers and winemakers to assess if advantages may accrue from zonal analysis and differential harvesting.

To assist with this assessment, a 'how to' guide has been produced as a supplement to this report. The guide will be made available via the web for general access.

In addition, an empirical approach to assessing the capacity for increased revenue from differential harvesting has been developed. This calculation procedure has been set out to allow individual managers apply the methodology for specific vineyard situations.

ACKNOWLEDGEMENTS

The authors of this report wish to acknowledge to substantial contributions made by the following

- Dr Rob Bramley, CSIRO Sustainable Ecosystems, for advice on zonal analysis and *k*-means clustering
- Dr Brenton Dansie, University of South Australia, for statistical analysis
- Paul Petrie, Foster's Group, for assistance with statistical analysis of the wine sensory assessment.
- Dr Richard Hamilton, Foster's Group, for assistance on general project design
- Myrrhee Consulting for assistance with berry analysis.
- The winemakers from the Foster's Group who willingly participated in the many sensory analysis sessions held over the course of the project.

APPENDIX 1

COMMUNICATIONS

Articles published
Luke, Rolley, Patrick Iland, Geoff Scollary, Rob Bramley and Susie Williams, *Managing vineyard variability for a targeted wine outcome*, **Australian Viticulture**, March/April 2006, 23-28.

Industry Presentations
Geoffrey R Scollary, *Viticulture trials, small lot winemaking and quality improvement*, NWGIC Industry Symposium, June 24, 2004

Geoffrey R Scollary and Don La Borde, *Managing vineyard variability – Sensory evaluation*, NWGIC Industry Symposium, June 24, 2004

John Blackman, *Small lot winemaking and sensory analysis at NWGIC*, Mudgee Wine Symposium, June 24, 2005.

Geoffrey R Scollary, *Managing vineyard variability - trial results and industry outcomes*, NWGIC Symposium, 22 June 22, 2006

Patrick Iland and Luke Rolley, Remote sensing – does it remotely work? Studies on vineyard variability, Foster's group Winemakers' technical meeting, Saltram Winery, Barossa Valley, 15 May 2007.

Technical article to be published
Australian Viticulture – in preparation for the March/April 2008 number

Scientific publications
Planning has commenced for one and possibly two publications. Manuscripts will be completed during 2008.

APPENDIX 2

INTELLECTUAL PROPERTY

The Outputs of this project involve significant knowledge for the benefit of the wine industry. This knowledge is presented in an easy-to-read 'How-to' web resource that will be available for ready access by vineyard managers and winemakers.

In addition, an economic model has been developed to assist vineyard managers in developing the most cost effective strategies for site management.

APPENDIX 3

REFERENCES

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Proffitt, T., Bramley, R., Lamb, D, and Winter, E. (2006). Precision viticulture – a new era in vineyard management and wine production. Winetitles, Adelaide, Australia.

APPENDIX 4

STAFF

The following table lists staff involved in the project. The role of each person and the funding source is also identified.

Name	Agency	Years in project	Role in project	Funding
Geoffrey Scollary	NWGIC, CSU	Full project	Project supervisor	NWGIC in-kind
Luke Rolley	Blaxland Vineyards Limited	Full project	Chief Investigator	Project funds and Blaxland Vineyards in-kinds.
Patrick Iland	Patrick Iland Wine Promotions	Full project	Consultant	Project funds
Allen Hart	Foster's Group	Full project	Winemaker consultant	Foster's in-kinds
John Blackman	NWGIC, CSU	Full project	Sensory analysis	NWGIC in-kinds
Emily Rouse	NWGIC, CSU	2005 – 2007	Experimental winemaker	GWRDC funds
Anthony Saliba	NWGIC, CSU	2007	Sensory analysis	GWRDC Winegrowing Futures funds
Brenton Dansie	University of South Australia	Full project	Statistical analysis	Project funds
Peter Morath	Gundagai Vineyards	Full projects	Graperower consultant	Gundagai Vineyards in-kinds
Don La Borde	NWGIC, CSU	2004 vintage	Winemaking assistance	Project funds
Wayne Brown	NWGIC, CSU	2005 & 2006 vintage	Winemaking assistance	Project funds
Angela Wilton	NWGIC, CSU	2005 & 2006 vintage	Winemaking assistance	Project funds
Ann Noble	UC Davis	2004	Sensory analysis	Project funds

APPENDIX 5

RAW DATA

APPENDIX 6

FINANCES

GWRDC cash
Separate documentation will be provided by Charles Sturt University

In-kinds
The contributed staff and facilities to this project generated considerable in-kinds.

G Scollary	$90,000*
J Blackman	$37,500*
L Rolley	$36,000**
A Hart	$20,000**
P Morath	$10,000**

**Calculated as 2.5 times project salary as NWGIC in-kinds*
***Calculated at the rate of $120 per hour for estimated hours on project*

Foster's staff in winemakers' sensory analysis*

2005	$4,800 (10 participants)
2006	$5,280 (11 participants)
2007	$5,760 (12 participants)

**Calculated at the rate of $120 per hour for 4 hours for each participant)*

NWGIC staff in descriptive sensory analysis*

2004	$28,800 (12 participants, each for 20 hours)
2004	$4,320 (9 participants, each for 4 hours)
2007(1)	$9,600 (10 participants, each for 8 hours)
2007(2)	$4,800 (10 participants, each for 4 hours)

**Calculated at the rate of $120 per hour)*

Vineyards

Vineyard 1	$6,000
Vineyard 2	$6,000
Vineyard 3	$2,000

Total in-kind contribution = $233,360