To develop monitoring protocols for vineyard irrigation with reclaimed water by determining the effects of irrigation on vine performance and soil properties



FINAL REPORT to
GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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Abstract
A long-term irrigation experiment comparing the use of domestic reclaimed water and potable water for vineyard irrigation was established in McLaren Vale in 1998. After nearly ten years of data collection no issues have emerged regarding grapevine growth, nutrient levels or berry development with the volume and reclaimed water quality applied at this site. Continuous monitoring of soil water content at depth below the sphere of influence of irrigation application suggests there is no movement of water or nutrient below the rootzone during the irrigation season. This was verified by additional monitoring with soil water solution extractors during the latter years of the investigation which also revealed data on nutrient movement below the rootzone during vine dormancy. Analysis of commercial wines made with fruit sourced from selected treatments over two vintages indicates no difference to 'control' wines.

Executive Summary
This report covers the entire period of data collection from a large field experiment on the use of reclaimed water for irrigation of Shiraz grapevines in McLaren Vale SA. GWRDC, Beringer Blass Wine Estates and the Willunga Basin Water Company initially funded this project. Since July 2003 Beringer Blass and the Water Company have funded the project. In 2005 the project site was incorporated into CRCV Project S2.3.6 and subsequent funding was received from CNRM in SA to monitor nutrient movement.

Results to date indicate that with the relatively small volumes of reclaimed water applied there have been no unforeseen consequences. Berry size, yield, petiole nutrient status are similar to that of vines receiving high quality potable water. Soil water monitoring indicates that no applied water is moving below the rootzone during the irrigation season. Additional monitoring equipment to quantify water and nutrient movement below the rootzone has thus-far coincided with a number of seasons of below average rainfall, however some trends have emerged.

Analysis of wines made in 2002 and 2003 reveal no differences in minor and major elemental analysis. These analyses included a wide range of heavy metals. The concentrations of aromatic or chlorinated hydrocarbons were at or below detectable limits in all wines for all classes of compounds.

This experiment has demonstrated that the use of reclaimed water for vineyard irrigation may present no additional issues compared with more traditional water sources. However, the reclaimed water used in this experiment is of relatively high quality (moderate salinity, low nutrient status, low concentrations of heavy metals etc) compared with some other reclaimed water sources and as such the level of environmental/plant monitoring required is probably no greater than, for example, where similar water salinity from underground sources is used for vineyard irrigation . Where lower grade or more variable reclaimed water is used a number of additional monitoring protocols should be considered to ensure long-term sustainability and minimal on- and off-site impacts:

- Bloom time petiole nutrient analysis should be conducted on a regular basis and seasonal trends monitored. Although benchmark data are lacking, petiole nutrient analysis at veraison may, with time, indicate any potential plant and berry nutrient imbalances during ripening.
- Continuous logging soil water sensors should be installed, including sensors below the rootzone. Consideration should be given to the installation of soil water solution samplers; however, experiences at the Mclaren Vale indicate that samples are difficult to collect during the irrigation season when only relatively small volumes of water are applied. Further information on salinity management practices and the use of solution samplers is available in the NPSI Sustainable Irrigation Management Update "Salinity Management Practice Guidelines – Managing rootzone salinity for irrigated horticultural crops in the winter rainfall zones of Australia" (2009).
- Soil sampling, within and at the edge of the zone of influence of irrigation should be collected at the beginning and end of the irrigation season to assess soil salinity and sodicity hazard. Rootzone depth should be determined by examining soil pits at mature representative vines

- Volumetric soil water sensors should be calibrated for the soil type or alternatively soil matric sensors should also be installed to accurately reflect potential drainage issues.
- Irrigation scheduling should be based on soil water sensors in preference to modelling of crop water use using weather data where some assumptions need to be made at the beginning of the irrigation season regarding soil water content and crop water use. Weather data can however be used to help validate soil water information. This will ensure over-irrigation and hence nutrient movement below the rootzone is minimised. In high winter rainfall regions cover crops could be utilised to reduce potential off-site leaching of applied nutrients.
- Detailed water quality data are recorded as short periods of elevated salt or nutrient loadings are as important as long-term averages depending on when such spikes occur during the growing season.

These protocols may already be required by local or state government instrumentalities responsible for the safe use of reclaimed water on agricultural crops. Since the commencement of this investigation a number of Industry-applicable publications on guidelines for the use of reclaimed water and rootzone salinity management have been published and are readily available. There are a growing number of websites where information on the use of reclaimed water in horticulture can be sourced; some of these are listed in the references. (Appendix 3). The findings from the McLaren Vales site reported here suggest that for the reclaimed water quality currently being used in the region presents few issues for winegrape growers and potentially is a preferred water source to the more saline underground water being used by some growers in the region

Background

The Australian Wine Foundation's *Strategy 2025* (1996) set a target of Australia achieving 6.5 percent of world wine production by the year 2025 and to achieve this a doubling of production was required. It was estimated that an estimated additional 70,000 million litres of water would be required to support such an expansion. While this target has already been achieved, primarily through water licence transfers concern is growing about the long-term security of some water sources, in particular if changes due to climate change eventuate.

Most regions in Australia now have restrictions on water allocated to irrigators, for instance the cap on water drawn from the Murray-Darling System and many other grape growing regions have imposed limits on both surface and underground water resources. This limits opportunities for future vineyard expansion. On the other hand, pressure to restrict the disposal of nutrient-rich municipal wastewater into fresh water rivers and creeks or the ocean has led to a rapid expansion of municipal wastewater available for irrigation (Balks et al. 1998) such as both north and south of Adelaide, the Barossa Valley, Ararat, Werribee, and many other locations across Australia.

The grape and wine industry has responded to the need to reduce inputs and waste generation in many areas of production and processing including conservation of water in vineyards and wineries. To achieve this, the utilisation of the community's municipal wastewater as a resource will be another step towards creating a sustainable industry existing in harmony with the environment that it shares with the greater community.

As a consequence of this the use of treated wastewater for vineyard irrigation is rapidly increasing in Australia as sources of "new" water become limited. Large-scale developments are in place or under way in the McLaren Vale area with Adelaide reclaimed domestic water, around towns in the Barossa Valley and in Gt. Western with wastewater piped from the city of Ararat and other regions. Future developments are planned in SA, NSW and Vic. The use of reclaimed water for vineyard irrigation is not new in Australia; however, with the exception of limited studies in the early 1970's there has been no intensive examination of the use of these water sources in viticulture in Australia. If poorly managed it may cause environmental problems and this would not reflect favourably on our "green & clean" image. Potential environmental problems include recharge to groundwater accompanied by salts and nitrate, accumulation of salts and trace contaminants in the soil and the associated increased risk of runoff of these contaminants into waterways. The development of sound soil and irrigation management practices and the adoption of these practices by industry are paramount to achieving an environmentally sound system; these guidelines and recommendations do not currently exist. In addition there is a need to understand the relationship between wastewater use, vine performance and fruit composition with regard to nitrogen content and fermentation. Reclaimed water sources with high Potassium concentration need careful management with respect to impacts on the soil, plant and wine. Most of the research to date has been carried out overseas, whereas Australia is still in the research stage. Consequently there are no sets of standards or guidelines in Australia for the use of municipal wastewater in vineyards and guidelines developed in both Israel and California are not applicable due to significant differences in wastewater characteristics, soils, irrigation practises, the environment and wine grape specification

Project Aims

1. To develop an understanding of the long-term effects of irrigation with reclaimed water on vine establishment, growth and wine quality
2. Gain an understanding of the long-term effects of reclaimed water on soil chemical and physical properties.
3. Provide guidelines to the grape industry for design, establishment and management of vineyards using reclaimed water

General Methods

Site Information

The experimental site was located on a Fosters Wine Estates (FWE) vineyard, locally known as Logans Legacy, approximately 1 km southwest of the McLaren Vale township adjacent to the Main South Road. The vineyard was planted in 1998 using planting material supplied by Fosters (then Beringer Blass). One half of the experimental block was planted with own rooted Shiraz clone 1654, the other half being Shiraz vines grafted onto P1103 rootstock. At the time of establishment 2 drip lines were installed along each vine row to permit later conversion to either reclaimed water or high quality water (the regions potable water supply and hereinafter referred to as Mains water). This occurred prior to the 2001-2002 growing season. A prerequisite was for each treatment plot to be of sufficient size to yield sufficient fruit for semi-commercial winemaking (2 T lots). Prior to planting a comprehensive soil survey was conducted to match irrigation shifts to soil water holding capacity and in 2004 an EM38 survey was conducted to further describe soil properties in the experimental area.

Experimental Design & Irrigation treatments

Five irrigation treatments were imposed on own-rooted and grafted vines. T_1 vines continued to be irrigated with reclaimed water (Figure 1) while T_5 vines were switched to mains water for the entire irrigation season. T_2 vines were irrigated with mains water from flowering to veraison only with reclaimed water the remainder of the season. T_3 vines were watered with reclaimed water from the start of the irrigation season to veraison when they were switched to mains water to harvest. T_4 vines received mains water only after harvest. The treatments were designed to elucidate the impacts of the application of the reclaimed water during the key growth and berry development phases.

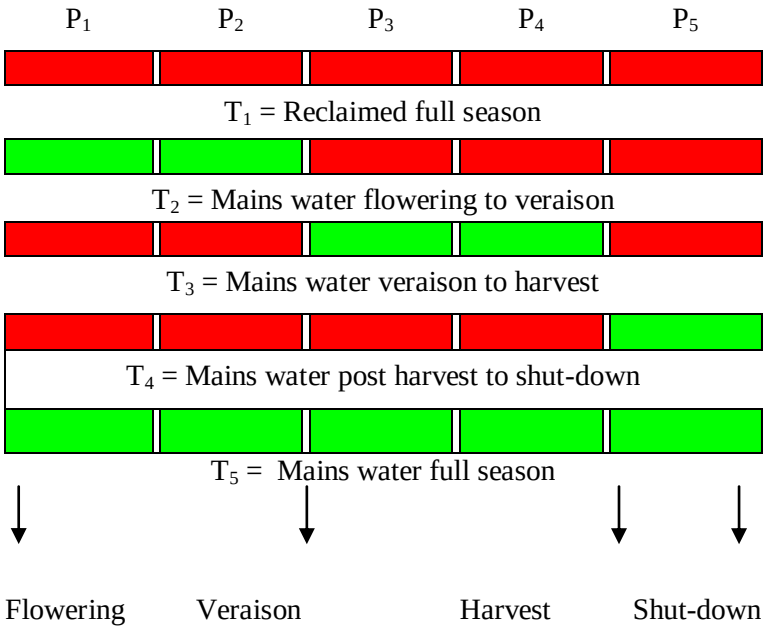


Figure 1 Schematic representation of the timing of reclaimed and mains water application in Beringer Blass McLaren Vale vineyard

FWE determined the timing and volume of irrigation water applied in each season. Irrigation switching occurred at defined key phenological stages. In all seasons little irrigation water was been applied after harvest and it was decided not to implement T_4. In the 2004/2005 season in particular only small volumes of irrigation were applied before veraison.

Soil water monitoring

Two GSM linked EnviroScan(TM) units were installed. Access tubes were located in T1 & T5 in own-rooted & rootstock blocks. Sensors were placed at 10, 20, 30, 50, 70, 90, 120 & 150 cm depth

and soil water data was recorded every 30 minutes. In 2006 one of the EnviroScan units was integrated in a logging system comprising gypsum blocks, a CSIRO drainage meter and an automatic weather station. Sentek SoluSamplers(TM) were installed in two treatments in 2006.

Weather

An AgriLink(TM). automatic weather station was installed at the experimental site by FWE who provided summarised data as required. In 2006 an MEA Automatic Weather Station was installed at the site

Irrigation water quality

Water quality of both water sources was regularly monitored by relevant authorities for a wide range of anions, cations, heavy metals, chemical residues etc

Petiole analysis

Basal petioles opposite bunches were collected at flowering, veraison and harvest from selected treatments during each season; however, not all treatments were sampled at each phenological time. Petioles were collected from vines chosen at random along the entire middle row of each treatment and samples form the two replicates were bulked prior to analysis. In recent years only selected treatments on own-rooted vines were sampled. Petioles were analysed by the Analytical Crop Management Laboratory at Loxton.

EM38

A shallow and deep EM38 survey was conducted by Mr Terry Evans (Rural Solutions SA) in April 2004 at the end of the irrigation season using a unit towed behind a 'quad' bike fitted with differential GPS. The shallow and deep survey comprised the 0-60 and 60-120 cm zones respectively.

Yield and Maturity Indices

Three subplots each of nine vines were tagged in each treatment and hand-harvested each year for yield estimation. Subplots comprised vines of approximately similar trunk diameter, however, it was not always possible to tag nine adjacent vines and in some subplots only 7 or 8 adjacent vines were used. In seasons berry development was monitored all berry samples were collected from subplots for the determination of ^{o}Brix, pH, titratable acid and, in some seasons, berry anthocyanin content and concentration.

Wine Composition

Beringer Blass processed commercial-size wine lots. For each nominated treatment approximately 2T fruit was machine harvested by Beringer Blass by harvesting the middle row of each treatment plot and combining the two replicates. Single ferments were used for each treatment and processed using standard in-house winemaking procedures. Wines were analysed by AWRI post malo lactic conversion. A range of analyses were conducted on wines.

Results & Discussion

Water Application

An example of the change in soil water content for one set of soil water sensors is presented in Figure 2.

Soil water content data presented in Figure 2 does not accurately represent actual soil water content as the sensors were not calibrated for the soil type in the experimental area; only changes in soil water content can be reported.

The sensors placed at 10 & 20 cm depth recorded each irrigation event during the 2004-05 irrigation season. The 30cm sensor detected most irrigation events, however, by February the magnitude of the changes were smaller than at the beginning of the irrigation season. The 50 cm sensor only detected two irrigation events in early January 2005 with a season-long trend of soil drying. Sensors at 70, 90, 120 and 150 cm did not detect any irrigation events throughout the irrigation season and at all depths there was gradual drying of the soil profile commencing in late November/early December. Unfortunately, as the sensors were not calibrated the absolute soil water content is unknown. Values for 120 & 150 cm depths perhaps suggest the profile was saturated but this is unlikely. The installation of drainage meters and soil matric potential sensors subsequently indicated that the profile at depth was not above Field Capacity.

Accepting the un-calibrated nature of the sensors data presented in Figure 2 suggest there was no irrigation water moving below about 70 cm (sensor at 70 cm indicated soil drying) and consequently, at least during the irrigation season, there is unlikely to be movement of nutrients or other constituents in the reclaimed water. The soil water content at depth did increase during the 2004 winter, however, later data indicated there was little nutrient leakage below the rootzone during the winter-early spring period.

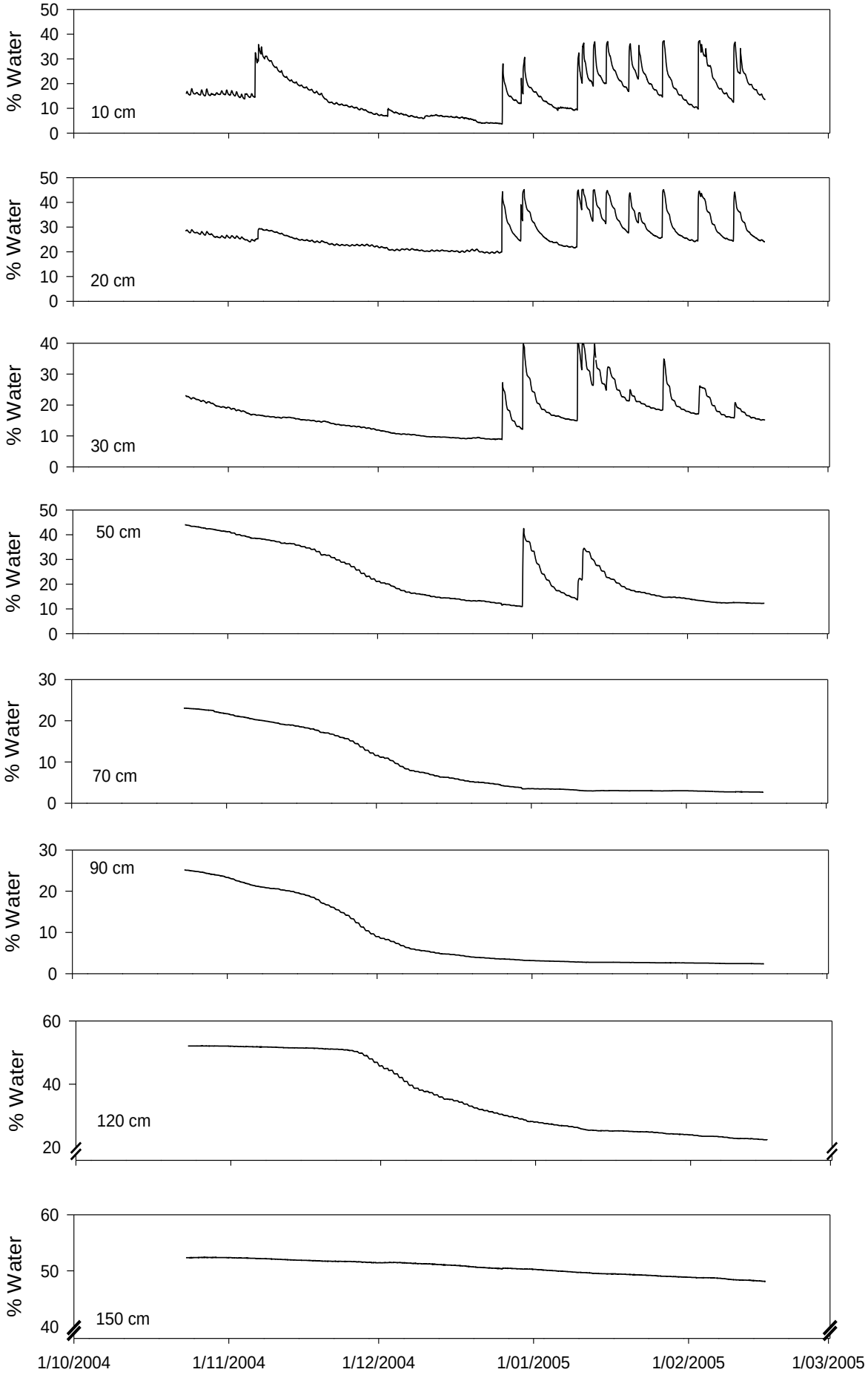


Figure 2 Change in soil water content at each sensor depth for vines irrigated with reclaimed water during the 2004-05 irrigation season

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Quality of Irrigation Water

Reclaimed water

Similar to all sources of reclaimed water the concentration of major and minor elements and other compounds varies throughout the year. Christies beach treatment works outfall is generally considered to be good quality reclaimed water with low levels of all constituents and acceptable salinity and pH levels (**Table 1**).. Oxidisable forms of Nitrogen was considered the greatest potential problem through stimulation of excessive vegetative growth, however petiole analysis indicates this has not occurred. The concentration of heavy metals in the reclaimed water is well below the guideline values for irrigation water quality for SA *(South Australian Reclaimed Water Guidelines (Treated Effluent), Environment Protection Agency & Public and Environmental Health Service 1999)*

	Bicarb	Chloride	Fluoride	P - Total	Sulphate	TKN	COD	Aluminum	Arsenic	Beryllium	Boron	Calcium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium
July	218	344	0.9	7.7	110	14.1	91.5	0.071	0.0010	0.0005	0.328	43.25	0.0005	0.00333	0.0005	0.00833	0.0317	0.0005	0.007
August	233	347	0.9	8.6	119	21.6	147.0	0.048	0.0023	0.0005	0.365	46.9	0.0005	0.00333	0.0005	0.01200	0.0367	0.0006	0.009
September	201	317	0.9	7.8	115	18.1	102.0	0.046	0.0020	0.0005	0.370	44.1	0.0005	0.00550	0.0005	0.01350	0.0300	0.0007	0.009
October	237	322	0.8	9.5	104	20.7	120.0	0.085	0.0013	0.0005	0.372	43.3	0.0005	0.00333	0.0005	0.01267	0.0310	0.0007	0.010
November	218	298	0.9	9.4	122	18.9	159.0	0.109	0.0010	0.0005	0.355	40.9	0.0005	0.00500	0.0005	0.02150	0.0525	0.0015	0.009
December	172	275	0.9	9.7	109	11.4	138.0	0.050	0.0010	0.0005	0.327	39	0.0005	0.00533	0.0005	0.01600	0.0250	0.0008	0.008
January	193	254	0.7	9.8	107	14.4	140.0	0.032	0.0015	0.0005	0.307	39.6	0.0005	0.00950	0.0005	0.01650	0.0185	0.0009	0.007
February	149	249	1.0	10.0	100	14.3	128.0	0.042	0.0013	0.0005	0.294	37.6	0.0005	0.00367	0.0005	0.01400	0.0133	0.0007	0.008
March	146	229	0.8	9.6	102	12.8	61.0	0.022	0.0010	0.0005	0.241	35.7	0.0005	0.00450	0.0005	0.01200	0.0370	0.0007	0.009

	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Vanadium	Zinc	Antimony	Tin	Thallium	pH	TDS	BOD	NH3	OxN
July	32.25	0.0203	0.0005	0.00237	0.00687	21.55	0.003	0.002	227.5	0.0153	0.041	0.00050	0.00077	0.0005	7.48	958	2	12.10	9.18
August	33.7	0.0220	0.0005	0.00280	0.00870	20.9	0.003	0.002	239	0.0110	0.047	0.00050	0.00103	0.0005	7.50	978	2.2	17.70	7.38
September	30.7	0.0190	0.0005	0.00565	0.01825	21.6	0.0035	0.002	224	0.0240	0.051	0.00050	0.00135	0.0005	7.52	1016	2.8	16.04	6.70
October	30.8	0.0150	0.0005	0.00733	0.00983	22.4	0.003	0.002	204	0.0200	0.039	0.00053	0.00083	0.0005	7.56	944	3	16.10	10.20
November	27.3	0.0199	0.0005	0.00410	0.02425	21.8	0.003	0.002	193	0.0350	0.052	0.00050	0.00090	0.0005	7.50	875	2.6	12.56	10.04
December	26.1	0.0213	0.0005	0.00523	0.01323	20.9	0.003	0.002	186	0.0340	0.049	0.00050	0.00097	0.0005	7.42	812	3	10.00	12.78
January	24.4	0.0237	0.0005	0.00340	0.01050	21.1	0.003	0.002	171	0.0095	0.052	0.00050	0.00185	0.0005	7.42	812	3.5	11.60	13.80
February	23.1	0.0241	0.0005	0.00187	0.01467	24.5	0.003	0.002	173	0.0043	0.043	0.00050	0.00103	0.0005	7.52	797	2.8	11.56	8.44
March	22	0.0231	0.0005	0.00230	0.01305	21.5	0.003	0.002	170	0.0030	0.043	0.00050	0.00110	0.0005	7.46	723	2.5	10.36	8.70

Table 1 Selected analysis data of reclaimed water between July 2003 and March 2004.

Units as listed in Table 4.

Mains water.

The mains water used was sourced from the Myponga reservoir/water treatment plant and is regularly monitored by SA Water to ensure it complies with Public Health Water Quality standards. On average the salinity of the Mains water was less than half that of reclaimed water in the 2003-2004 irrigation season.

Parameter	Avg	Min	Max	Median
pH (pH units)	7.4	7.1	7.9	7.3
Total dissolved solids (mg/L)	380	360	420	370

Table 2 Selected analysis data of Mains water for 2003-2004. (SA Drinking Water Quality Report 2003-2004. SA Water)

EM38 survey

The EM38 survey, which was conducted at the end of the 2003-04 irrigation season, did not detect any treatment differences in soil salinity either in the 0-60 or 60-120 cm zones (Figure 3). Salinity in the shallow survey was slightly higher towards the eastern end of the experimental area and this was more apparent at depth. While plant analysis indicated lower petiole Na^+ & Cl^- this was surprisingly not reflected in soil salinity.

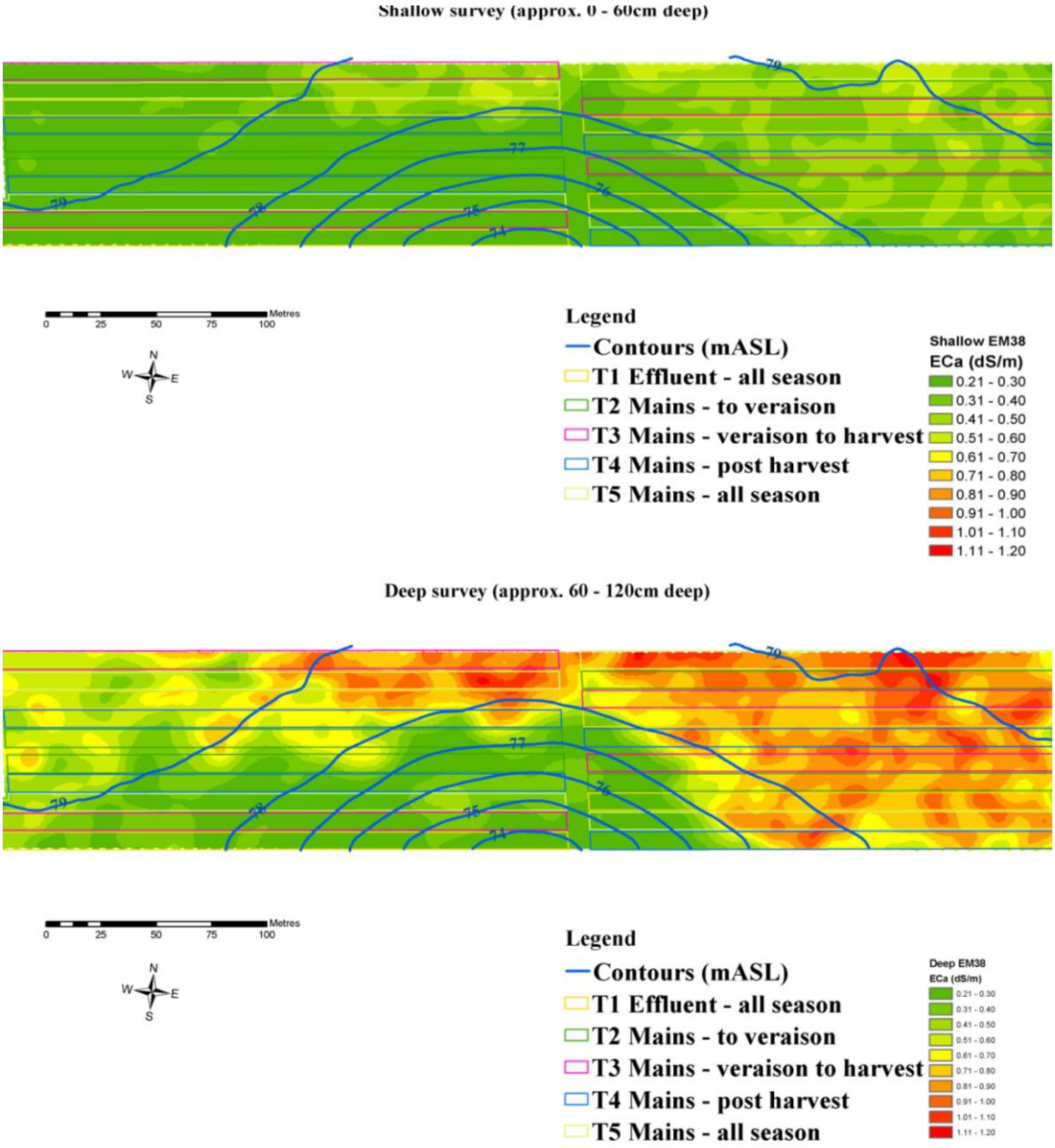


Figure 3 Shallow (upper) and deep (lower) EM38 survey of the experimental area conducted in April 2004.

Maturity Indices

Weekly samples were collected for the determination of °Brix, pH, titratable acid during berry ripening and in 2002 and 2003 additional samples were collected for the determination of berry anthocyanin content and concentration. Data for the 2003 season are presented here and are similar to other seasons.

There was no difference in °Brix, pH & titratable acid (Figure 4, 5 & 6) between treatments on any of the seven weekly sampling times with all treatments exhibiting normal ripening patterns. With only two replicates and field variability it was unlikely that statistical differences would be found.

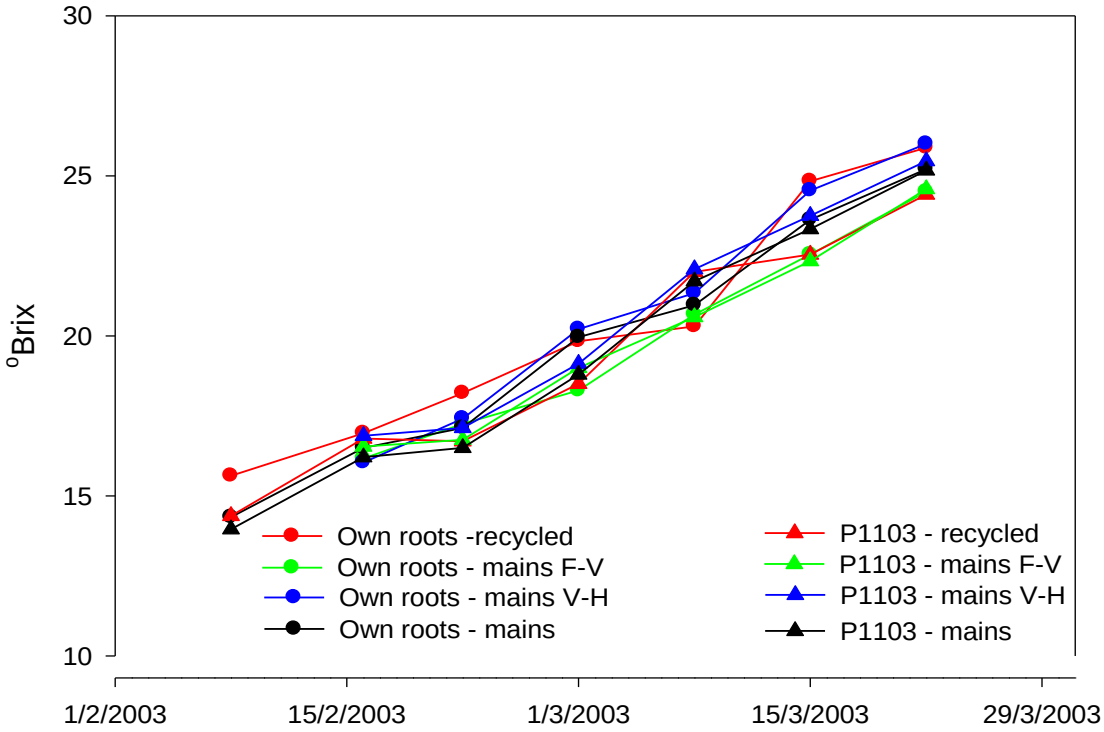


Figure 4 Change in °Brix with time for selected treatments during berry ripening in 2003

The favourable ripening conditions in February & March 2003 resulted in a steady increase in sugar concentration and at harvest juice pH and titratable acid reflected these conditions.

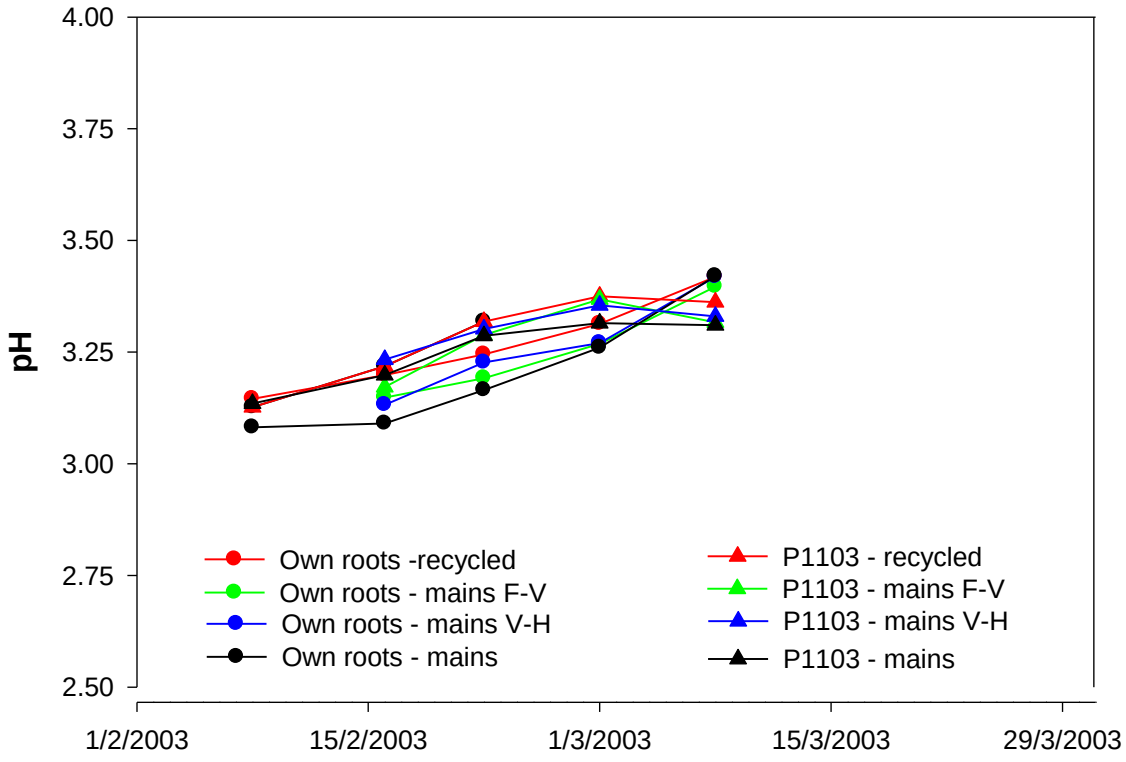


Figure 5 Change in pH with time for selected treatments during berry ripening in 2003

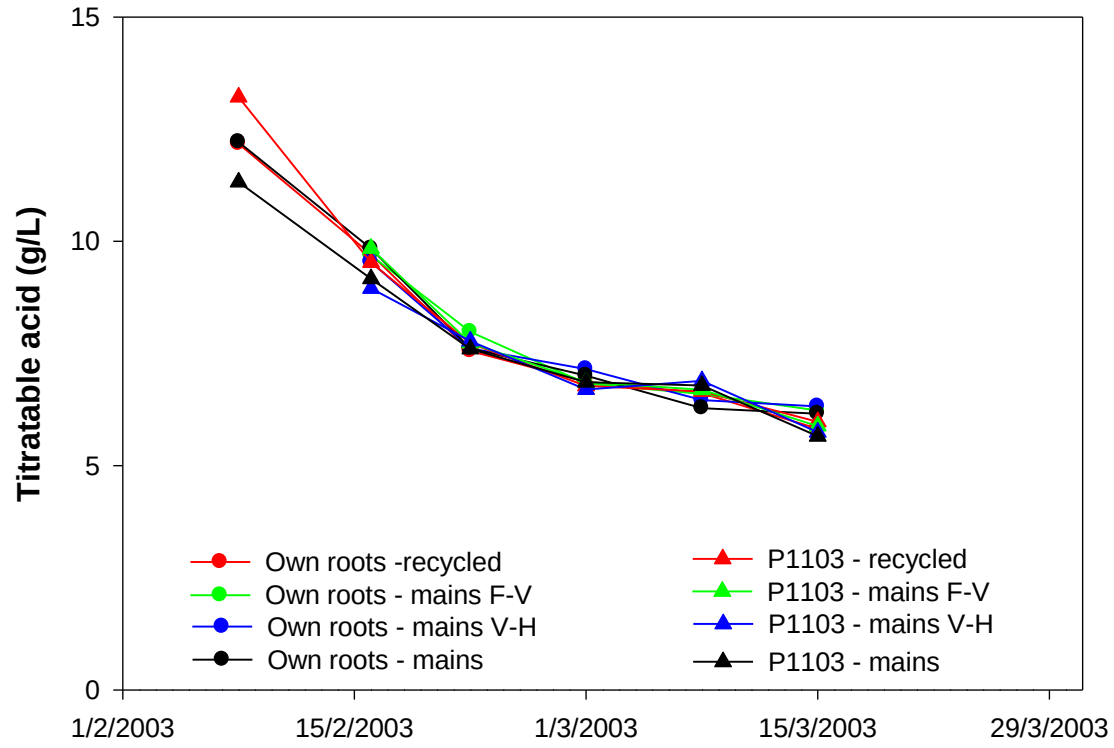


Figure 6 Change in titratable acid with time for selected treatments during berry ripening in 2003

As there were no significant differences between treatments in either 2002 or 2003, weekly sampling was not undertaken in later years.

Berry weight & yield

Weekly berry samples were collected post veraison from selected treatments in 2002 and 2003 for the determination of °Brix, pH, titratable acid and berry weight. Data for 2003 is presented (Figure 7). There was no irrigation of rootstock effect on berry weight and all treatments exhibited typical weight loss commencing about 90 days after flowering.

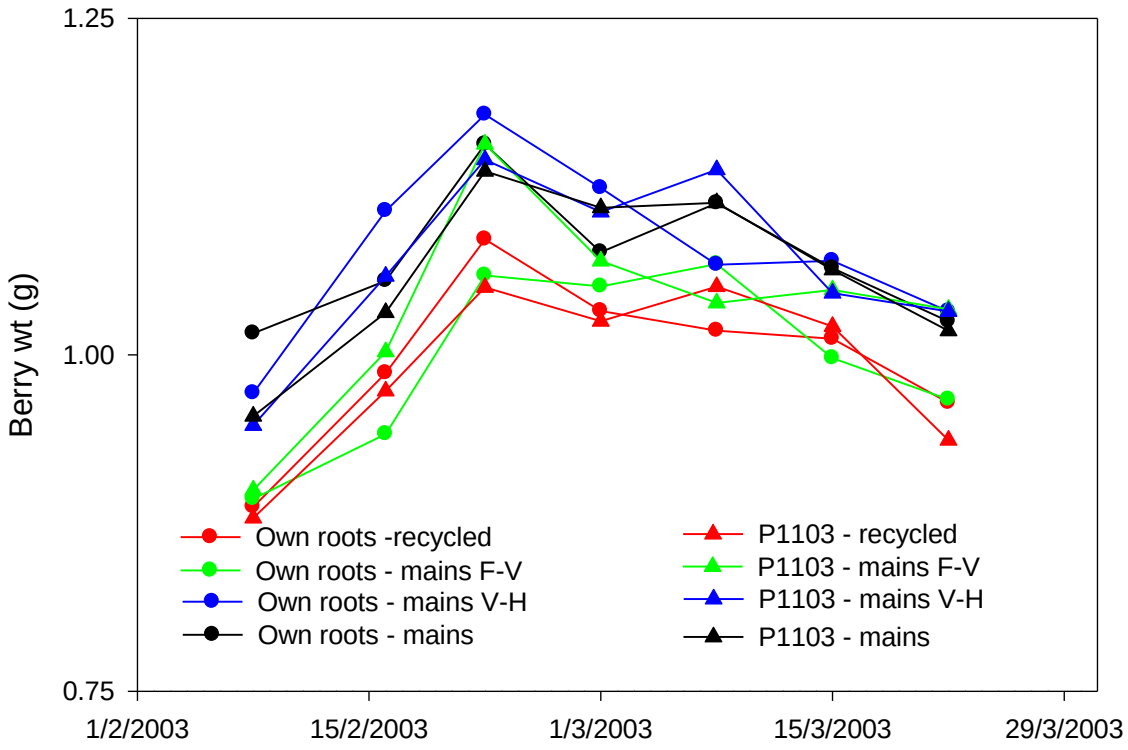


Figure 7 Change in berry weight of selected treatments during ripening in 2003.

Yield per vine of selected treatments was measured immediately prior to machine harvest in March 2002-2004. Plots were not hand harvested in 2005 in view of the small volumes of irrigation applied in the 2004-05 season as a result of adequate winter-spring rainfall. There was no significant effect of rootstock or irrigation treatment on average yield of selected treatments for 2003 and 2004 (Table 3), however, vines on P1103 tended to out-yield own rooted vines in each irrigation treatment.

	Rootstock	
Irrigation Treatment	Own roots	P1103
Reclaimed water	6.3	7.9
Mains - Flowering to Veraison	6.4	6.6
Mains - Veraison to Harvest	6.5	7.6
Mains water	6.8	7.5

Table 3 Average yield (kg per vine) of selected treatments for 2003 & 2004 harvest

Petioles

Nitrate Nitrogen

No additional fertiliser was applied to the experimental area between vineyard establishment and 2004. At bloom 2002 the nitrate-nitrogen content of petioles of grafted vines irrigated with reclaimed water had significantly higher than the other treatments depicted in Figure 8. However, between bloom 2002 and 2003 petiole nitrate-nitrogen concentration declined to be within the accepted adequate range. Vines irrigated with mains water were considered to be borderline at bloom 2003 and prior to the 2004/05 growing season about 1T/ha of Neutrog(™) was applied to T_5 vines; this resulted in a large increase in petiole nitrate-nitrogen concentration of petioles of grafted vines and about a doubling of the concentration for own-rooted vines. At bloom in November 2006 all treatments were below suggested critical limits and the two treatments sampled at bloom in November 2008 were again below the suggested critical limit. These data suggest that the low concentration of the different forms of available and potentially available N in this reclaimed water source does not present any issue.

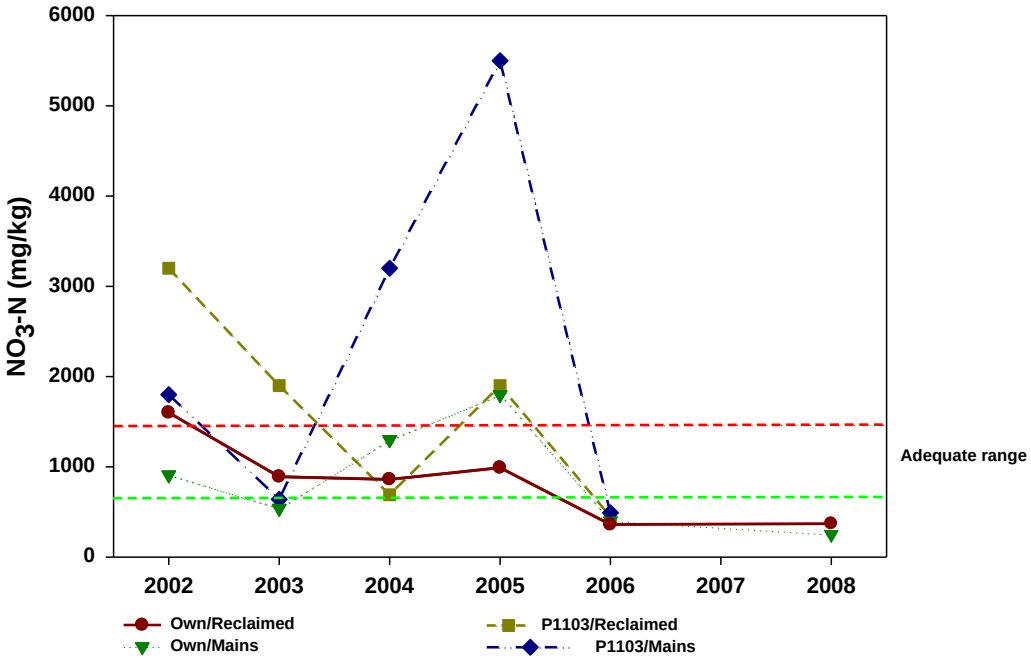


Figure 8 Bloom time Nitrate nitrogen concentration (mg/kg) of selected treatments over seven consecutive seasons

Phosphorus

At bloom in 2002 and 2003 the petiole phosphorus concentration of selected treatments (Figure 9) were in the adequate range, however by bloom in 2004 these four treatments were in the possible deficient range with vines irrigated with mains water slightly lower than vines irrigated with reclaimed water. In 2005 and 2006 petiole phosphorus concentration of all treatments were within or slightly higher than the suggested critical range and the two treatments sampled at bloom in 2008 were within the adequate range suggesting that, as for Nitrogen, this reclaimed water source does not present any problem with excessive phosphorus addition.

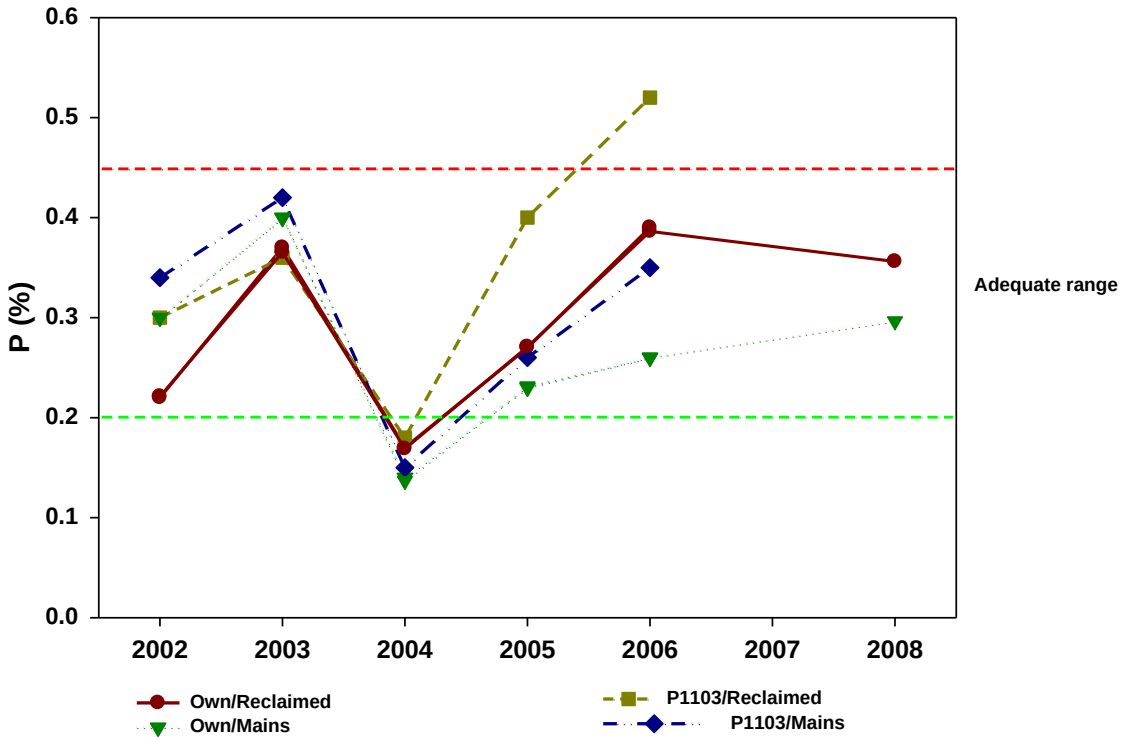


Figure 9 Bloom time Phosphorous concentration (% dry wt) of selected treatments over seven consecutive seasons

Chloride

The influence of rootstock on bloom petiole chloride concentration in each season was considerably greater than the influence of reclaimed water (Figure 10) and confirms the chloride exclusion ability of P1103 rootstock. All treatments reported are within the range expected for own rooted and grafted Shiraz vines in the McLaren Vale region. The small decline in petiole chloride concentration between 2002 and 2004 may reflect more effective winter leaching during 2003 and 2004 and the slight rise in 2006 the result of insufficient leaching during the dry 2006 winter. At bloom 2008 the petiole chloride concentration of own-rooted vines irrigated with mains water had declined, probably reflecting a return to more normal winter rainfall, however, this was not reflected in vines irrigated with reclaimed water which were slightly higher than in 2006. Higher values are commonly reported for drip irrigated vines in similar regions using underground water sources.

Potassium

Irrigating vines grafted onto P1103 with reclaimed water tended to depress the petiole Potassium concentration at flowering in Nov 2004 (Figure 11) compared to grafted vines irrigated with mains water. Similarly, irrigation of own-rooted vines with reclaimed water tended to depress potassium concentration at flowering in Nov 2004 compared with mains water. By flowering in 2006 the petiole Potassium concentration of petioles from grafted vines was higher than own-rooted; own-rooted vines irrigated with reclaimed water had the numerically lowest petiole Potassium concentration, however there were greater seasonal differences than between own-rooted and grafted vines. There is a trend of increasing potassium concentration since bloom 2005, however, the levels are less than those recorded in 2004 and within the range commonly seen in Australian vineyards planted on finer textured soils.

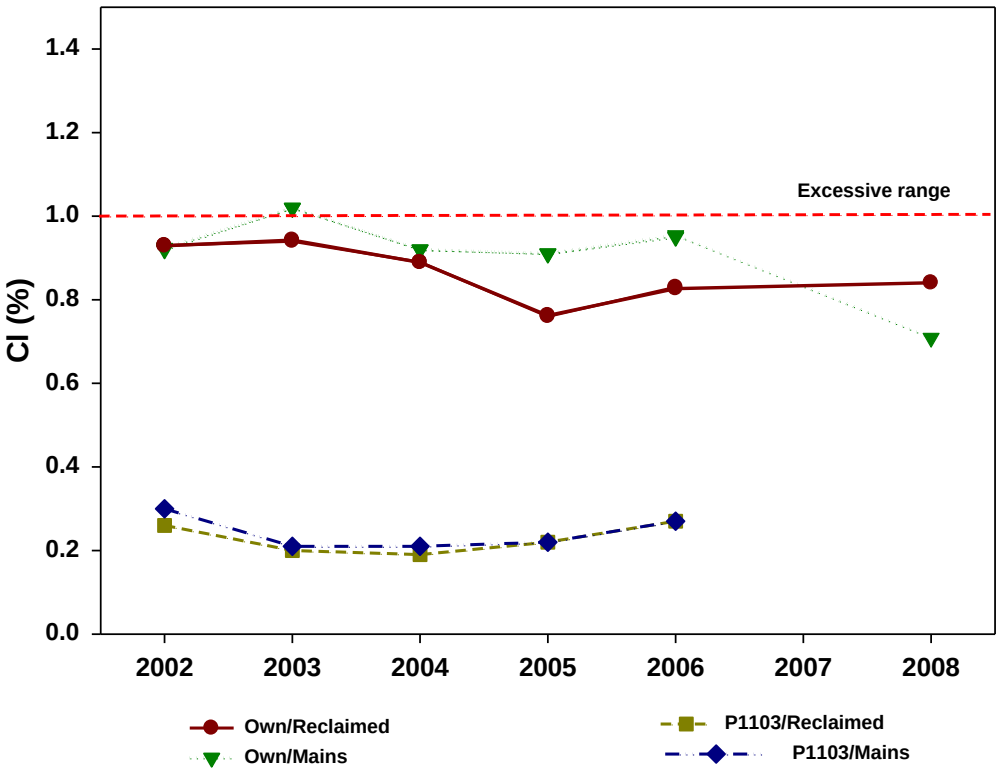


Figure 10 Bloom time Chloride concentration (% dry wt) of selected treatments over seven consecutive seasons

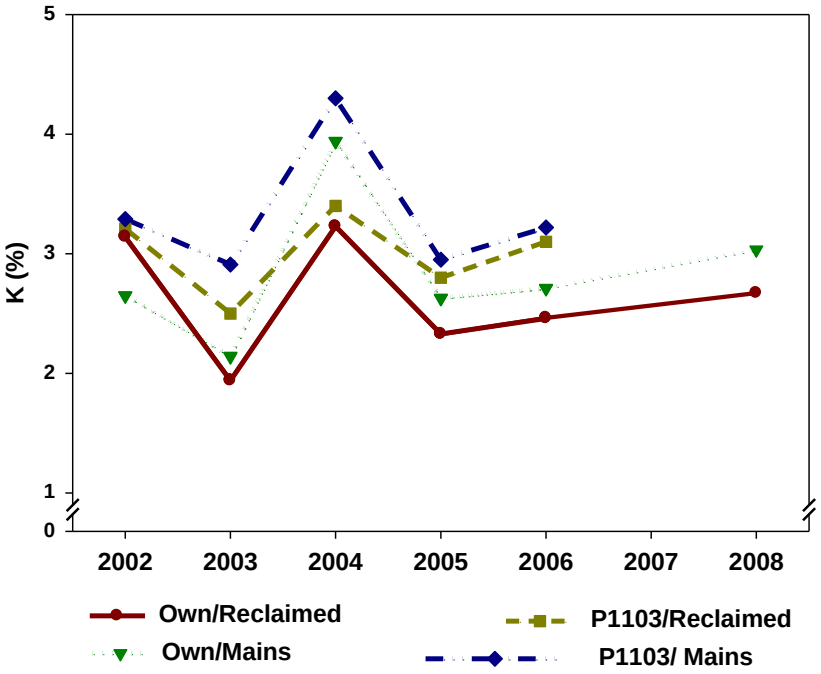


Figure 11 Bloom time Potassium concentration (% dry wt) of selected treatments over seven consecutive seasons

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Sodium

Petiole Sodium concentration showed a similar pattern to chloride with the greatest effect being rootstock and only small differences apparent between irrigation treatment. There has been a slight downward trend in concentration over the seven seasons which may reflect the gradual reduction in irrigation volume and sufficient winter 2008 rainfall to help leach irrigation salts below the rootzone.. All values are within the range expected in McLaren Vale vineyards.

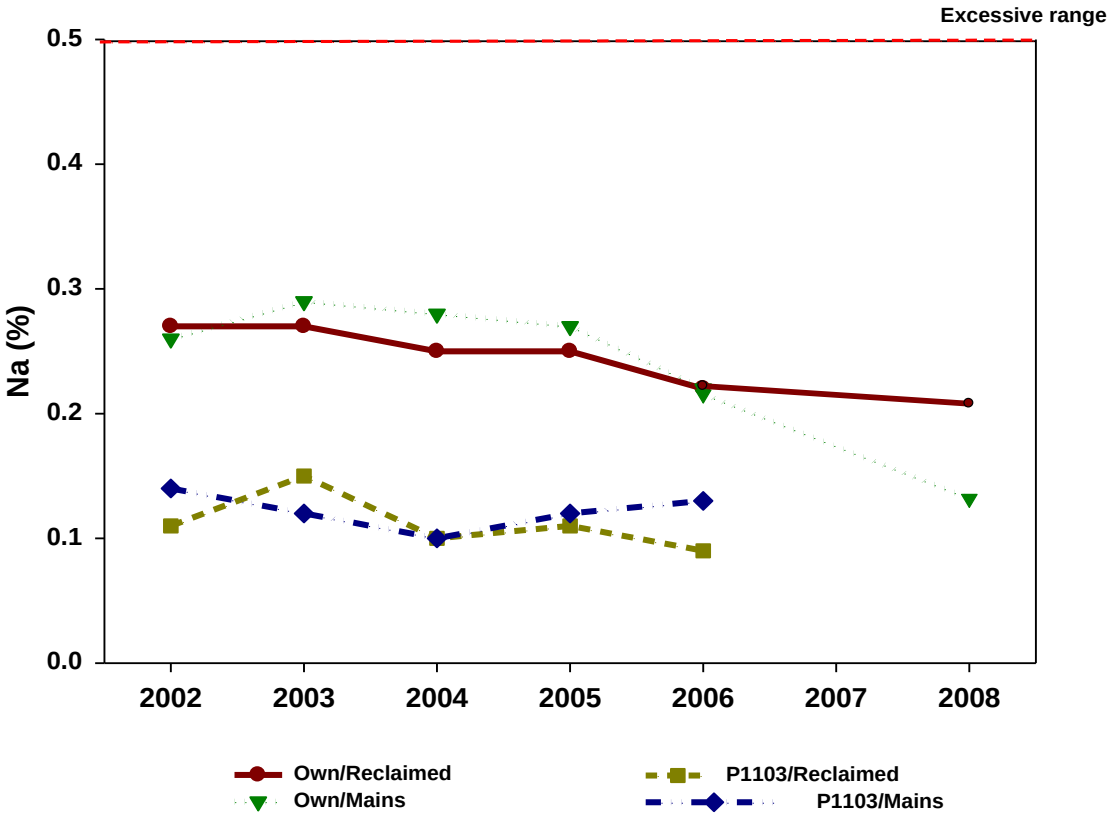


Figure 12 Bloom time Sodium concentration (% dry wt) of selected treatments over seven seasons

Wine Composition

Wines from a number of vintages vintage were subjected to comprehensive chemical analysis. No differences in aromatic & chlorinated hydrocarbons, agro chemicals or major & minor trace elements have been detected and most are at or below detectable limits. Major and minor elemental analyses for 2003 wines are presented in Table 4.

		Own roots			P1103		
		Recycled	Mains V-H	Mains	Recycled	Mains V-H	Mains
Al	mg/L	0.3	0.4	0.4	0.4	0.3	0.3
B	mg/L	14	7.6	13	13	12	12
Ca	mg/L	60	54	62	65	53	47
Fe	mg/L	0.8	0.5	0.8	1	0.9	0.9
K	mg/L	1103	1103	1150	1018	1061	1090
Mg	mg/L	130	108	126	153	145	138
Mn	mg/L	0.8	1.8	0.8	0.9	0.8	1
Na	mg/L	49	31	42	31	30	33
P	mg/L	246	265	268	244	234	244
S	mg/L	159	128	145	171	167	148
Be	ug/L	0.1	0.08	0.09	0.09	0.07	0.08
V	ug/L	0.7	0.6	1.1	1	1	1.2
Cr	ug/L	17	15	20	20	18	21
Co	ug/L	1.76	2.06	1.77	1.56	1.14	1.3
Ni	ug/L	7	8	8	7	6	7
Cu	ug/L	115	229	93	231	121	100
Zn	ug/L	280	802	284	419	357	357
As	ug/L	1.7	0.8	1.2	0.7	0.9	1
Se	ug/L	1	0.9	0.9	1.2	0.8	1.1
Sr	ug/L	1383	834	1475	1138	1068	1172
Mo	ug/L	1.9	1.4	1.9	1.8	1.5	1.3
Cd	ug/L	0.22	0.18	0.19	0.16	0.17	0.17
Sn	ug/L	1.8	1.4	2.2	2.4	2.4	3.5
Sb	ug/L	1.3	1.2	1.1	1	1.1	1.1
Ba	ug/L	138	177	138	124	120	121
Tl	ug/L	<1	<1	<1	<1	<1	<1
Pb	ug/L	5.2	10.8	8.8	4.4	3.6	4.3
Li	ug/L	11.7	7.8	10.8	9.9	9.6	9
Rb	ug/L	330	1050	330	330	360	300
La	ug/L	<.1	<.1	<.1	<.1	<.1	<.1
Ce	ug/L	0.18	<.1	0.16	<.1	<.1	0.16
Bi	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Th	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
U	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 4 Minor and major elemental analysis of finished wines for the 2003 season for 6 treatments.

The ratios of minor & major elements between wines made with fruit from vines irrigated with reclaimed water and mains water on either rootstock was similar. This suggests that vines irrigated with reclaimed water did not accumulate any higher concentration these elements in wines compared with wine made from fruit from vines on either rootstock irrigated with mains water. The absolute concentrations of the elements measured were higher in finished wines than the irrigation water.

Soil water solution analysis

Soil salinity

SoluSamplers™ were installed at 30, 60 and 90cm depths in a single row of own-rooted vines irrigated with reclaimed water in 2005 and water samples were collected at fortnightly intervals when available. Samples were analysed for EC_{SW}, pH and nutrient status. EC_{SW} data are presented in **Figure 13**.

Previous experience with SoluSampler™ indicated that in vineyards where relatively small volumes of irrigation water are applied it is not always possible to collect a water sample except immediately after irrigation and hence there are likely to be extended periods during the summer months when no soil water samples can be collected. In addition, if the irrigation schedule is designed to ensure the subsoil gradually dries over the course of the growing season, it is unlikely to be able to retrieve a soil water sample at depth.. Such was the case in this situation.

Rainfall events through winter 2007 increased soil moisture sufficiently to allow sampling at 60 cm and 90 cm in July and August. Data from these depths suggest that salts moved deeper but did not leave the rootzone. As the 2007/08 summer progressed, all levels of the profile dried with the deeper sensors registering dry (200 kPa). SoluSampler™ samples correspondingly ceased. Early winter rainfall in 2008 resulted in soil water tensions decrease at the 30 cm depth to a level that allowed 30 cm SoluSampler™ sampling to recommence in July.

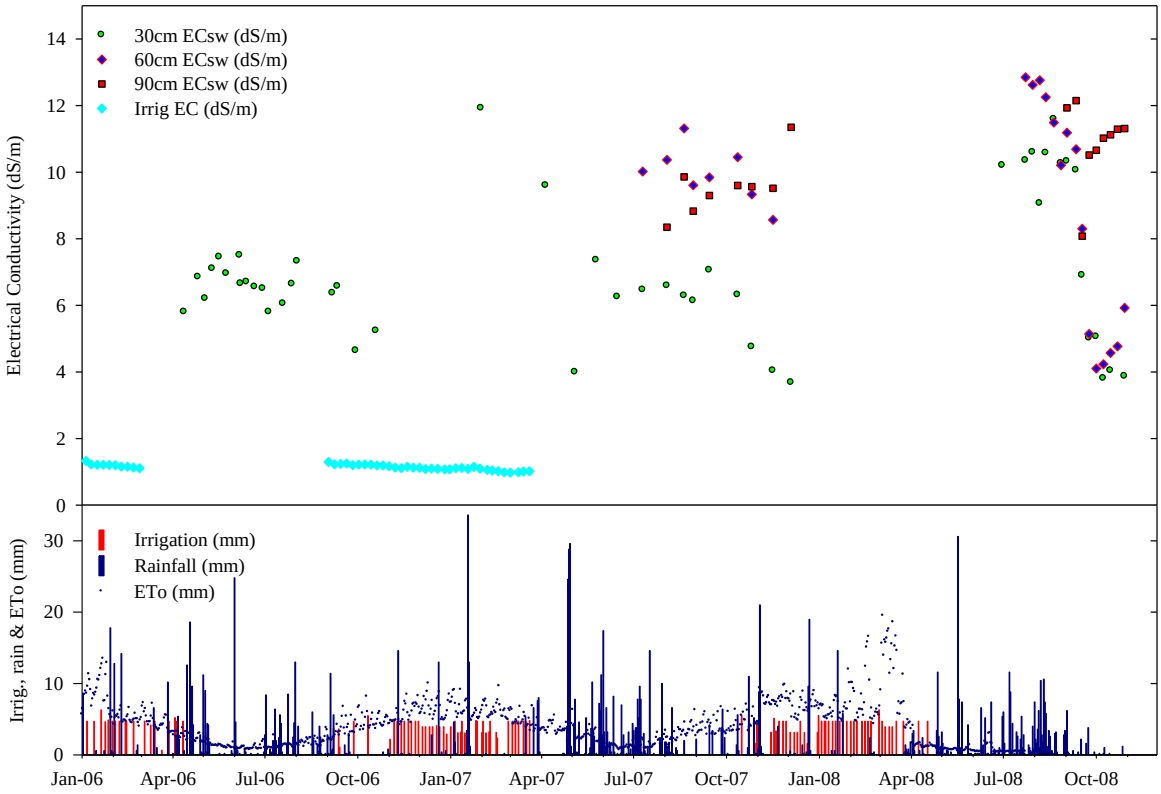


Figure 13**.** Changes in EC_{SW} over time, as measured by SoluSampler™, at 30, 60 and 90 cm.

Data supplied by T Biswas, SARDI

Soil water salinity data collected at this site are similar to other drip irrigated vineyards in similar environments. Although soil water salinity is elevated during the growing season it does not appear to be having a negative impact on yield and wine quality. However, the data highlight the critical importance of winter-spring rainfall in leaching applied salts form the vine rootzone. Future climate change projections of reduced winter-spring rainfall could impact on the efficiency of this process and other management options may need to be considered to ensure the rootzone is adequately leached prior to each growing season.

Rootzone Nitrate concentration

When possible, fortnightly soil water samples were collected at 30, 60 and 90 cm depth and analysed for NO_3^-N.

SoluSampler soil water No3-N (mg/L) Feb 2006- Jun 2008									
	30 cm			60 cm			90 cm		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
	<0.02	6.5	0.44	<0.02	0.69	0.17	<0.02	2.97	0.52
s.e.			0.22			0.07			0.49

Table 5.Rootzone nitrate concentrations between Feb 2006 and June 2008 at three depths.

Average NO_3-N across all depths was below the suggested general environmental maximum contaminant level of 10 mg/L. It should be noted that very few soil water samples were collected through the irrigation season due to low moisture contents. This highlights how unlikely it is that irrigation moved NO_3-N below the rootzone through the summer months of the trial period. Applied water was used via evapotranspiration, and had no opportunity to move beyond the rootzone. In addition the reclaimed water used at this site has low levels of oxidisable Nitrogen which may all be either absorbed by vine roots or soil and hence little residual N present to be leached. This may not be the case at sites where larger volumes of irrigation are applied or the reclaimed water has a higher N concentration.. Although winter rainfall provided enough water to allow movement beyond the rootzone, SoluSampler^{TM} samples at 90cm depth recorded NO_3-N levels well below EPA thresholds. The low concentrations of soil NO_3-N is reflected in the petiole concentration.

Conclusion

Results to date suggest that with the quality and volume of reclaimed water used to irrigate a Shiraz vineyard in McLaren Vale there are no significant changes in vine growth, yield or nutrient status. The concentration of minor and major elements in wines made from vines irrigated with reclaimed water are similar to that of wines from vines irrigated with high quality potable water. No differences in chlorinated or aromatic hydrocarbons were detected. There does not appear to be any influence of the P1103 rootstock. Thus far we have detected no loss of nutrients applied in the reclaimed water below the rootzone, however, during the period of the experiment there were no extended periods of above average rainfall (episodic events) that would have resulted in a significant leaching event.

Care should be exercised when extrapolating results from this experiment to vineyards in other regions using reclaimed water. The reclaimed used in the experiment reported here contains low concentrations of phosphorus, oxidisable nitrogen and potassium, water pH and SAR is of no to minor concern and water salinity is lower than many underground sources used for irrigation in Australian vineyards. Other sources of reclaimed water may not be so benign and monitoring protocols should appropriate for the water quality.

Appendix 1: Communication

Conference proceedings
N/A

Industry Publications
N/A

Attendance at conferences
3rd Australian Wine Industry Environment Conference. Adelaide Convention Centre Feb 2005
4th Australian Wine Industry Environment Conference, Adelaide Convention Centre, August 2007

Industry Presentations
3rd Australian Wine Industry Environment Conference, Willunga Basin Research Project - Reclaimed water use in a McLaren Vale vineyard. Adelaide Convention Centre, Feb 2005

4th Australian Wine Industry Environment Conference, Adelaide Convention Centre, August 2007
Irrigating with reclaimed water

Annual presentation to Willunga Basis Water Company Board and Shareholders.

McLaren Vale SAFF Annual Growers Day 2002 & 2004
The benefits or otherwise of irrigating with recycled water
Update on Reclaimed Water Trial Logan's Legacy Vineyard

Appendix 2: Intellectual Property
N/A

Appendix 3: References
NPSI Sustainable Irrigation Management Update "Salinity Management Practice Guidelines – Managing rootzone salinity for irrigated horticultural crops in the winter rainfall zones of Australia" (2009).

Guidelines for developing recycled water schemes in horticulture: http://www.npsi.gov.au/

Using Recycled Water in Horticulture. A growers guide: http://www.npsi.gov.au/

Nursery Industry Water Management. Best practice guidelines: http://www.npsi.gov.au/

Irrigation of Amenity Horticulture with Recycled Water: http://www.recycledwater.com.au/

10 years of recycled water use at Virginia" ReWater: http://www.recycledwater.com.au/

Using Recycled water for Irrigation: An overview of the issues, opportunities and challenges: http://www.npsi.gov.au/

Using Recycled Water. A Manual for the Pasture and Fodder Crop Industries: http://www.rmcg.com.au/Home.html

"Recycled water: How good should it be?" Irrigation Australia Vol. 24, No. 2: http://www.irrigation.org.au/

Australian Guidelines for Water Recycling: Managing Health and Environmental Risk: www.nepc.gov.au/taxonomy/term/39

Appendix 4: Staff

SARDI
Dr M M^{c}Carthy (Project Leader)
Dr Belinda Rawnsley
Dr Tapas Biswas & Mr Tim Pitt

Flinders University
Dr John Hutson & students

Beringer Blass Wine Estates
Mr Chris Dundon
Mr Wayne Kaesler
Mr Syd Kyloh
David Hansen
FWE vineyard staff

Thanks to the various winemakers at Beringer Blass for processing the experimental wines & Dr Yoji Hayasaka, Manager - Waite Campus Mass Spectrometry Facility for conducting wine analyses.

Appendix 5: Information supplied by Dr Belinda Rawnsley, SARDI

Project title: Implications of strategic irrigation management practices for vine root health

GWRDC project No: SAR 03/04

Preliminary studies were undertaken at the McLaren Vale trial site in addition to a number of other sites being used in this project. Soil cores to a depth of 45 cm were collected from vines treated with Mains and Reclaimed water. Samples were analysed for (1) root health and distribution, (2) presence of fungal pathogens and (3) microbial activity.

The majority of roots were located at 10-30 cm down the soil profile. The four main fungal root pathogens isolated from roots were *Fusarium*, *Pythium*, *Cylindrocarpon* and *Rhizoctonia*. Other fungi, such as *Aspergillus*, *Alternaria*, *Trichoderma*, *Penicillium* and *Verticillium* were also isolated.

The activity of the soil biota is largely responsible for nutrient transformations in soils. Plant health is thus directly related to microbial communities in the soil. Changes in soil microbial activity provide an accurate indication of soil degradation and changes to soil productivity over time. β-Glucosidase, the rate-limiting enzyme in microbial degradation of cellulose to glucose, is the most sensitive and consistent indicator to reflect major soil degradation processes. At harvest time in 2004, soil under vines irrigated with reclaimed water showed higher microbial activity than soil irrigated with mains water (Figure A). Results so far suggest that viticultural soils have low microbial activity. Intensive soil sampling throughout the season was carried out in 2004/2005 from vine dormancy to harvest. Microbial activity and microbial biomass C and N is being analysed from rhizosphere soils (i.e. soil directly around the root).

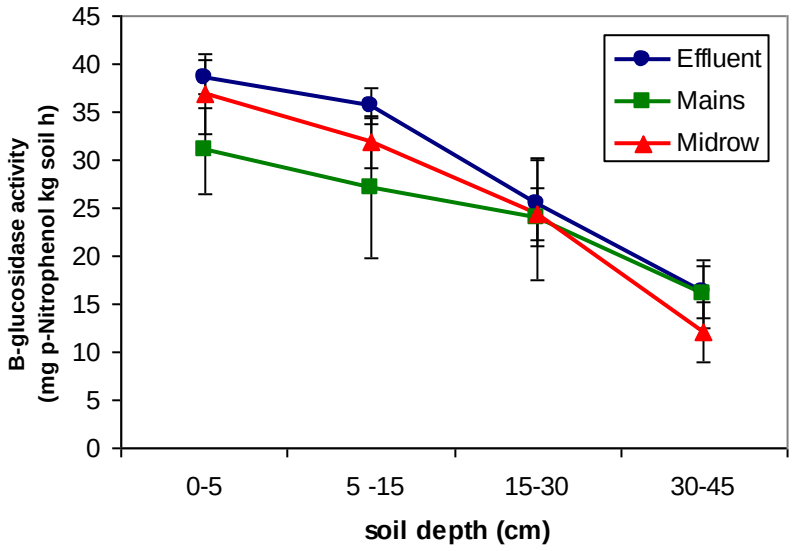


Figure A. β-Glucosidase activity in soil collected at various depths from the mid row and under vines irrigated with reclaimed or mains water, March 2004, McLaren Vale, SA.