CLEANER PRODUCTION: NEW TECHNOLOGY FOR WATER RECYCLING AND CLEANER PRODUCTION



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Abstract

Recent projects investigating winery wastewater have identified a number of new technologies that may help to reduce or recycle wastewater and ensure wine is produced cleanly. An industry survey was performed to gather a list of potential technologies which might lead to cleaner production methods. In total, this approach covered approximately 70% of Australian production by volume. The survey was intended to identify the potential technologies and operational strategies which the industry considered to be worth further investigation. Broadly speaking, the suggestions were related to four main categories:

- Cleaning efficiency
- Separation of solids
- Separation of waste streams
- Transfer related activities

This project tested and demonstrated these technologies and deployed case studies within the wine industry to facilitate their uptake.

Technologies were ranked using a combination of factors including ease of implementation, economic and environmental assessment. Where required, bench top and winery trials were performed to generate additional data to assist in assessments. The highest ranking opportunities were reuse of cleaning chemicals, minimisation of transfers and the solids separation techniques of lees cross flow filtration and secondary settling. Ice pigging, the re-use of crusher to press push water and an automated stormwater diversion system also ranked highly. However, the high equipment capital costs and ongoing operational costs mean that in general these techniques will not be viable for most sites. However, wineries particularly heavily constrained by wastewater treatment should consider a further evaluation of these technologies.

We identified a large number of technologies and methods that can be used to streamline, reduce, reuse and recycle winery wastewater. The re-use of caustic cleaning agents has the potential to reduce sodium levels in winery wastewater. The use of a caustic recovery system is also expected to reduce labour requirements associated with tank cleaning as it eliminates the ‘preparation step’ currently required prior to every cleaning operation. Other benefits of reuse include improved OH&S and less expenditure on chemicals. There may also be an opportunity for some wineries to reduce wine movements through working with customers to improve forecasting of product requirements, with the goal of being able to group orders from different customers into larger packaging runs. Efficiently recovering value from wine and juice lees, which typically comprise solid contents of 20-35%, is a task that provides a significant challenge to wineries of all sizes. This investigation has evaluated technologies including the Pall HS Oenoflow and the TMCI Padovan Dynamos cross-flow filters. These technologies, and potentially others such as the Bucher-Vaslin Flavy Leestar, canprovide the opportunity to improve both the economic and environmental impact of current practice lees processing, with very significant reductions in water consumption and improvements in filtration efficacy and corresponding product quality.

As a case study, a whole of winery salt balance was used to estimate the sources of salt (sodium and potassium, Na and K) in a medium sized winery and several specific issues addressed, including salt concentration in the wastewater treatment train, caustic washes of red ferments and management of waste at the centrifuge. In this trial, the removal of potassium and sodium by way of the solids recovery at the centrifuge had no material impact on the salt loading of the wastewater treatment plant. However, solids recovery significantly reduced the COD entering the treatment plant.

As the wastewater system is largely open top, there is potential for concentration of wastewater by evaporation throughout the system, and particularly in the storage lagoon in hot dry months. In colder wetter months there is likely dilution of the effluent in the treatment plant and lagoon from incident rainfall. Concentration during the warm months has the potential to compromise the quality of the water for land application, which is at the time of year of highest wastewater volume production and when suitable irrigation water is likely to be most beneficial to a range of land uses including grapes. Cleaner production requires a focus not just on reduced water use and downstream treatment, but also on reducing organic loading and salt (Na and K) loading by addressing these contaminants at the source level. It is critical to understand the importance of potassium for soils as the balance between sodium and potassium cleaners may need to be reviewed to reduce potassium levels, if the impact is in balance.

The new knowledge generated by this project can now be use to:

1. Extend the technical knowledge and tools to industry via road shows so that adoption can occur in all wine regions.
2. Update the operating guidelines based on the new information generated through this project.

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Executive summary

Waste minimisation is slowly being adopted in the wine industry, owing to a combination of powerful drivers, which are either internally or externally motivated. However, these waste minimisation practices in the wine industry are still carried out in an *ad hoc* fashion and have proven to be ineffective in many cases. The lack of a systematic methodology of synthesising and targeting specific waste streams by the industry has been identified as a major cause of failure in realising the full potential of waste minimisation in the wine industry. Recent projects investigating winery wastewater have identified a number of new technologies that may help to reduce or recycle wastewater and ensure wine is produced cleanly. This project tested and demonstrated these technologies and deployed case studies within industry to facilitate their uptake.

In order to identify potential strategies and cleaner production technologies which might be suitable for the Australia wine Industry an extensive survey process was completed using two approaches:

- An online survey – primarily aimed at small to medium sized producers; and
- Personal visits to various wine producing companies – targeted more at large producers.

The information was drawn from a wide distribution of winery sizes and locations. In total, the surveys collected information from wine producing companies which represent about 70% of the total tonnes crushed in Australia. Cleaning efficiency and cleaning related projects were considered the most important with 77% of all survey participants suggesting ideas or opportunities within this category. Transfer related process changes were the second most requested opportunity, listed by 66% of participants. The separation of streams and wastes was considered less important with 29% requesting opportunities related to stream separation and 17% suggesting solids separation processes be further investigated.

The suggested opportunities were each evaluated using an assessment method designed to identify which technologies or operational practices were likely to be most beneficial within Australian wineries. Following the general observation stage, each process was ranked against three criteria:

1. Technical feasibility/ difficulty of implementation
2. Economic benefit; and
3. Environmental benefit.

Technical feasibility/ difficulty of implementation were used to represent and measure the difficulty such an opportunity might present to the winery. This was intended to encompass the difficulty associated with retraining people, working with highly technical equipment, commissioning equipment of a nature that staff is not currently familiar with, commissioning temperamental equipment and dealing with other implementation problems. The ranking of technical feasibility/difficulty to implement was based on an assessment of potential time to implement the opportunity and have it successful working within a winery setting. Technical feasibility was given a rating of 1-5. The final evaluation category considered was environmental benefit. Measuring environmental benefit is particularly difficult. There are number of methods available within life cycle assessment processes which place specific weightings on various environmental factors which enable a general environmental ranking, but these factors are not particularly relevant in terms of wastewater. In this case, it was deemed that the most significant environmental impacts associated with the wastewater were sodium and potassium discharge, biochemical oxygen demand (BOD) or chemical oxygen demand (COD) and total water consumption. Each of these factors can be given an economic value, for example sodium and potassium discharge can be priced based on the purchase cost of land needed based on specified salt loadings. Similarly a price can be put on COD associated with the cost of providing aeration and land to dispose of the sludge generated. In this way an economic value was used to rank environmental benefit.

The highest ranking opportunities were reuse of cleaning chemicals, minimisation of transfers and the solids separation techniques of lees cross-flow filtration and secondary settling. Ice pigging, the re-use of crusher to press push water and an automated stormwater diversion system also ranked relatively highly.

A detailed evaluation of ice pigging of must lines was performed in the 2010/11 FY. This case study was developed and run at Yalumba's Moppa winery, South Australia. Ice pigging has been shown to be a very effective method of reducing the environmental impact associated with wine transfers and has additional benefits associated with pipe cleaning. However, the high equipment capital costs and ongoing operational costs mean that in general this will not be viable for most sites. However, wineries particularly heavily constrained by wastewater treatment should consider a further evaluation of this technology.

The second phase of this project involved case studies on the following three technologies identified as being most beneficial to Australian wineries.

1. The reuse of cleaning chemicals and the design/development of a speciality cleaning system which will allow chemical reuse and heating. This will include the development of methods to assess caustic concentration and top-up/ disposal requirements;
2. The development of method(s) to reduce the number of transfers performed in wineries. This project is expected to combine elements of scheduling, ullage management and blending techniques; and
3. The implementation of lees separation techniques including an evaluation of various newly developed lees cross-flow filtration systems.

The fourth case-study assessed the salt balance at a medium sized winery and identified opportunities to reduce salt load in the wastewater treatment plant

Case-study 1- Reuse of Caustic Cleaning Agents

Cleaning is one of the most repeated and important tasks in a winery. It is time consuming, tedious, costly and potentially dangerous. In most wineries cleaning is predominantly achieved through the use of sodium hydroxide based caustic cleaners.

A case study was completed at a medium sized (approximately 10,000 tonnes per annum) winery in Victoria, assessing the benefit of implementing a caustic recycling system.

There is an increasing focus on the minimisation of caustic material within wineries. This is primarily driven by the following factors:

- Chemical cost;
- Occupational health and safety requirements;
- Waste water quality implications; and
- The potential re-use of winery waste water in irrigation applications.

Caustic recovery systems significantly reduce the hazards associated with winery cleaning. Sodium hydroxide is classified as a dangerous good. It is a corrosive chemical and causes burns by all exposure routes. Delivered as a solid, it is normally used as a solution, requiring an intermediate solution preparation step. The addition of water to solid sodium hydroxide causes a vigorous exothermic reaction generating heat, often in sufficient quantities to boil the water. This hot solution, may contain up to 50% sodium hydroxide, and is highly corrosive. Lower concentrations of sodium hydroxide, such as that used regularly in

tank cleaning operations, pose a reduced risk (although still corrosive). Caustic recovery systems limit the exposure of staff to high concentration caustic solutions.

Caustic cleaners are the main source of sodium salts in winery wastewater. At high concentrations sodium salts reduce the suitability of water for irrigation applications. Recent waste water analysis at the case study winery suggest that current practices are not adversely impacting waste water quality, however, it is expected that analysis of waste water immediately after vintage would likely show higher levels of salt. The re-use of caustic cleaning agents has the potential to reduce sodium levels in treated wastewater that is used for irrigation. The use of a caustic recovery system is also expected to reduce labour requirements associated with tank cleaning as it eliminates the 'preparation step' currently required prior to every cleaning operation.

In the case study winery, over the last 12 months, $9,360 worth of sodium hydroxide was purchased. The introduction of a caustic recovery system is expected to reduce caustic consumption by up to 50%. In order to implement the system, some capital purchases will be required. The expected project cost to implement the recovery system is $12,825. The expected payback period for the project is just over one year (taking into account both economic and environmental benefits).

Case-study 2-In-winery Product Movements

Wine is moved between tanks to facilitate many winery processes, including racking wine off solids, using equipment (e.g. a centrifuge or a filter) and blending wines from different tanks. Each movement uses labour, water and cleaning chemicals and produces wastewater. These resources are used at the start and end of a wine movement and also for the tank cleaning operation that often accompanies a movement. Wine is also lost and/or diluted with water.

In this work, experiments were performed to better understand wine losses to wastewater during wine movements. A case study was then performed at one large winery to better understand the actual number of movements performed and the drivers behind them. The number of movements was principally by analysing entries in the winery's label integrity program (LIP) database.

Experiments showed only small wine losses (< 20 L) during simple pump movements not involving processing equipment. This was in contrast to one previous literature report where wine loss was approximately 370 L for a wine movement including an in-line plate heat exchanger. As a general rule, movements involving processing equipment are likely to result in larger wine losses to wastewater. Wine losses will also be larger for longer movements and slower push flow rates. The practical opportunities to improve the manner in which an individual movement is performed are judged to be rather limited. The biggest improvement opportunity is in working to reduce the absolute number of movements.

At the case study winery, the average numbers of movements in red and white wine lifetimes were estimated from LIP entries using two different methods. The first method was a simple average and was calculated by summing the volume of wine moved through an operation type at the winery and dividing that by the volume of wine produced. Using this method there were on average 10.6 movements for red wines and 8.6 movements for white wines. This essentially describes the average number of times that each drop of wine was moved. The second method was a size-weighted average. Using this method there were on average 25.6 movements for red wines and 16.9 movements for white wines. The size-weighted average is likely to have a closer relationship with the actual number of movements performed at the winery as the simple average will be skewed by large volume movements.

Some wine movements were performed at the same time and will therefore involve less effort. Grouping jobs based on a common operations note showed there were 1.9 movements per job.

Excluding final filtration, red wines were clarified by centrifugation or filtration an average of 3.9 times on a simple estimate basis or 7.7 times on a size-weighted basis. Similarly, white wines were clarified by centrifugation or filtration an average of 3.8 times on a simple estimate basis or 5.5 times on a size-weighted basis. This large number of clarifications is worthy of further investigation by the case study winery. There may be opportunities to reduce this number by coupling additions and therefore clarifications steps, relaxing requirements for clarity during storage, or substituting earth filtration systems with cross-flow filtration systems that may be able to achieve the same level of clarification in fewer passes.

Pump movements were the dominant movement type and a large number of these were small volume movements. 24% of red wine and 12% of white wine pump movements were less than 2 kL. Moving leftovers after filling export containers was a major contributor to this result. This is likely to be a common issue at many wineries given that bulk wine exports now make up more than half of all Australian wine exports.

Approximately 40% of pump movements occurred at the 'Finished' production stage. This was surprising given that most core operations had been completed by that time. A contributor to this was small packaging runs that required reorganisation of leftover wine from a tank to prevent the remaining wine being ullaged. It would be advantageous if improved low cost techniques to prevent wine quality loss during ullaged storage could be developed so that the only driver in keeping tanks full was to free up storage capacity.

Scheduling/tank farm optimisation software has the potential at this and other large wineries to significantly reduce movement numbers and distances. This non-standard software may be too expensive for all but the largest and most complex wineries and is also likely to require cultural change in many wineries.

Decision-making in many wineries is quite distributed with cellar hands sometimes making decisions on which tanks to use. There is an opportunity in some large wineries to reduce product movements through standardisation and formalisation of production rules (e.g. specific winery zones to be used for different operations). Extensive preliminary consultation with production staff would be required if this was to be effective.

There may also be an opportunity for some wineries to reduce wine movements through working with customers to improve forecasting of product requirements, with the goal of being able to group orders from different customers into larger packaging runs. The same principle applies to reducing movements of export leftovers. If more export containers can be loaded in a single run there will be fewer parcels of leftover wine.

An aspirational long-term goal to reduce product movements is to have techniques in place that allow wines to be kept in their most base state and then be able to blend, stabilise, clarify and package them into a high quality consistent product to order in one action.

Case-study 3- Improving Lees Filtration Processing Efficiencies

Efficiently recovering value from wine and juice lees, which typically comprise solid contents of 20-35%, is a task that provides a significant challenge to wineries of all sizes.

Typically most wineries that do process their lees utilise rotary drum vacuum (RDV or RVD) technology to recover a significant quantity of this juice or wine. However whilst RVD can handle high solids levels, the filtration process itself will generally result in a quality downgrade of product recovered and it produces an additional solid waste stream. Additionally there are the well know OH&S issues surrounding the use of diatomaceous earth, which in itself has driven a shift towards using perlite as a filter medium.

Newly developed cross-flow filtration systems capable of handling the high solids levels associated with lees and the associated difficulties posed by bentonite, have the potential to improve recovery of wine from the lees, whilst reducing the environmental impacts of water use, wastewater loading and the generation of an additional solid waste stream associated with earth based filtration.

This investigation evaluated technologies including the Pall HS Oenoflow and the TMCI Padovan Dynamos cross-flow filters, and has demonstrated these technologies, and potentially others such as the Bucher-Vaslin Flavy Leestar, can improve both the economic and environmental impact of current practice lees processing, with very significant reductions in water consumption and improvements in filtration proficiency and corresponding product quality.

Whilst there is no one-size-fits-all finding generated from this investigation, there is scope for individual wineries to refine their lees processing requirements, and in-turn the report will assist in quantifying the potential benefits available from these new processing technologies.

Additionally, the investigation has quantified the water consumption associated with rotary drum vacuum processing, and has demonstrated that low technology opportunities do exist to significantly reduce water consumption of existing technologies.

Case-study 4- Winery Salt balance

As part of a larger review of techniques and technologies to improve wastewater management at Australian wineries, a series of cleaner production investigations were conducted at the Wirra Wirra winery in the McLaren Vale wine region to the South of Adelaide, South Australia. This site was selected as representative of a medium sized winery with specific issues with salt loads in wastewater. The winery is considering how to best improve it wastewater quality for irrigation and to effectively manage wastewater capital and operating costs.

As part of the investigation the whole of winery mass balance was reviewed and several specific issues addressed, including salt concentration in the wastewater treatment train, caustic washes of red ferments and management of waste at the centrifuge. In this trial, the removal of potassium and sodium by way of the solids recovery at the centrifuge had no material impact on the salt loading of the wastewater treatment plant. However, the exclusion of some COD load from the treatment plant is significantly beneficial. Based on these results, by recovering or diverting the solids discharge waste stream, the

wastewater COD is reduced by approximately 2,000mg/L at the wastewater treatment plant inlet. The pre-screenings waste stream if separated, by an equivalent of 330mg/L per annum, representing approximately a 4% decrease in COD over the year.

Potassium from cleaning agents contributed between aproximately 25 and 60% of the estimated potassium loads, depending on year. Changes in cleaning agents are clearly reflected in the resulting potassium loads in the wastewater. Winery efficiency and improved management of potassium cleaning both have the potential to reduce potassium impacts on the wastewater. Cleaning of heavily tartrated tanks and management of winemaking lees are likely to be effective targets.

At this site, which has high use of potassium based cleaning agents, the potable water supply is as significant a source of sodium in the wastewater as the use of sodium cleaning agents. Potable water efficiency is, therefore, a significant opportunity for management of salts in wastewater. However reduction of stormwater inputs into the waste stream has potential to increase wastewater salinity. To recover the entire caustic cleaning solution utilised on site would require approximately 21kL of storage and remove over 81kg of sodium and over 96kg of potassium from the wastewater. The effect of this would equate to an equivalent of 34mg/L of Na and K salts removed from wastewater.

Salt concentration in the wastewater treatment train, which is predominantly open to the atmosphere during the warm months, has the potential to decrease the quality of the water for land application. This occurs at the time of year of highest wastewater volume production and when suitable irrigation water is likely to be most beneficial to a range of land uses including grapes. Cleaner production requires a focus not just on reduced water use and downstream treatment, but also on reducing organic loading and salt (sodium and potassium) loading by addressing these contaminants at the source level. It is critical to understand the importance of potassium for soils as the balance between sodium and potassium cleaners may need to be reviewed to reduce potassium levels.

Recommendations

The new knowledge generated by this project must now be considered in terms of:

1. A concerted effort to extend the technical knowledge and tools to industry via road shows so that adoption can occur in all wine regions. This would highlight the benefits of
    a. Recycling cleaning agents;
    b. Reducing the number of movements of wine; and
    c. Improving lees filtration.

The road show would also give an update on ice pigging.

2. Update the operating guidelines based on the new information generated through this project with a view to reducing the wine industries industrial footprint while not imposing an economic cost..

This research was co-funded by GWRDC and CSIRO and was conducted in collaboration with AWRI and DO. The project team acknowledges the support of all the wineries who contributed significantly by sharing their data and participating in the auditing process during this project.

1 Background

Waste minimisation is slowly being adopted in the wine industry, owing to a combination of powerful drivers, which are either internally or externally motivated. However, these waste minimisation practices in the wine industry are still carried out in an *ad hoc* fashion and have proven to be inefficient in many cases. The lack of a systematic methodology of synthesising and targeting specific waste streams by the industry has been identified as a major cause of failure in realising the full potential of waste minimisation in the wine industry. The waste of water in wineries is very widespread. Previous work identified a 1L/L benchmark for winery water use. Water audits conducted as part of previous research and commercial work by Provisor has identified that this level is rarely achieved with values of 4 times higher common and 10 times higher occurring in some wineries. This water has a variable cost, depending on the source, but a value of up to $1/kL is applicable.

Many wineries must operate in regions with significant water restrictions, both for winery use and irrigation. Implementing sound technologies to reuse overall water use in the wineries and improve the quality of water entering wastewater treatment facilities will not only help wineries meet demands of regulators and consumer expectations but also have a significant impact on the cost of winemaking operations.

CSIRO, in work funded by GWRDC, have identified opportunities for more effective management of water in wineries. In addition, we have been exposed to a large number of development projects in water management that are at the “close to ready” stage for implementation, but require some effort to validate their concept, economic performance and overall effectiveness.

The wine industry has been investigating the use of cleaning chemicals, resulting in a reduction in caustic use, or potential to do so. Significant progress has been made towards understanding potassium sources in wastewater streams, including identifying that it comes in with grapes. Recent work has shown that wineries currently send significant volumes of waste solids, which are easily separated (containing BOD and potassium) into treatment facilities where they are converted into dissolved forms which are hard to remove or separate. This presents an opportunity to revolutionise winery waste treatment from being purely an end of pipe scenario to having preliminary treatment within each processing stage in the winery.

Transfer operations between crushing and pressing operations for white wines and crushing and fermenters for red wines are typically conduced in large diameter pipes producing large volume loadings of waste water, organics and salts that must be managed by treatment systems. Minimising mixing at the interfaces of these transfer operations, diverting waste water with very high organic or salt loadings for disposal for reuse elsewhere (i.e. Tarac technologies), and recovering good quality waste streams for reuse in the winery will have a significant impact on the environmental impact of wineries and the costs of wastewater management The opportunities we have identified fall into five categories:

1. Preliminary treatment at the unit process (e.g. filtration or separation for removal of solids);
2. Alterations and new technologies to assist transfers (e.g. pigging, fluid interfaces and pipe mixing, auto cut out techniques using spectroscopic technologies);
3. Reuse of water (e.g. collection and reuse of water in wine transfers, reuse of water in downgraded applications such as truck washing or preliminary cleaning);

4. Reuse of cleaning chemicals and water or other cleaning techniques (such as the use of hot water); and
5. Segregation of waste streams.

We have observed that whilst some opportunities are relatively close to application, there is a hurdle of acceptance that can be easily overcome with appropriate demonstration projects.

Recent projects investigating winery wastewater have identified a number of new technologies that may help to reduce or recycle wastewater and ensure wine is produced cleanly. This project tested and demonstrated these technologies and deployed case studies within industry to facilitate their uptake. In this project, we tested the technologies from the 'idea' phase to reality, using a rigorous development and assessment process including:

1. Identification of high benefit to cost process impact areas
2. High impact area technology screening based on the following performance criterion
    - Economic parameters including the purchase cost, cost of implementation and operation
    - Environmental evaluation (salt and organic load)
    - Design and utility
3. Proof of concept including bench-top trials
4. Case studies

We understand that "recycling" covers streaming, reducing, reusing, recycling, and disposal of process water in wineries. Technological and processing advances will be developed in each of these areas with the most promising technologies taken through to the case study and implementation stages.

We reviewed a range of available technologies that needed to be adapted or demonstrated within the winery/vineyard. These technologies were drawn from:

- CSIRO, ARRI and DO Consultant research into winery wastewater;
- Industry surveys
- Lessons from other industries' and
- Wine professionals and suppliers

The following opportunities that require some development as identified in our literature survey and previous work include:

- **Receival area re-development**. Grape receival is typically responsible for up to 30% of winery water use. A simple process based on principles developed within the chemical industry, is proposed that will utilise counter current treatment methods and separation screens commonly used in sludge processing. This technology will remove solids and allow the remaining water to be recycled. It is expected that this process could reduce water needs in the grape receival area by 75%.
- Small winery water **push-through recovery** for reuse.
- **Ice and gas pigging** of transfer lines.
- **In-winery solids separation,** using techniques common in piggeries, to take high BOD/COD solids from liquid waste streams directly to solid waste treatment areas so that they do not need to be treated in wastewater plants.
- **Cleaning chemical reuse**. A number of wineries have reduced their consumption of cleaning chemicals by developing effective recycling programs. This practice needs further investigation and development.

- **Vacuum water recovery**. Many wineries have not implemented changes to vacuum pump design which see large volumes of clean water sent to treatment facilities. There is a potential to save 10% of water use within these wineries by modifying vacuum pump cooling and gland seal water systems.

These opportunities along with others were further explored in this project.

2 Project aims and performance targets

The overarching objective of this project was to ensure the rapid development of cost effective and beneficial processing improvements which will reduce the amount of wastewater produced in wineries

The revised timelines and performance targets on the review process as outlined in Table 2.1

Table 2.1 Outputs and performance targets of the project

Year 1 2010-11	Output	Performance targets
1.1	**Creation of project steering group and signing off the contract.**	**1.1.1** Identification of suitable members from wineries, suppliers and service providers.
		1.1.2 Initial meeting of project steering group to outline project scope and responsibilities.
1.2	**Identification of high benefit to cost processing areas within the winery.**	**1.2.1** Preliminary winery site investigations and review of past work.
		1.2.2 Develop an online survey template and questionnaire.
1.3	**Identification of potential technologies and practices for further evaluation.**	**1.3.1** Survey the Australian wine industry. Report findings.
		1.3.2. Collation and documentation of cleaner production strategies and recommendations in literature including recent project work by the GWRDC and CSIRO.
		1.3.3 Field visits and phone communication to several wine regions and other industries investigating water and wastewater technologies.
1.4	**Evaluation of cleaner production processes using the rigorous assessment method.**	**1.4.1** Sorting and ordering of potential technologies.
		1.4.2 Identification of the relevant merits of each of the new technologies or methods, using a robust assessment method, including: ▪ Preliminary concept evaluation; ▪ Economic evaluation; ▪ Environmental evaluation; ▪ Engineering design; ▪ Proof of concept. ▪ Bench-top wastewater analysis
		1.4.3 Documentation of findings.
		1.4.4 Selection of technologies for site investigation.
1.5	**Preliminary Site or Bench top Case Studies**	**1.5.1** Site mapping
		1.5.2 Analyses of wastewater
		1.5.3 Analysis of water associated with these processes

1.6	**Communication of results and findings to the industry and linkage with Project 1.**	**1.6.1** Documentation of findings in a formal report to GWRDC.
		1.6.2 Creation of fact sheets to present the findings on each technology or method assessed based on critical criteria.
		1.6.3 Selected photography and video presentation for communication and linkage with Project 1.
Year 2 2011-12	**Output**	**Performance targets**
2.1	**Establishment of which wineries will participate in the case studies.**	**2.1.1** Identify and select two key wineries where successfully evaluated new technologies will be implemented.
		2.1.2 Investigate current water and wastewater management practices within these wineries. This will include base line wastewater sampling.
		2.1.3 In conjunction with the selected wineries purchase necessary capital equipment to facilitate the implementation of new technologies.
2.2	**Development and implementation of case studies.**	**2.2.1** Commission and implement beneficial technologies into at least two large wineries.
		2.2.2 Commission and implement beneficial technologies into at least the two small wineries.
		2.2.3 Train winery staff to use the technology.
Year 3 2012-13	**Output**	**Performance targets**
3.1	**Quantification of benefits.**	**3.1.1** Quantify the reduction in waste water volume and contaminant loading. **3.1.2** Identify the Economic and Environmental benefit.
3.2	**Promotion of case studies and all findings to the wider wine industry.**	**3.2.1** Document findings in a formal report to GWRDC.
		3.2.2 Disseminate results to the wider Australian wine industry via road shows and regional workshops
		3.2.3 Promote wide spread implementation of beneficial technologies through technical conferences and papers.
		3.2.4 Development of short videos and linkage with Project 1.
		3.2.5 Development of fact sheets to present finding on each technology.

2.1 Approach and Methodology

This is a four stage project.

Stage 1

a. Establish a stakeholder's group to capitalise on significant industry expertise in engineering consulting firms, selected wineries and industry suppliers.
b. Preliminary evaluation of high benefit to cost process impact areas. Conduct a survey to ensure that any technologies close to ready for the identified high impact applications have been effectively sought out.

Stage 2 is a sorting process of high impact area technology based on the following performance criterion:

a. Sorting by readiness. Techniques that are not relatively simple or relatively ready for application will be identified and classified as more complex.
b. Sorting by level of technical risk. Projects that are ready and demonstrated in other industries will be reviewed for the degree of technical risk. Elements of the technical risk review will include:
    - availability of technology, parts and spares
    - maturity of the suppliers and availability of supply
    - requirement for complex monitoring systems
    - requirement for a high degree of specialist expertise.
c. Sorting by cost both implementation and operating.
d. Sorting by environmental risks (reuse potential of the winery water)

Stage 3 is the formal evaluation of each technology. It is expected that only four or five of the most appropriate technologies or methods will proceed past the economic and environmental evaluation stages. The formal evaluation will consist of:

- Preliminary concept evaluation;
- Economic evaluation including implementation costs;
- Environmental evaluation;
- Engineering design; and
- Proof of concept and bench-top trials to evaluate the effectiveness of technologies.

Stage 4 will involve establishing and commissioning the most appropriate technologies within winery settings (small and medium) as identified by the project team. It is expected that four or five technologies will be established. This stage will employ linkages between this project and Project 1, in order to ensure the results and findings are communicated to the industry using the methods and strategies developed by Peter Day Resources.

In order to meet this objective, communication of the project findings and results were also critical. We targeted this through two formats:

- Development of specific project material; for example at the end of the preliminary concept evaluation stage a document will be produced outlining the concept of each technology included within the project; and
- Linkages into the work being completed by Peter Day Resources to help communicate with industry.

2.2 Results/Discussions

This section has been summarized in the following chapters (Table 2.2). This series of short chapters provides brief methods followed by the results and conclusion for each research activity. At the end of each chapter indicated, the outputs associated with each activity to which the reader is directed for further detail.

Table 2.2 Overview of chapters presented in the following report

Chapter	Activity
3.1	Identification of high benefit to cost processing areas within the winery
3.2	Survey results
3.3	Evaluation of cleaner production processes using the rigorous assessment method
4.1	Cleaner production opportunities: Crusher push water re-use
4.2	Cleaner production opportunities: Ice pigging
4.3	Cleaner production opportunities: Transfer minimisation
4.4	Cleaner production opportunities: Automated mixed interface detection
4.5	Cleaner production opportunities: Marc bay roofing
4.6	Cleaner production opportunities: Lees solid separation
4.7	Cleaner production opportunities: Must solids separation
4.8	Cleaner production opportunities: Cleaning chemical type evaluation
4.9	Cleaner production opportunities: Cleaning chemical reuse
5	Case study 1- reuse of caustic cleaning agents
6	Case study2- In-winery product movements
7	Case study 3- Lees filtration processing efficiencies
8	Case study 4- winery salt balance
9	Overall conclusions and recommendations

3 Cleaner production technologies- sorting of high impact areas

In order to identify potential strategies and cleaner production technologies which might be suitable for the Australia wine Industry an extensive survey process was completed using two approaches:

- The online survey – primarily aimed at small to medium sized producers; and
- Personal visits to various wine producing companies – targeted more at large producers.

The survey was intended to:

1. Identify operational practices and technologies which could be incorporated into wineries to improve their production practices; and
2. Promote the project to allow for possible future collaboration in later stages of the project.

3.1 Identification of potential technologies and practices for further evaluation

An online survey was developed using Survey Monkey. The survey was promoted both verbally and using email bulletins sent out by AWRI (AWRI's eNews). The survey questionnaire is attached as Appendix 1. The primary objective of the survey was to develop a list of operational techniques and technologies which might result in cleaner wine production.

In total we received 32 completed online surveys. The distribution of wineries by size is shown in Figure 3.1. In total the online participants represented about 5% of the Australian crush, and this provided a reasonable indication of the needs and desires of the small to medium sized producers.

In order to gain further insight into potentially appropriate technologies and solutions for the industry the project team consulted 15 of Australia's larger wine producing companies, as well as industry researchers, wastewater service providers and consultants. These consultations, usually involved a site visit, which provided insight into the various ways that wastewater is managed within wineries. The 15 companies that were visited are responsible for about 65% of Australia's total wine production. Many observations were made during the visits. The project team was surprised at the diversity of wastewater management techniques employed in amongst very similar processing facilities.

In total the surveys collected information from wine producing companies which represent about 70% of the total tonnes crushed in Australia. The information was drawn from a wide distribution of winery sizes and locations as shown in Figure 3.1 and Figure 3.2.

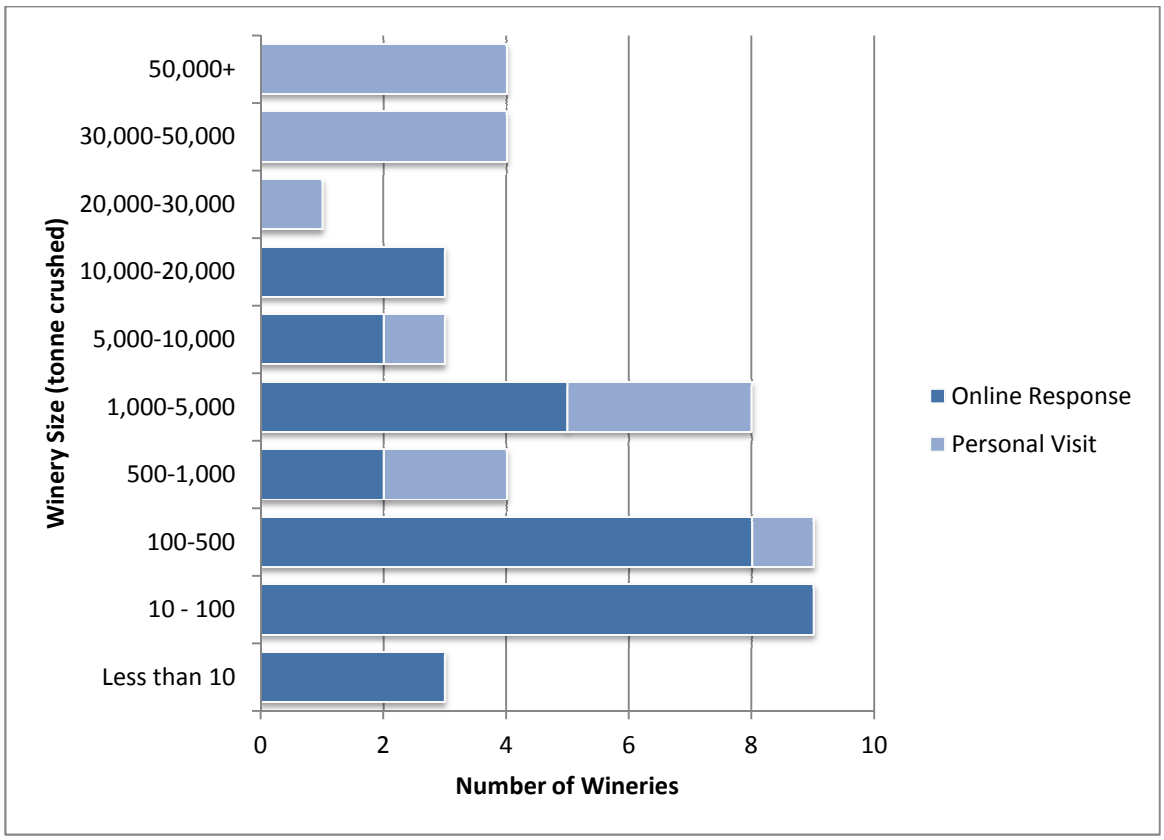


Figure 3.1 Distribution of surveyed wineries by size

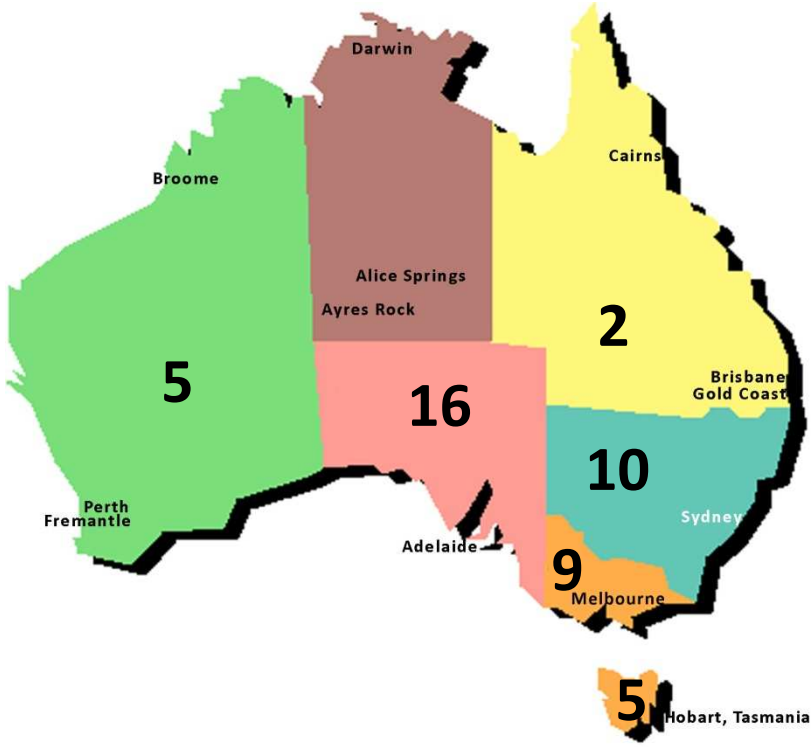


Figure 3.2 Distribution of surveyed wineries by state

3.2 Survey results

The survey was intended to identify the potential technologies and operational strategies which the industry considered to be worth further investigation. Broadly speaking, the suggestions were related to four main categories:

1. Cleaning efficiency
2. Separation of solids
3. Separation of waste streams, and
4. Transfer related activities

The full list of suggested cleaner production opportunities are presented in the Table3.1. Cleaning efficiency and cleaning related projects were considered the most important with 77% of all survey participants suggesting ideas or opportunities within this category. Transfer related process changes were the second most requested opportunity, listed by 66% of participants. The separation of streams and wastes was considered less important with 29% requesting opportunities related to stream separation and 17% suggesting solids separation processes be further investigated.

Table 3.1 Suggested cleaner production opportunities

Opportunity category	Sub category
Transfer efficiency	
1	Re-use of crusher to press/tank push water
2	Pigging of pipes (flexible pigs)
3	Pigging of pipes with an ice slurry
4	Minimisation of transfers
5	Automated mixed interface detector
Streams separation	
6	Automated cut-out valve for stormwater
7	Marc bay roofing
8	Wine loss identifier
Solids separation	
9	Lees cross-flow filtration
10	Secondary settling
11	Must solids separation
Cleaning efficiency	
12	Ice pigging with caustic/biocide ice mix
13	Cleaning chemical type evaluation
14	Re-use of cleaning chemicals
15	Heated cleaning solutions

16	Immediate clean/re-use of tanks
17	Ozone sanitation
18	Gas mixing versus wine pump-overs
19	When is it clean enough? Does cleaning matter?

Typical issues with winery wastewater treatment identified by survey respondents were as follows:

- Excessive odour
- Excessive electricity consumption of wastewater treatment equipment
- Poor reliability of wastewater treatment equipment
- Seasonal fluctuations in volume and influent BOD/COD
- Undersized treatment plant

3.2.1 ADDITIONAL DATA FROM WEB-BASED SURVEY OF WINERY WASTEWATER-RELATED PRACTICES

Mains water was the major source of water at wineries and was often supplemented by rain water, bore water and dams (Table 3.2). Water use at wineries varied between 600-3300 L/tonne crush (Table 3.3). The treated wastewater was used mainly for irrigation on lawns, vines, pastures or for growing beneficial crops (Table 3.4).

Table 3.2 Source of water for winery survey respondents of different sizes

Eq. crush[a] (tonnes)	Mains	Bore	Dams	Irrigation network	On-site recycling	Rain
>10,000	100%					
5,000-10,000	100%					
1,000-5,000	40%					60%
	90%					10%
	100%					
	100%					
	50%		30%		10%	10%
	100%					
100-500		80%				20%
	100%					
	100%					
	99%					1%
	100%					
						100%
	100%					
						100%

	100%			
	5%			95%
10-100	80%			20%
		25%		75%
		5%		95%
				100%
		20%		80%
		30%	20%	50%
			98%	2%
				100%
		100%		
< 10		99%		1%
	100%			

[a]Incorporates purchased juice and/or wine

Table 3.3 Calculated water use per equivalent tonnes crushed

Statistic	Water use per eq. crush[a] (L/tonne)
Median	1,300
Minimum	600
Maximum	3,300
Data points	14

[a]Incorporates purchased juice and/or wine

Table 3.4 Calculated water use per equivalent tonnes crushed

Eq. crush[a] (tonnes)	Sewer/ tanker	Wood-lot	Vines	Water-ways	Process reuse	Other crops/ pasture	Lawns/ gardens	Evaporation	Other
>10,000			30%		5%	40%	20%	5%	
5,000-1,0000			95%				5%		
1,000-5,000						20%	80%		
1,000-5,000	100%								
			50%		20%		20%	10%	
	100%								
100-500		50%	50%						
	10%	20%	20%				50%		
							20%	80%	
						15%		85%	
	100%								
		100%							
							100%		
							100%		
						20%		80%	
10-100								100%	
	100%								
						100%			
						50%		20%	30%
<10		50%							50%
	10%			30%	20%	20%	20%		

[a]Incorporates purchased juice and/or wine

Other interesting statistics from survey worth reporting are:

- 45% of survey respondents practiced some form of sodium hydroxide or potassium hydroxide recycling for cleaning.
- 4 wineries reported some use of treated wastewater effluent for vineyard irrigation, typically in combination with other water sources.

3.3 Evaluation of cleaner production processes using the rigorous assessment method

The suggested opportunities, listed above, were each evaluated using an assessment method designed to identify which technologies or operational practices were likely to be most beneficial within Australian wineries. In some case it was not possible to accurately assess the opportunity without further investigation as was the case with transfer related opportunities. Site visits and experimental work were used to either generate data for economic and environmental assessment or validate the potential of future more rigorous work.

3.3.1 EVALUATION METHOD

Each opportunity was initially consider using a general observation of the potential merits, benefits and barriers to uptake. Two opportunities did not pass this stage; ozone sanitation and gas mixing versus wine pump-overs. Both of these opportunities, although potentially useful within the wine industry, were considered to have little impact on water quality or cleaner production methods and were therefore dropped from any further evaluation.

Following the general observation stage, each process was ranked against three criteria:

1. Technical feasibility/ difficulty of implementation
2. Economic benefit; and
3. Environmental benefit.

Technical feasibility/ difficulty of implementation was used to represent and measure the difficulty such an opportunity might present to the winery. This was intended to encompass the difficulty associated with retraining people, working with highly technical equipment, commissioning equipment of a nature that staff is not currently familiar with, commissioning temperamental equipment and dealing with other implementation problems. The ranking of technical feasibility/difficulty to implement was based on an assessment of potential time to implement the opportunity and have it successful working within a winery setting. Technical feasibility was given a rating of 1-5 (

Table 3.5).

Due to the current financial climate faced by the Australian wine industry the economic benefit of each opportunity was expected to be a critical element in a wineries decision to adopt a change or not. Economic benefit was assessed by using the net present value (NPV) and payback period. In some instances, the use of NPV and payback period proved problematic, as in the case when considering various lees management concepts, where establishing a baseline for comparison was difficult. In this case each management solution was compared against the discharge of lees directly to a waste treatment facility.

Table 3.5 Ranking criteria

Ratings	Technical feasibility /difficulty in implementation	Economic benefit	Environmental benefit
1	- 18m+ to be implemented - Highly complex or significant resource	Payback>5yrs Capital >100K	$0-0.25/kL
2	- 12m+ to be implemented - Complex or significant resource	Payback 3-5yrs Capital 50-100K	$0.25-0.50/kL
3	- 6-12m to be implemented - Fairly simple implementation, but may require significant resource	Payback 18m-3yrs Capital 30-50K	$0.50-0.75/kL
4	- 3-6m to implement - Simple or requires little resource	Payback 6-18m Capital 10-30K	$0.75-1.00/kL
5	- Could be implemented in <3m - Very simple or little/no resource	Payback <6m Capital <10K	>$1.00/kL

The final evaluation category considered was environmental benefit. Measuring environmental benefit is particularly difficult. There are number of methods available within life cycle assessment processes which place specific weightings on various environmental factors which enable a general environmental ranking, but these factors are not particularly relevant in terms of wastewater. In this case, it was deemed that the most significant environmental impacts associated with the wastewater were, sodium and potassium discharge, biochemical oxygen demand (BOD) or chemical oxygen demand (COD) and total water consumption. Each of these factors can be given an economic value, for example sodium and potassium discharge can be priced based on the purchase cost of land needed based on specified salt loadings. Similarly a price can be put on COD associated with the cost of providing aeration and land to dispose of the sludge generated. In this way an economic value was used to rank environmental benefit.

3.3.2 BASIC ECONOMIC DATA

The foundational economic data as given in Table 3.6 and Table 3.7 were used for the assessments. In Table 3.8, the preliminary evaluation data is presented for the selected cleaner production opportunities.

Table 3.6 Basic economic data

	Winery size			
Utility	**Small**	**Medium**	**Large**	**Unit**
Electricity	18	12	8	c/kWh
Natural gas	5	3	2.5	c/MJ
Water	0.2	0.15	0.12	c/L
Ethanol		1		$/L
Ice		100		$/T

Table 3.7 Treatment costs

Treatment costs	$/kg
Biological oxygen Demand (BOD)	1.57
Sodium (Na)	140.00
Potassium (K)	46.67
Solids	1.95

Table 3.8 Evaluation results

Opportunity category	Sub-category	Passes preliminary evaluation	Payback (years)	Environmental benefit ($/kL wine processed, yr. 0)	Capital outlay ($)	Score
Transfer efficiency						
1	Re-use of crusher to press/tank	Y	3.12	0.71	$57,000	42
2	Pigging of pipes (flexible pigs)	N	NA	NA	NA	0
3	Pigging of pipes with an ice slurry	Y	4.01	0.71	$70,000	40
4	Minimisation of transfers	Y	Assessed by site audit – economic data not			75
5	Automated mixed interface	Y	2.52	0.00	$50,000	15
Streams separation						
6	Automated cut-out valve for	Y	2.82	0.36	$30,000	30
7	Marc bay roofing	Y	4.90	0.60	$60,000	32
8	Wine loss identifier	Y	5.87	0.20	$50,000	5
Solids separation						
9	Lees cross-flow filtration	Y	1.30	10.00	$330,000	45
10	Secondary settling	Y	3.39	6.00	$100,000	45
11	Must solids separation	Y	3.70	0.40	$25,000	9
Cleaning efficiency						
12	Ice pigging with caustic/biocide ice	Y	Combined with opportunity 3, pigging of pipes with an ice			
13	Cleaning chemical type evaluation	Y	NA	-0.04	$0	15
14	Re-use of cleaning chemicals	Y	0.65	1.17	$62,500	100
15	Heated cleaning solutions	Y	Combined with opportunity 14		$7,500	24
16	Immediate clean/re-use of tanks	Y	NA	NA	NA	NA
17	Ozone sanitation	N	NA	NA	NA	0
18	Gas mixing versus wine pump-overs	N	NA	NA	NA	0
19	When is it clean enough?	Y	Combined with opportunity 4, minimisation of transfers			

The highest ranking opportunities were reuse of cleaning chemicals, minimisation of transfers and the solids separation techniques of lees cross-flow filtration and secondary settling. Ice pigging, the re-use of crusher to press push water and an automated stormwater diversion system also ranked relatively highly.

Details on each opportunity are presented in Chapter 4.

4 Cleaner production opportunities

4.1 Crusher push water re-use

4.1.1 OPPORTUNITY

Re-circulation/re-use of push water used to aid wine transfers.

4.1.2 BACKGROUND

Water used to prime transfer lines prior to wine transfers and push through residual wine after transfer is generally disposed of immediately to drain. This push water could be re-circulated and re-used for subsequent wine transfers or vessel washing many times, prior to disposal.

4.1.3 PRACTICAL IMPLICATION

Practically, this practice could be implemented immediately in most wineries as long as there are existing tanks that could be utilised to hold the re-circulated water and pumps are available to transfer the push water back from the destination tank to a holding tank. Additional power is required to pump the water back to the holding tanks.

There would be no additional labour requirements, above and beyond those already employed for wine transfers.

4.1.4 ENVIRONMENTAL EVALUATION

Reduced water use would also result in a lower volume of wastewater requiring treatment. Organic loading in the wastewater from wine transfers would not change, as the lower volumes would contain a higher concentration of organics as the water is re-used. Wine losses would not change.

Economic evaluation of crush push-water technology is given in Appendix 2.

4.2 Ice pigging

4.2.1 OPPORTUNITY

Exploring the feasibility of using ice pigging to clean pipes and efficiently push grape must from the large crushers at the end of batches in wineries.

4.2.2 BACKGROUND

Pigging is an established practice in the wine industry; the pumping of a solid object through a pipe to clean the pipe walls or to clear the remaining contents from the pipe at the end of batches without mutual contamination with a “push” fluid or subsequent product.

Reducing axial mixing of adjacent fluids and slurries in fluid transfers has economic and environmental benefits that include: product recovery, reduced BOD and potassium in wastewater, increased water recyclability and reduced water consumption. The physical scraping of pigs whilst cleaning pipework can

increase cleaning efficacy compared to chemical washing alone, and hence reduce chemical loading when combined. The use of scourer pigs with caustic washing is widespread in wineries.

Ice pigging is the pumping of high-solids (>80%) ice slurry in pipes, in attempts to deliver the same benefits of conventional pigging without the disadvantages of trying to pump solid objects. It exploits the beneficial physical properties of a solid, whilst retaining versatile flow characteristics of a fluid.

Unlike conventional pigging with projectiles, ice pigging does not require specialised high-tolerance pipework, valves, or in-line pig launchers and catchers. Ice pigs can traverse drastic pipe diameter changes, butterfly valves, thermowells, pumps, manifolds, nozzles etc. whilst retaining integrity; potentially offering a retrofittable pigging operation in conventionally “unpiggable” plant. Most wineries are majorly comprised of “unpiggable” plant.

The potentially most valuable use of ice pigging in wineries is the pushing of crushed grapes from the large crushers to the tanks or presses in large diameter (6”) pipes. In this operation, at the end of crushing a batch of grapes, when the must pump fails to gain a purchase to clear the remnants in the pipe, an ice pig would be fed into the pump and followed by water to push the line clear. The widely used practice of ‘water pushing’ grape must in large pipes results in large amounts of mutual contamination of the product and push water when the flow is diverted from the target vessel to the waste stream for product and push water respectively. Contamination from water pushing accounts for a very large proportion of total winery waste contributions and water use. A recent study by CSIRO (Kumar, 2009) found that of the total winery output, the large crusher push water accounts for on average 39.3% of COD, with similar values for sodium, potassium and suspended solids. A perfectly performing pigging operation has the potential to reduce these contributions to zero, whilst also reducing wastewater volumes, product dilution and potable water use substantially.

The value to wineries in using ice pigs to clean pipes (caustic/acid/biocide ice pigs) lies in its heightened efficacy and lower chemical requirement than the current practice of chemical washing alone or even with scourer pigs. Also, if an equivalence ratio of ice pig to scourer pig is quantifiable, especially with respect to cleaning hard deposits and biofilms, then ice pigging might represent a breakthrough new ‘clean in place’ technology capable of physically abrading inaccessible and unpiggable plant.

Ice pigging has been successfully applied in the food (Kiholm, 2000 and Quarini, 2002), nuclear (Greaney, 2001), coatings and water industries (Quarini, 2010). No industrial trials had previously been performed at a winery.

Feasibility studies in 2009 deemed that existing ice pigging equipment was too costly, time consuming and used too much salt for practical applications in wineries. A new method for producing ice pigs was designed and built specifically for testing during vintage 2011 by Lewellin Engineering Ltd.. The new prototype ice pigging machine was designed to be capable of producing ice pigs:

- with higher ice fraction (83.7% vs. 60% ice by weight)
- from delivered and stored ice cubes (vs. purchasing a slurry ice machine)
- in shorter times (20 minutes vs. 8 hours per pig)
- with less additive (1% vs. 4.75% concentration)
- with various types of additive complementary to winery products and processes (ethanol, potassium carbonate, caustic, organic solutions, acids, bases, gels, biocides, solid particles, etc.).

During vintage 2011, many experiments were performed to test the new ice making process and establish best practices for making ice pigs suitable for cleaning pipes and pushing must in large diameter pipes.

4.2.3 EXPERIMENTAL WORK

Setup and procedure for making an ice pig

1. After necessary sanitation practices, about 10% of the final ice pig volume of an aqueous additive solution is added to the ice pigging machine. The additive's purpose is to stabilise the ice slurry by separating the ice crystals and preventing them from freezing into an un-pumpable block. The additive can be chosen from a wide range of possibilities based on either beneficial chemical effects (caustic, acid, biocide) or being benign to the product and environment (ethanol or potassium carbonate). About 1% by volume of additive is required for an ice pig, although more can be used to prevent crystal size growth and hence smoothness.
2. The ice pigging machine is then turned on and single phase ice (solid cubes, tubes, nuggets, scales or flakes) is taken from storage and fed into the crusher chute until the desired solids content is achieved.
3. Adjustments to the machine controls and preparation times can be made to control ice crystal size (grittiness), ice fraction and ice pig permeability. Different properties affect the pig's longevity in the pipe, pumping pressure requirements and ability to scour the pipe walls.
4. When the desired ice pig consistency is achieved, usually 20 minutes for a 250 litre pig or 30 minutes for a 750 litre pig, valves on the machine are operated to inject the ice pig through standard winery hoses into plant, pipes or pumps.
5. If delays occur and the ice fraction drops in the machine due to melting, the addition of more ice will quickly raise it to standard.

For the work done in these trials, 10 kg bags of hygienically produces ice cubes were delivered from an ice factory on pallets, fork lifted and stored in a 20 foot long refrigerated container until required.

The ice pigging machine and setup is shown in Figure 4.1.

Figure 4.1 The ice pigging prototype machine and ice storage container

4.2.4 PRELIMINARY WORK

Initial experiments were performed to test how thick the ice pigs were in terms of ice fraction by mass. Measuring the ice fraction by pressing with a cafetiere as described by Shire et al. (2008) and Ainslie (2009) was not useful as there was not enough free flowing water content in the ice slurry to be pressed to the surface and measured. A calorimetric method of inferring the ice fraction by careful and measured mixing with hot water yielded a typical ice fraction of 83.7%. The consistency of the ice following pumping out of the delivery nozzle was that of a malleable solid and could be sliced with a knife and lifted by tongs without dripping, as in Figure 4.2.



Figure 4.2 Once pumped from the machine, the fluid ice slurry displays solid characteristics

Grape Must pushing experiments

For each of the must pushing experiments, ice pigs were made as described in the procedure above with either 1% ethanol or 2% potassium carbonate as the additive. Ice pig volumes were varied between 200 litres and 800 litres in order to determine the amount of ice pig required to remain coherent and last the duration of the flow. As the ice pig travels along a pipe, it absorbs heat and melts which causes it to shrink in length; an ice pig can be made to last longer simply by making it bigger. For different pipe diameters, lengths, water and product temperatures, different minimum volumes of ice pig were inferred. All of the must that was pushed from the large pumps went through 6” diameter stainless steel 304 pipes / tubes to the final destination via tube in tube heat exchangers. Some heat exchangers were 5” in diameter and some 6”, and the longevity of various ice pigs was studied according to the temperature and operational state of the heat exchangers.

Due to the live nature of the trials with real product, robust scientific measurement was unfortunately at a minimum. Attempts were made to take samples during transitions from must to water and ice, but the high solids nature of the grape must clogged outlet ports and prevented useful data being recorded. Measurements of the contaminated wastewater cut from the transfers were also prevented by the fixed inaccessible pipework in place and the joining of multiple waste streams before access is available. The performance of the ice pigs and comparisons with water pushing were judged by qualitative analysis from video footage of the sight glass near the flow exit; the sight glass used by the cellar hand to judge when the product had changed to water and made the cut to drain.

Cleaning of pipe work

1. The first ice pig cleaning experiment occurred during vintage when the test pipe had been mainly used for transferring juice. A 400 litre caustic ice pig consisting of 2% (when melted) potassium hydroxide solution was pumped through a 500 metre 3" diameter stainless steel (304) pipeline (with a 3" hose in the middle and end). The caustic pig was preceded and followed by water, and all pumped at 4.7 litres per second. When the exit fluid showed signs of turbidity and/or ice, samples were taken for analysis. All of the turbid water at the exit was collected in a bin, and a representative sample was taken to gain an estimate of total solids removed.
2. The second ice pig cleaning experiment was performed at the end of vintage when the test pipes had been mainly used for transferring wine. The aim of this experiment was to try to establish a metric of equivalence between conventional scourer pigging and ice pigging. Four x 250 metre 3" diameter stainless steel (304) transfer pipes that were deemed similarly used (by opinion, not measured) were joined into 2 x 500 metre pipelines. In the first pipeline, a caustic wash was performed with a scourer pig placed in the middle of 500 litres of 2% potassium hydroxide solution. In the second pipeline, a 300 litre caustic ice pig (1% potassium hydroxide concentration when melted) was pushed by water to pig the line. After both pipelines were pigged, another 300 litre 1% caustic ice pig was used to pig the first pipeline that had already been caustic washed / scour pigged. All of the pigging was performed with the pump at 4.7 litres per second. To measure the amount of solids removed from all 3 pigs, turbid exit water was captured, measured and analysed.

Turbid water from each experiment was analysed for dried solids by the standard practices of the wastewater manager at the winery; a known volume of sample was filtered, with the filtrate dried in an oven and weighed with accurate scales. In the second experiment, the samples were also tested with a turbidity meter to compare the amounts of suspended solids removed from the pipe walls that water flushing could not remove.

Figure 4.3 shows the scourer pig used in experiment 2.2

4.2.5 RESULTS

Grape must pushing experiments

The figures below (Figure 4.4 to Figure 4.6) are stills from a video of an ice pig pushing must along a 6" steel pipe (with hose at exit) into a tank via a heat exchanger:



Figure 4.3 Scourer pig used to clean 3”diameter pipes



Figure 4.4 The end of a batch of crushed grape must is pumped into a tank



Figure 4.5 The ice pig forms a plug and pushes all of the product into the tank



Figure 4.6 Following the ice pig, the push water is clean and recyclable

The diagrams presented in Figure 4.7 compare the outlet sight glass view over time as grape must is pushed by water (above) and an ice pig followed by water (below). They were both pumped at 6 litres per second. A video was taken of the whole transition, and at each frame of the video, pixels from 9 spots on the sight glass were compiled in a continuous fashion from left to right with time and volume. The colour of the reflected and transmitted light (from a light behind the sight glass) is unadjusted and was filmed with set exposure and aperture settings, giving a representation of wine concentration. The 9 spots from where the pixels were taken were in a vertical line up the horizontal pipe; resulting in higher concentrations of dark specs from solids in the bottom portions of each diagram – as observed in the pipe flow due to gravity. The

volume along the bottom x-axis of each diagram is the volume of the pipe (4000 litres) subtracted from the amount of water pumped in to push the must. Where this volume is at zero litres, a pipe volume of water has been pumped in, and for a hypothetical plug flow, a step transition would occur.

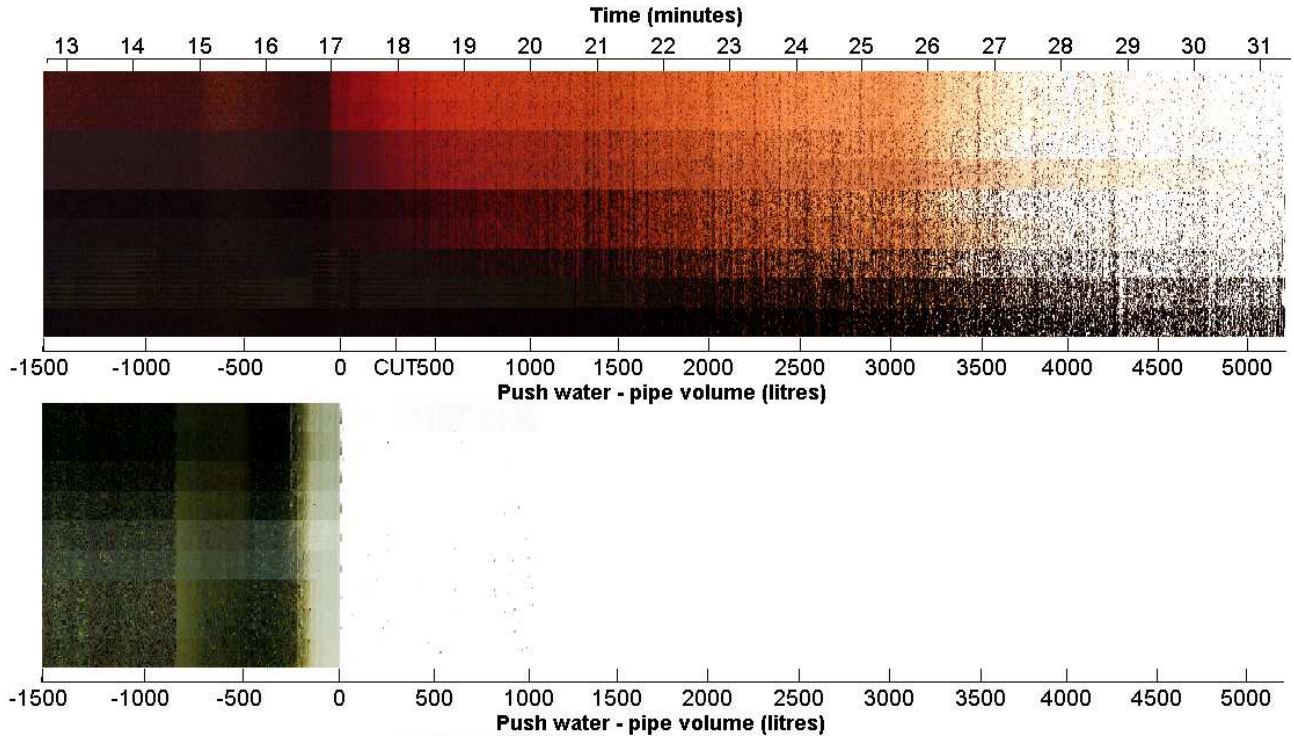


Figure 4.7 Diagrams of exit concentration over time and volume for a water push (top) and a 1% ethanol ice pig followed by a water push (bottom)

Figure 4.8 is a similar exit concentration diagram for another must transfer with an ice pig. In this diagram, the vertical striations from different grape must textures can be seen to the left (before the ice), along with a short transition to the ice pig, clean ice and a very sharp rear interface of the pig to the push water. The first few hundred litres behind the ice pig is very clear, before clumps of grape solids follow (higher concentrations of dark specs). This is an unavoidable consequence of “dead ends” in the pipework from valved off branches, where grape must collects during the transfer, remains as the ice pig pushes past and is then washed out by the turbulent push water. The clear gap between the rear of the ice pig and the stray solids is due to the lower speed of the solids as they drag on the pipe walls and fall backwards through any upward stretches of pipe.

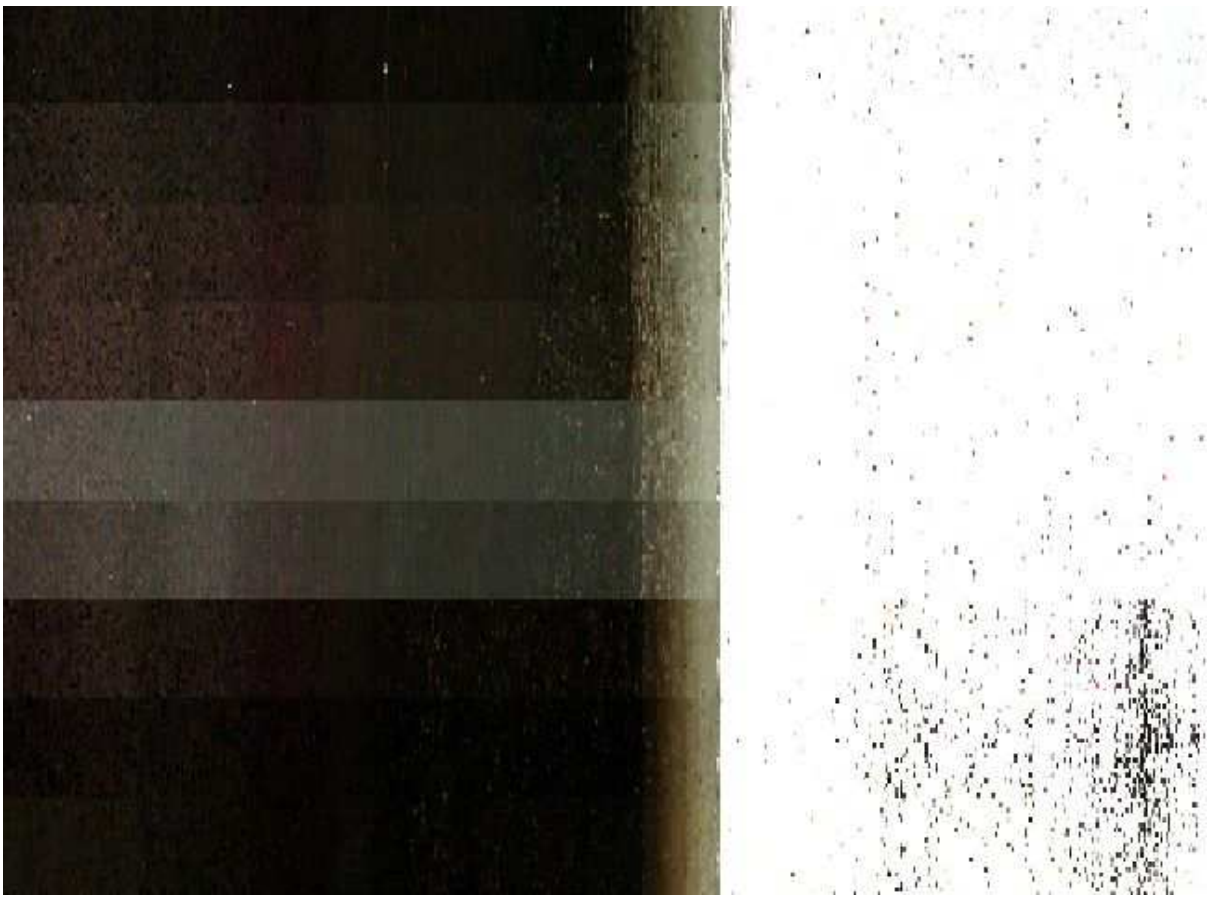


Figure 4.8 Exit concentration of a must transfer pushed with an ice pig and then water

Cleaning of pipe work

Figure 4.9 shows the dark turbid grape proteins scraped off the pipe walls by the caustic ice pig. The water that preceded and followed this effluent was clear, showing that water flushing alone at the same flow rate does not remove these hardened deposits.

Of the samples taken during this experiment, the highest solids loading was 1.875 grams per litre (dried mass), and the average for the 400 litres removed was 1.142 grams per litre (Figure 4.10). The total dried mass removed from the 500 metre pipe was 457 grams or 0.91 grams per metre of 3” pipe.



Figure 4.9 400 litre 2% caustic ice pig cleaning 500 m of 3” juice line



Figure 4.10 400 litres of dirty ice collected in a bin after pigging the pipe

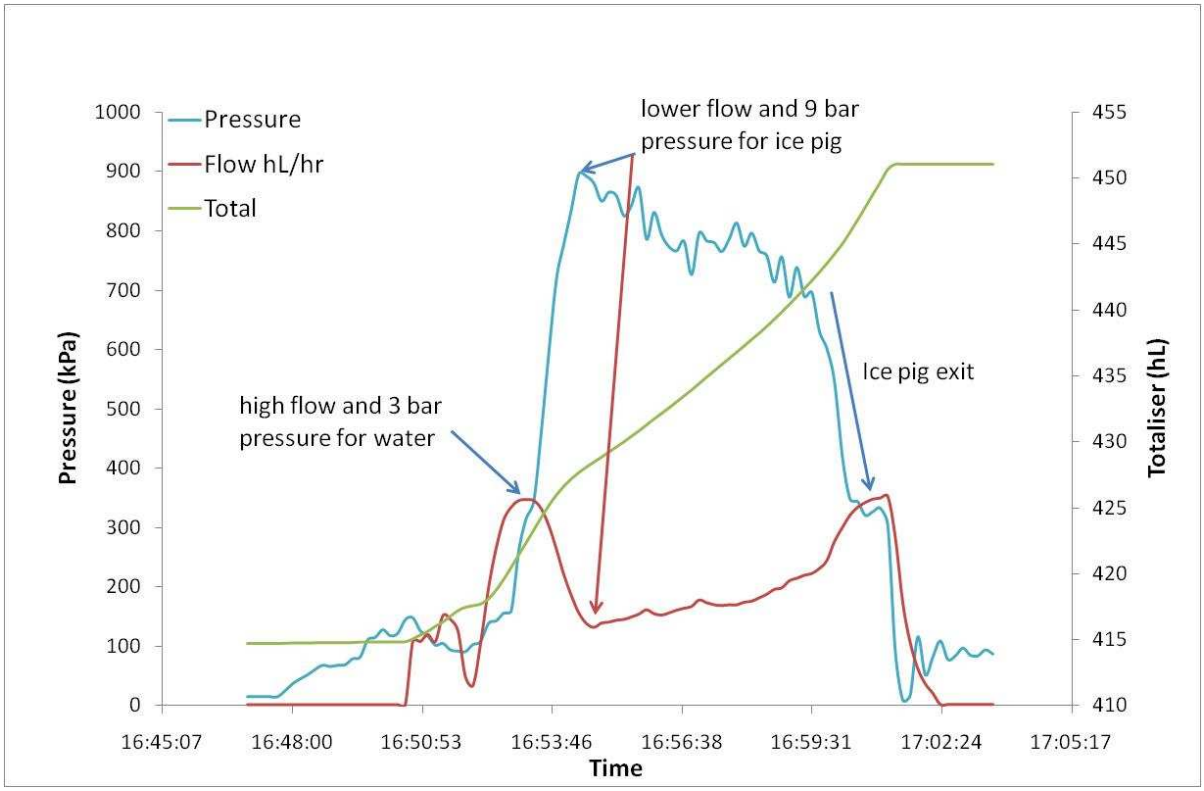


Figure 4.11 Graph of pressure and flow speed behind the caustic ice pig during cleaning

In Figure 4.11, data recorded by the winery SCADA system shows the pressure and flow rate measured at the pump while the caustic ice pig is pumped from the pump's 6" outlet into the 3" test line. The pressure drop across the ice pig is 6 bar more than for water alone.

Caustic wash with scourer pig vs. caustic ice pig

Table 4.1 shows analysis results from samples taken from the collection bins after pigging operations. In pipe 1, a 500 litre 2% caustic wash with scourer pig was deployed, followed by a 300 litre 1% caustic ice pig. In pipe 2, just a 300 litre 1% caustic ice pig was deployed.

Table 4.1 Analysis of output from pigging comparison experiments

Pipe	Experiment	Vol. Collected (L)	Conductivity (mS/cm)	Turbidity (NTU)	Dried solids (mg/L)	Total solids (g)	Caustic (L)
1	Caustic/scourer	680	74.5	8.9	165.5	113	10
1	Ice pig chaser	300	50.6	18.8	160.5	48	3
2	Ice pig	650	23.4	32.9	368.1	239	3

Figure 4.12 shows a photograph of the sample bottles and their resulting dried filter specimens.



Figure 4.12 From left; samples of 2% caustic/scourer pig wash, 1% caustic ice pig that followed the wash/scourer pig and 1% caustic ice pig in a different similar pipe.

The measured turbidity (Hach 2100N Turbidimeter) of the caustic wash /scourer pig was lower than that resulting from the caustic ice pig that followed it in the same pipe. The dried filtrates look to give a similar result as the middle filter paper is darker than the paper on the left. However, the measured dried mass of the filter papers shows that the mass loading of the first sample is in fact greater than that of the ice pig that followed it. When the collected volume of output is accounted for, the caustic wash / pig removed over twice the amount of the following ice pig. The caustic ice pig used on the other pipe removed the most solids and had the higher turbidity, but it is unsure how equally soiled the pipes were to begin with.

In this experiment, the caustic ice pig removed 2.1 times the amount of dried solids that the caustic / scourer pig managed, whilst using only 1/3rd of the chemical cleaner.

4.2.6 OUTCOMES

Grape Must pushing

Although rigorous measurements are lacking regarding both the extent of axial mixing using current water push techniques and ice pigs, the qualitative data shows a marked difference between the two techniques. The push water immediately following ice pigs was deemed “clean” by cellarhands, and the switch to drain and subsequent shutting off of the push water occurred immediately in the many successful trials performed during the course of vintage 2011. This practice reduced the amount of product lost to the drain per wash through drastically, thereby reducing COD and potassium loading of the winery wastewater. The volume of push water required was reduced from between 1.5 and 2.5 pipe volumes to a single pipe volume. Further, the single pipe volume of push water used was deemed “clean” and recyclable multiple times with a push water recycling facility, thereby reducing the water required to push the product (with ice pigs) to fractions of a single pipe volume per wash through.

Cleaning of pipe work

The first experiment showed the efficacy of using a caustic ice pig (that had never been done before anywhere) to clean hard deposits off internal pipe walls, and the measured pressure drop across the pig gives insight into the abrasive forces imparted to pipe walls by high ice fraction pigs.

The second experiment showed that the physical abrasion of ice pigging does contribute greatly to cleaning efficacy, allowing reductions in chemical loading for the same cleaning performance. It also demonstrates an equivalence between scourer pigging and ice pigging, proving a physically abrasive cleaning technique for unpiggable plant.

The analysis of the samples taken from the second experiment shows how the colour and turbidity of winery pipe fouling does not necessarily correlate with measured dried solids loading. It also shows that the types of solids removed by caustic wash / scourer pigs and ice pigs are different regarding turbidity and density.

Economic evaluation of ice pigging technology is given in Appendix 3

4.3 Transfer minimisation

4.3.1 OPPORTUNITY

Quantifying the amount of axial mixing of product and push-water during transfers in long 3” pipes.

4.3.2 BACKGROUND

When juice or wine is transferred between vessels during the winemaking process, it is often pushed by water at the end of the batch to transfer the last pipe volume that the pump can’t gain a purchase on. Similarly at the beginning of a transfer, caustic solution is often pushed through by water to sanitize the pipe run, this water is then pushed out to drain by the product. During these two turbulent journeys along the semi-permanent wine-line (i.e. a permanent line and flexible hose combination), the initially sharp interface between the product and water mixes due to diffusion and radial differences in flow speed, leading to a gradual transition or exit concentration of product with time.

At the product destination, a cellar hand makes a judgement by taste or sight, of when the flow is product or water and appropriately ‘cuts in’ to the tank or out to drain. Axial dispersion and mixing of the fluids is unavoidable and unwanted as it results in product dilution and product loss wherever the ‘cut’ is made.

Deans 2006 measured the mixing interface of a wine / water transfer through a 500 metre length of 76mm semi-permanent wine-line with a plate heat exchanger which resulted in 189 litres of water entering the product and 179 litres of wine loss to drain. Transfers may occur more than ten times during the wine’s processing, and with 2 incidents of mixing per transfer, there has been concern that transfers represent significant wine dilution and waste contributions (Deans 2006). However, as the independent contribution of the measured mixing from normal pipe flow and the plate heat exchanger is not well established, these data provide limited use in predicting the mixing of the majority of transfers that occur in wineries (i.e. a constant diameter wine-line with no plate heat exchangers).

Studies of axial dispersion of adjacent fluids in pipe flows has been well documented in the literature (Taylor (1954), Tichacek (1957) and many others), and analytical models for predicting the residence time distributions for these fluids has been established (Danckwerts, 1954). The general diffusion equation for the concentration profile of an interface over time is:

$$\frac{\partial c}{\partial \theta} = D \frac{\partial^2 c}{\partial x^2}$$

Where c is the mean concentration of the preceding species at a plane x at time θ. D is a "diffusivity" which must be empirically determined. Appropriate D values could not be found for wine / water interfaces in the literature.

Concentration measurements of wine water transfers were conducted to establish a few actual D values, in order to solve Danckwerts' solution to the general equation; enabling the prediction of mixing volumes over a range of flow speeds and distances of 76mm pipe.

4.3.3 PROCEDURE FOR PERFORMING A TRANSFER

During a routine transfer of product from tank to tank, the line is connected up as in Figure 4.13. Hoses are used to connect fixed objects and valves. The procedural steps performed during a transfer, including sterilization with a 2% caustic (potassium hydroxide solution was used) are described in Table 4.2.

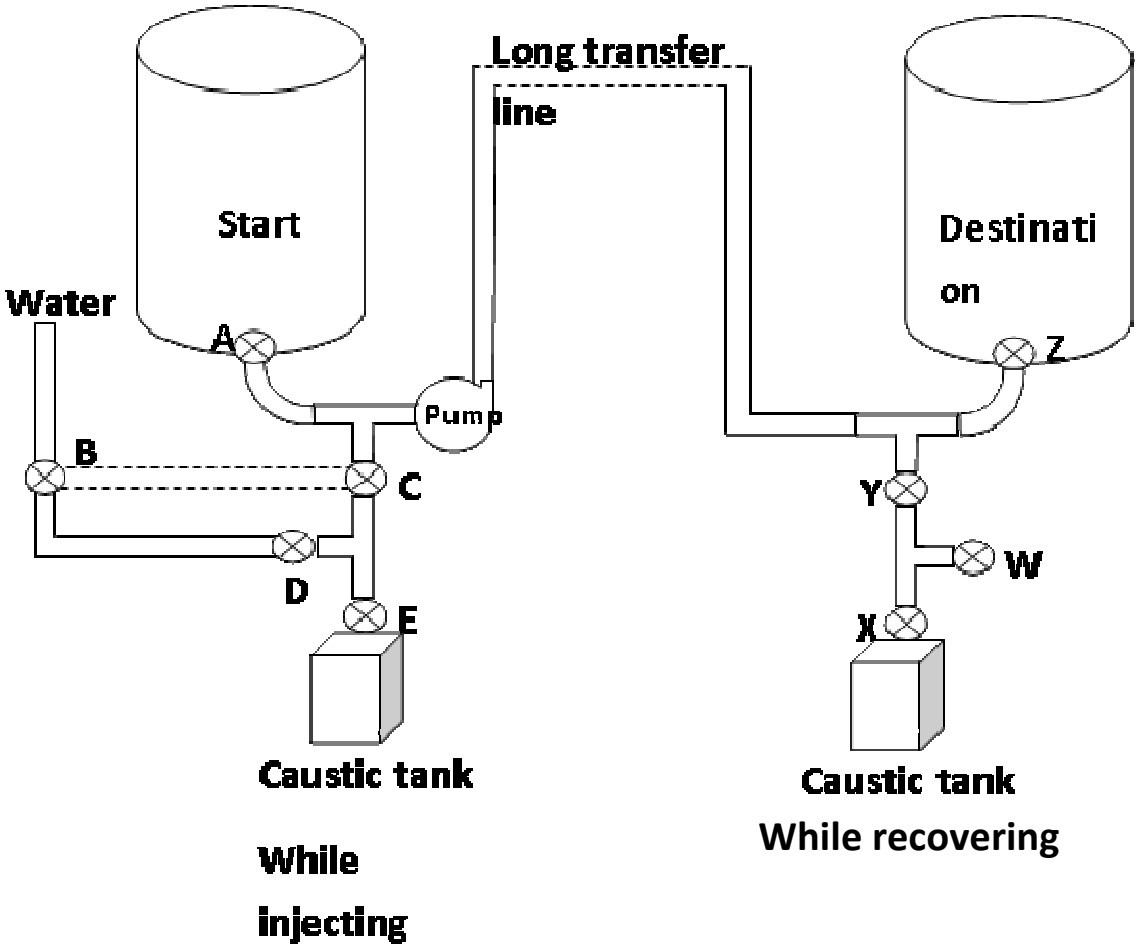


Figure 4.13 Schematic of objects involved during a transfer from the start to the destination tank

In step 11, cutting from water to caustic is performed by the cellar hand when he sees the colour change of the flow as it flows to drain. He recaptures the same volume of the used caustic that he put into the line at the start by looking at the volume markers on the caustic tank.

In steps 15 and 17, the cellar hand must either look at the colour change of the fluid in a sight glass, or "taste out" the interface in order to judge when to make the cut. When "tasting out", the butterfly valve to drain that should be closed is opened very slightly to allow a small fast flowing jet to flow; he then

frequently uses his hand to scoop some liquid to his mouth to taste the change from product to water or vice versa.

Table 4.2 Valve positions and description of steps involved with a transfer

Step	A	B	C	D	E	Pump	W	X	Y	Z	Description
1	X	X	O	O	X	OFF					START – no flow.
2	X	O	O	O	X	OFF					Open water supply to prime the pump
3	X	X	O	O	X	OFF					Shut off water supply
4	X	X	O	X	O	ON					Pump in 2% caustic solution
5	X	X	O	X	O	OFF					Turn off pump after 200 litres
6	X	O	O	O	X	OFF					Close off caustic, flush with water
7	X	X	O	O	X	OFF					Turn off water when caustic is clear of pump
8	X	X	X	X	X	OFF					Remove caustic, D, E. Reroute water to C. Move caustic container to end of line, ready to recover caustic.
9	X	O	O			OFF					Turn on water supply, wash through caustic.
10	X	O	O			OFF	O	X	O	X	Water drains from W when it reaches the end.
11	X	O	O			OFF	X	O	O	X	Cut caustic to caustic container.
12	X	O	O			OFF	O	X	O	X	Cut water to drain. Walk to start - valve B.
13	X	X	X			OFF	O	X	O	X	Stop water supply. Pipe run is filled with water.
14	O	X	X			ON	O	X	O	X	Open product valve and turn on the pump.
15	O	X	X			ON	O	X	X	O	Cut product into destination tank – keep pumping until required volume is pumped. Return recovered caustic, disconnecting at Y.
16	X	O	O			ON			X	O	Switch product for water at start, push product.
17	X	O	O			ON			O	X	Cut water to drain
18						OFF					STOP

4.3.4 EXPERIMENTAL WORK

To detect and analyse the transition from product to water for real wine / water transfers in 76 mm pipes, the conductivity and flow rate of the fluids were measured at the nearest possible point to the destination tank. The average flow rate for the whole journey of the interface was measured and recorded. Figure 4.14 shows how the two meters were placed into the flow through the 76mm hoses used for the transfer.



Figure 4.14 An inline flow meter and conductivity meter were used to measure the transfer transitions

Conductivity was measured by an ABB TB457 4-electrode conductivity cell, connected to an ABB AX400 transmitter. The transmitter was configured to output its readings via a 0-20 mA analogue current loop. It was found that the analogue output signal updated at 1 Hz.

The flow rate of the fluids was measured by a Siemens F M Magflo MAG6000 flow meter. Measurements were also outputted via a 0-20 mA analogue current loop. The two current loops were measured independently by measuring the voltage drop over 250 ohm resistors in the loops. The 0 – 5 volt signals were measured at 50 Hz and 10 bit resolution by an Atmel Atmega168-20AU microprocessor on an "Arduino" development board, programmed to average the voltages over 5 times and record data at 10 Hz. The equipment was set into the line for the whole duration of the transfer including caustic washing, to insure the hygienic integrity of the transfer operation.

4.3.5 RESULTS

The descriptors of 5 measured transfers are presented in Table 4.3. All transfers were performed on 76 mm diameter (3") pipelines. The contamination column is the volume of wine that would end up in the push water if a perfect cut was made at c=50%. Likewise "contamination" (or "holdup" in the literature) is also the volume of water added to the product during a perfect cut.

Table 4.3 Descriptors of measured transfers.

Product	Flow rate (L/sec)	Flow rate (m^3/h)	Distance (m)	Pipe volume (L)	Diffusivity	Contamination
Red	6.99	25.15	153	697	0.015	3.15
Red	6.03	21.70	153	697	0.026	4.46
White	5.25	18.90	184	839	0.019	4.48
White	5.00	18.00	480	2,189	0.020	7.61
White	6.10	21.96	480	2,189	0.016	6.17

The conductivity plots with respect to time and volume are plotted in Figures 4.15-4.19. On each graph is also a best fit plot to an analytical solution to the general diffusivity equation (Danckwerts 1954), with the associated diffusivity coefficient D. This equation for the exit concentration profile, for the boundary conditions of a normal wine transfer operation is:

$$c = \frac{1}{2}\left[1 - erf\left(\frac{x}{2\sqrt{D\theta}}\right)\right]$$

The Excel formula being:

=IFERROR(0.5*(1-ERF(-distance/(2*(time*D)^0.5),0)),0.5*(1-ERF(distance/(2*(time*D)^0.5))))

Danckwerts also provided the calculation for the contamination, in metres of pipe flow $\sqrt{\frac{DV}{\pi v}}$ or $\sqrt{\frac{DL}{\pi u}}$ Where V is the pipe volume, v is the volumetric flow rate, L is the pipe length and u is the flow speed in metres per second.

It can be seen from Figures 4.15-4.17 that during the transition, the conductivity meter repeated a single value; this value is assumed to be erroneous and has been ignored in data fitting and analyses.

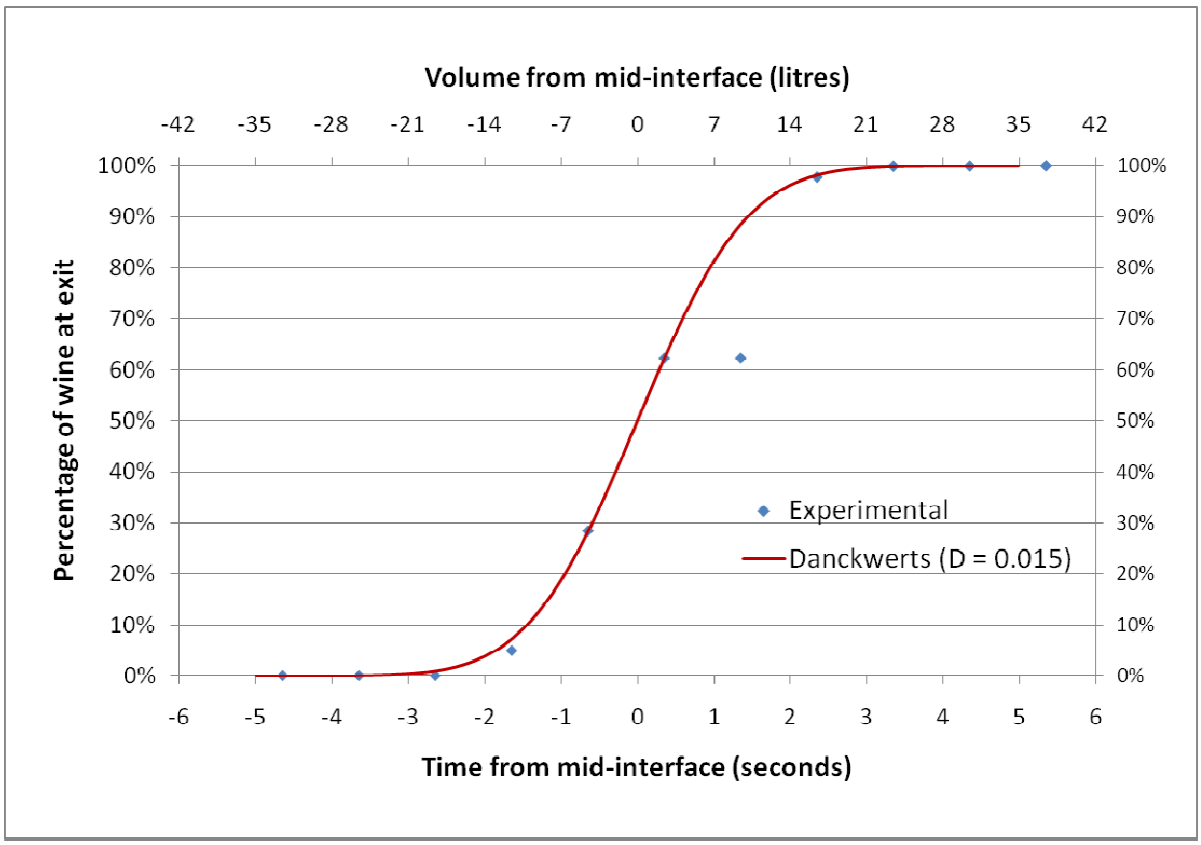


Figure 4.15 Water - Wine interface (7 l/s, 153m)

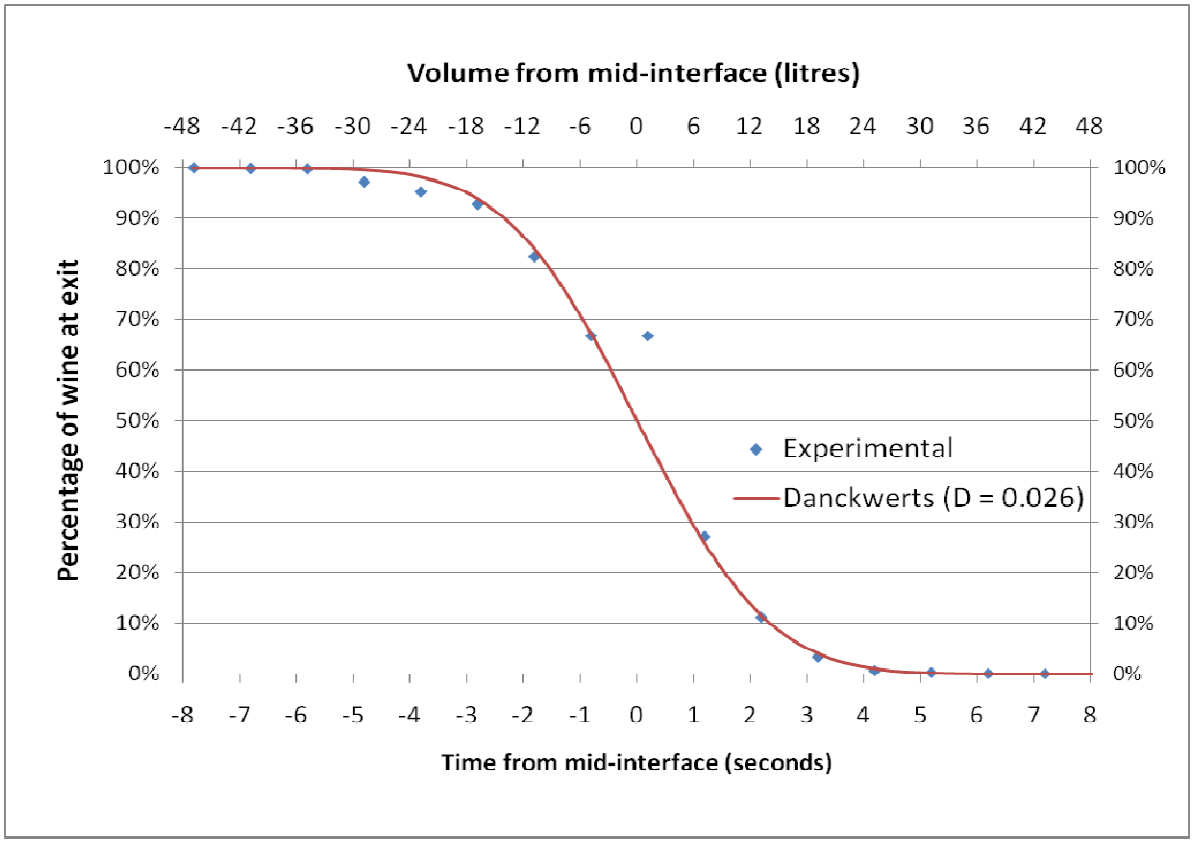


Figure 4.16 Wine - Water interface (6 l/s, 153m)

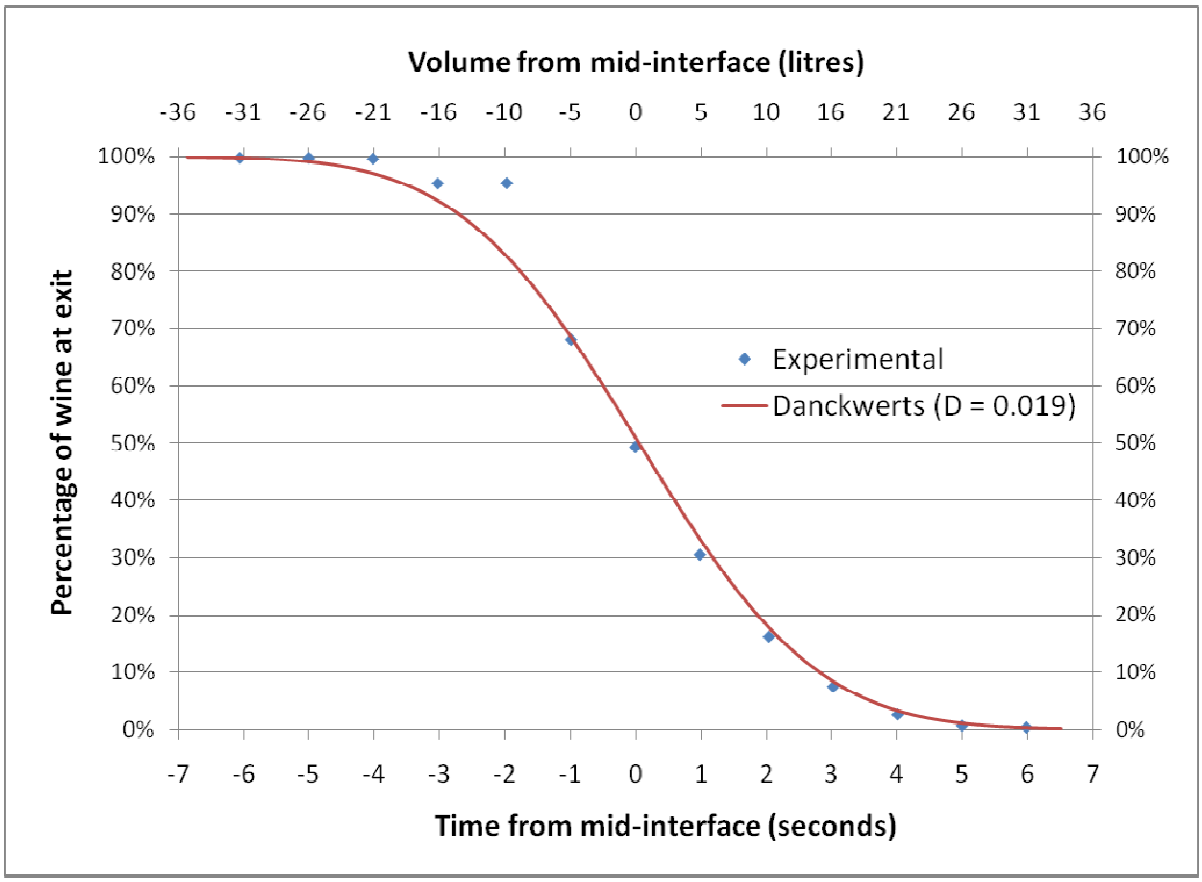


Figure 4.17 Wine - Water interface (5.2 l/s, 184m)

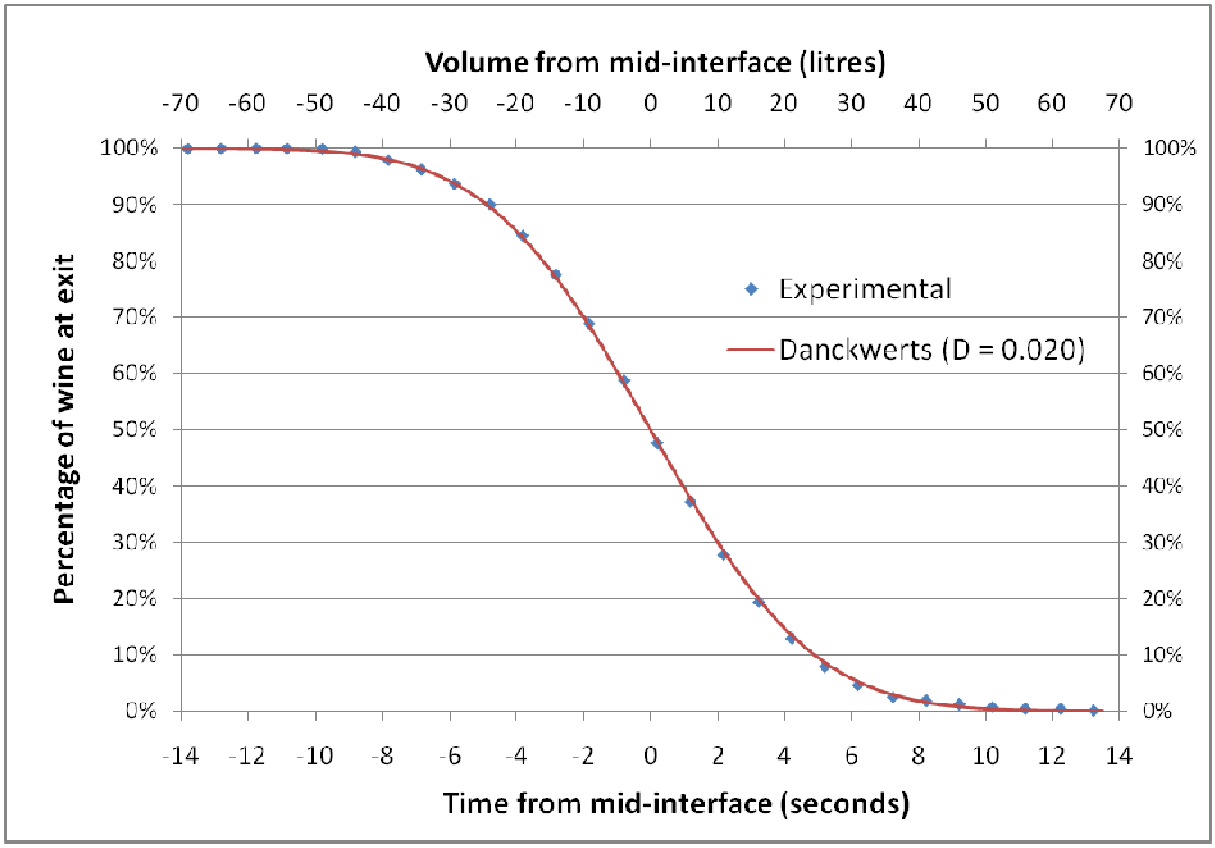


Figure 4.18 Wine - Water interface (5 l/s, 480m)

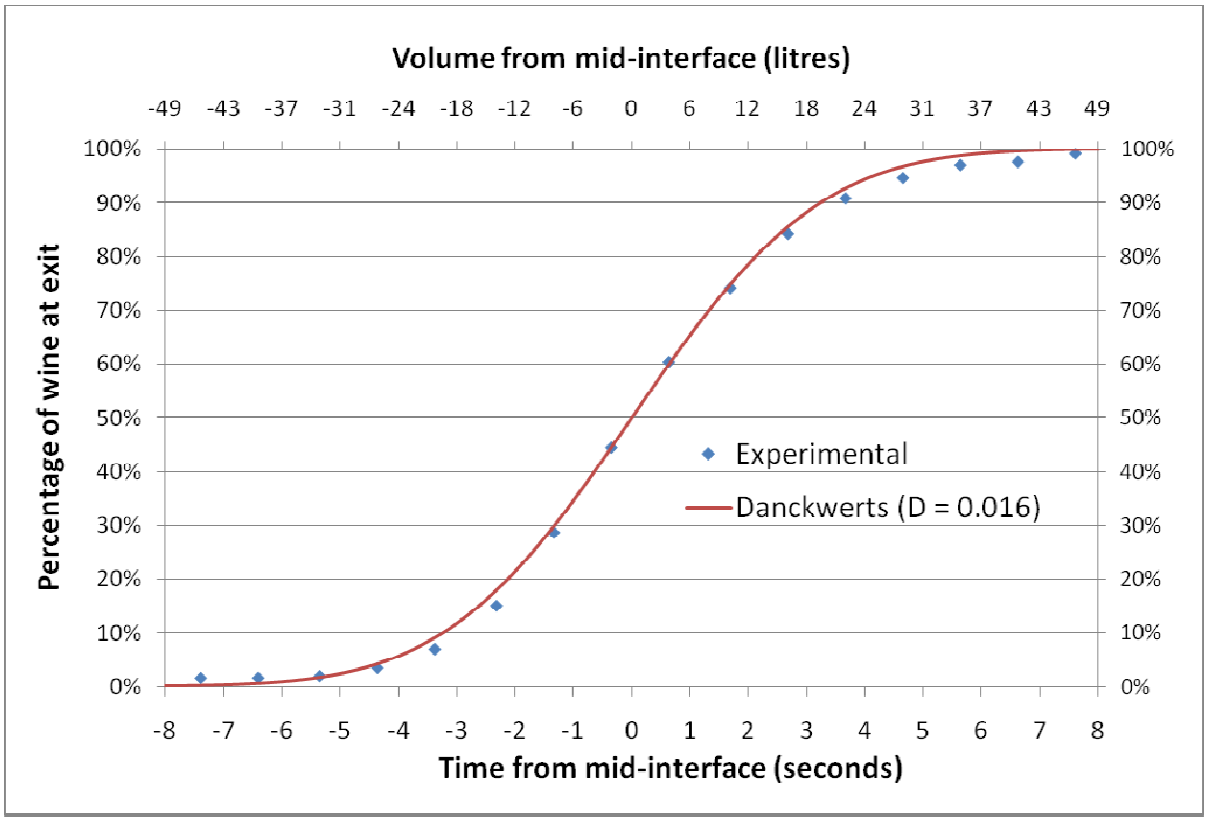


Figure 4.19 Water - Wine interface (6.1 l/s, 480m)

4.3.6 OUTCOMES

Measuring the conductivity of a wine / water transfer is achievable to useful degrees of measured and temporal resolution with off the shelf instrumentation. From a small range of real experiments on actual and untampered wine transfers, empirical values for diffusivity coefficients have been obtained that allow us to model the concentration profile to a very high degree of agreement. These diffusion coefficients are then able to accurately determine the unavoidable amount of wine and water contamination after a cut, and other useful metrics such as interface length, time of transition and contamination for cuts made at any concentration (cutting lean or rich).

The values for D ranged from 0.015 to 0.026, and are usually dependent upon the fluids used and the speed of the transfer, but not dependent upon the length of the transfer. According to the literature, the faster the fluid flow, the lower the diffusivity; especially if the flow regime is slowed to transition or laminar conditions (which is highly unlikely in 76mm pipelines at a winery). This correlation between diffusivity coefficient and flow speed is hinted at in the results, but the sample size and speed variations tested do not establish this to a high degree.

4.3.7 PRACTICAL IMPLEMENTAIONS

Obtaining some real diffusivity coefficients from experiments at a winery gives a starting point from which to quantify the amount of product dilution and COD contribution from transfers. Although there is scope for much more work on obtaining coefficients for different speeds, products, viscosities and pipe sizes, useful simulations of interface mixing can be obtained by using conservatively high diffusivity coefficients.

The current practice of performing wine transfers manually without plate heat exchangers seems to be very efficient in terms of product dilution and COD contribution, with contamination measured in litres and not hectolitres.

Instrumentation used at the exit end of transfers could aid cellar hands in performing transfer cuts and preventing large wine losses associated with accidentally missing the transition by large amounts of time. As far as improving current practices performed to standard, the potential value opportunity seems limited. Water use for wine transfers is typically about 2.5 pipe volumes per transfer (1 between the caustic and product, and 1 to push the product at the end). So there may be scope to reduce this.

4.4 Automated mixed interface detection

4.4.1 OPPORTUNITY

Automating the cut-out point during wine/juice transfers to minimise wastewater generation.

4.4.2 BACKGROUND

Typical winery transfers involve the use of water as a transfer medium to militate against oxygen pickup as well as minimise product loss. Transfer lines/pumps/heat exchangers are completely filled with water prior to the commencement of the transfer. As the transfer begins, wine flows through the pipe work displacing the water, which is then diverted to drain. As the wine travels through the pipework, there is a mixing of the two mediums, meaning by the time the wine arrives at the destination tank, there is no clearly defined cut out point. Current operating practices involve utilising a cellar hand or winemaker to taste the water/wine mixture at the point of the destination tank and make a subjective decision as to when the wine is no longer diluted with water. Until the cut out is made, the mixed water/wine interface is being pumped to the drain, therefore increase the loading on the waste water plant. Additionally, when the source tank is empty, and the transfer lines are still full of wine, water can be used as a medium to push the

residual wine through to the destination tank. Therefore there is a requirement to repeat the cut-out, this time identifying when the wine now contains water, and diverting the mixed interface to the drain.

Automating this process has the potential to increase the objectivity of the cut-out timing, avoiding the need for conservative cut-out timing in order to protect against wine quality loss. Therefore, and automated cut-out device could lead to reduced wine losses and subsequently reduced wastewater loading.

Screening experiments were conducted to assess possible sensing technologies that could be used to quantify the degree of mixing of various representative mediums.

4.4.3 EXPERIMENTAL WORK

A laboratory scale trial was conducted to establish the proficiency of the various sensing technologies in resolving the composition of wine/water mixtures. Thirty unique samples were prepared in 155m plastic vessels. These samples consisted of various water samples and red wine, white wine and white juice at the dilution ratio (water: test medium) below:

- 95:5
- 90:10
- 75:25
- 50:50
- 25:75
- 10:90
- 5:95

All dilutions were conducted using tap water.

Additionally, 2 different samples of marc run-off were also analysed.

All samples were then analysed using the following sensing technologies:

- Conductivity
- pH
- Refractive Index
- UV/Vis (Varian)
- FTNIR (Antaris II – 1mm path length)

4.4.4 RESULTS

Results are given in the figures below:

- Conductivity (Figure 4.20)
- pH (Figure 4.21)
- Refractive Index (Figure 4.22)
- UV/Vis (Varian) (Figures 4.23 to Figure 4.26)
- FTNIR (Antaris II – 1mm path length) (Figure 4.27 to Figure 4.30)

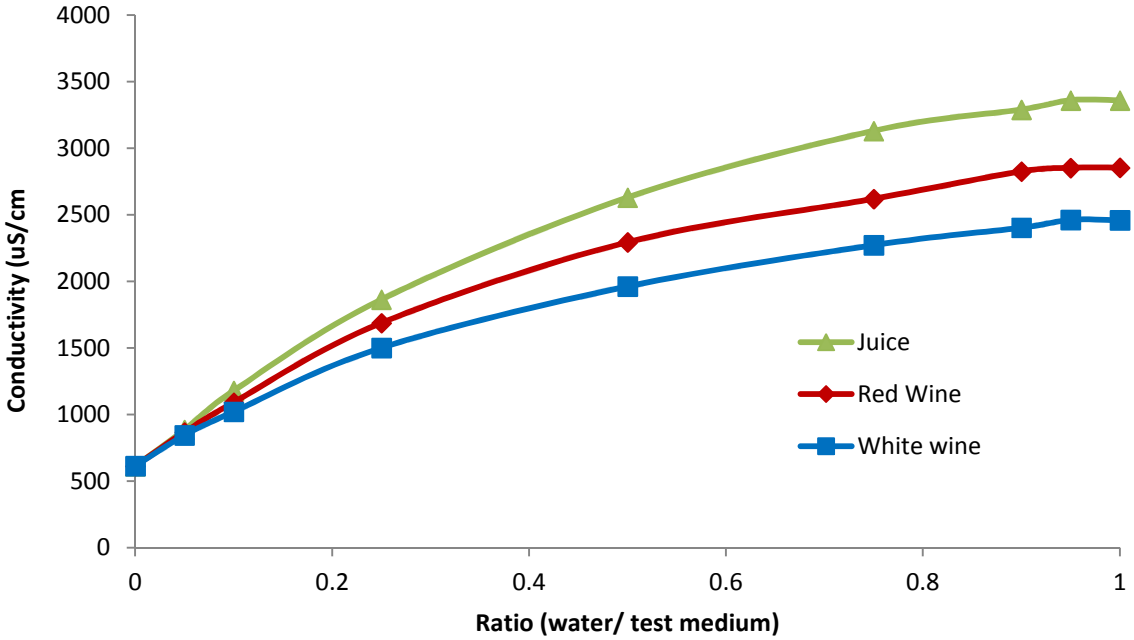


Figure 4.20 Conductivity response at differing dilution ratio's

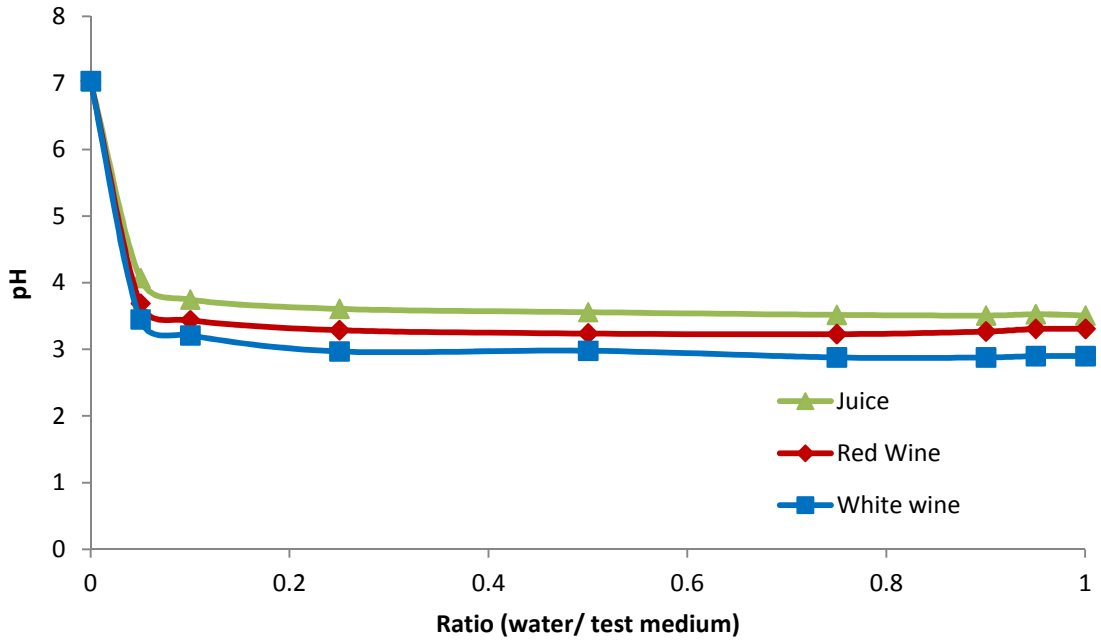


Figure 4.21 pH response at differing dilution ratio's

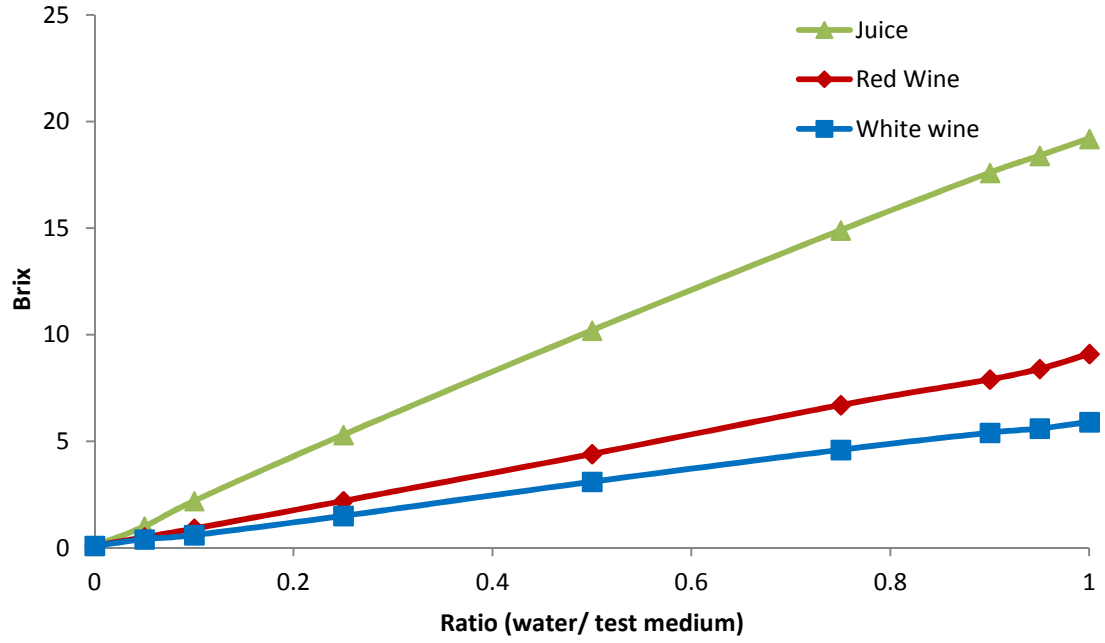


Figure 4.22 Refractive index (Brix) response at differing dilution ratio's

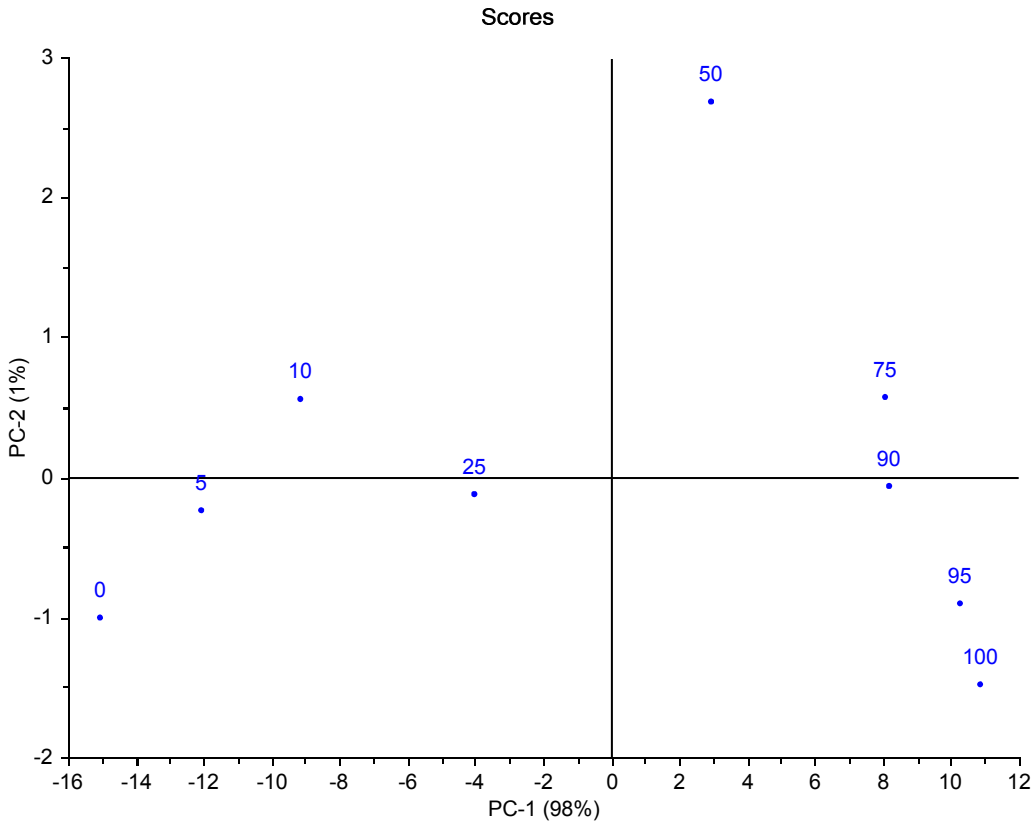


Figure 4.23 UV/Vis PCA – Juice

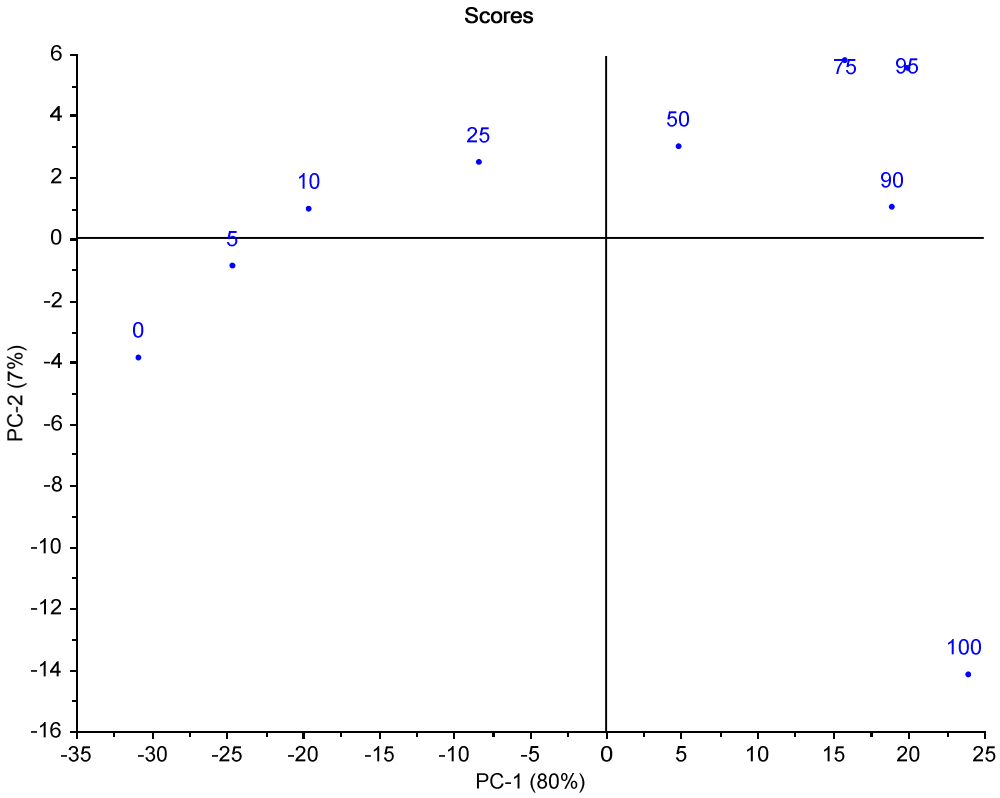


Figure 4.24 UV/Vis PCA – Red wine

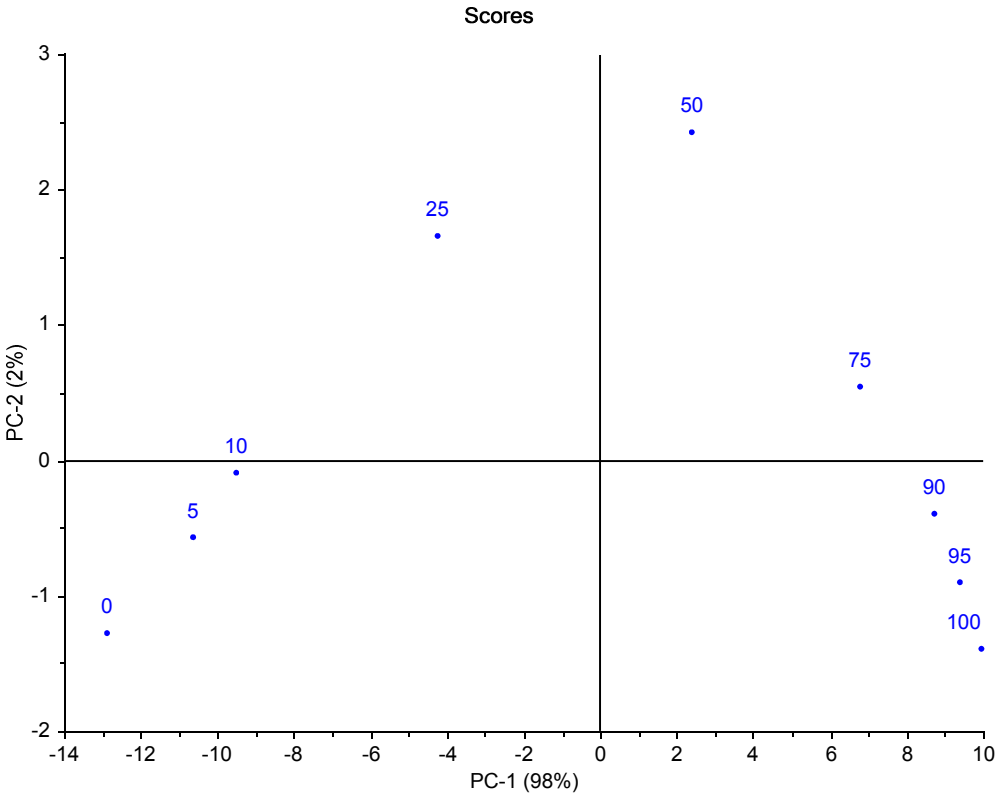


Figure 4.25 UV/Vis PCA – White wine

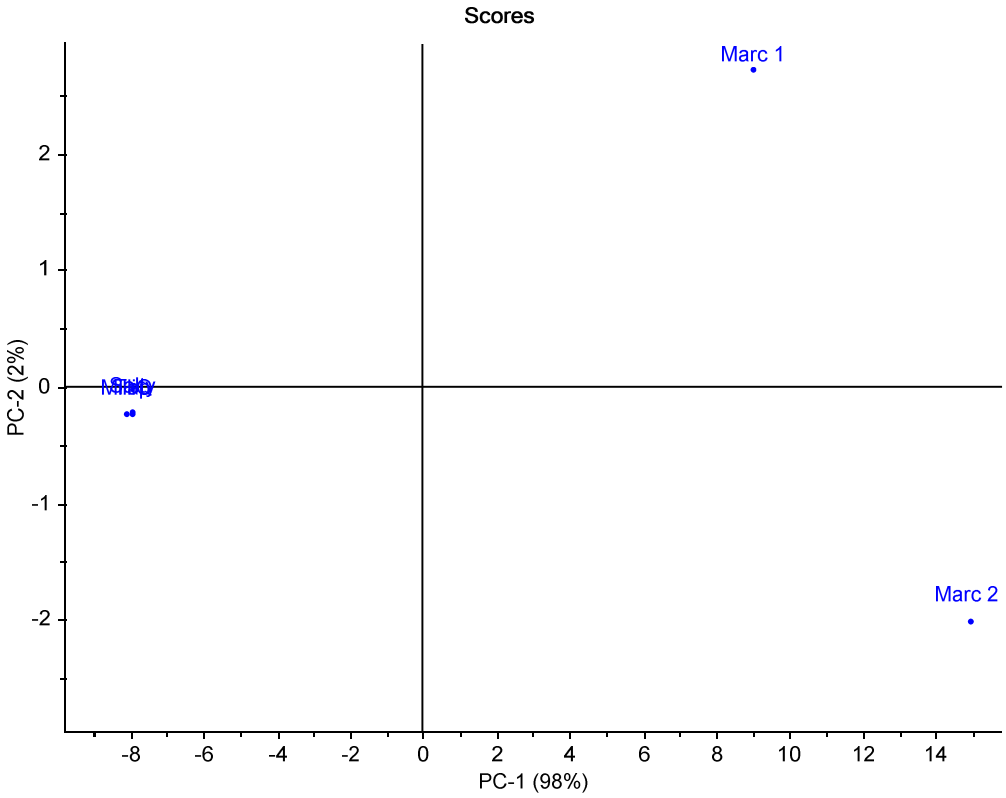


Figure 4.26 UV/Vis PCA – Water samples (including 2 x marc run of samples)

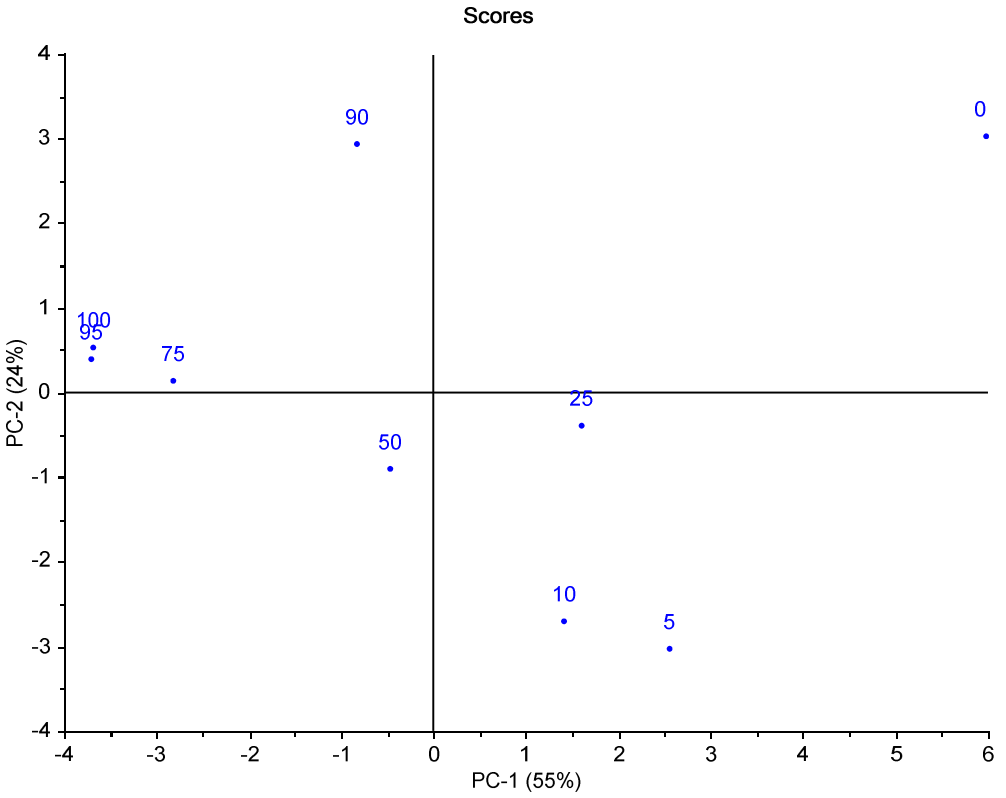


Figure 4.27 FTNIR PCA plot – Juice

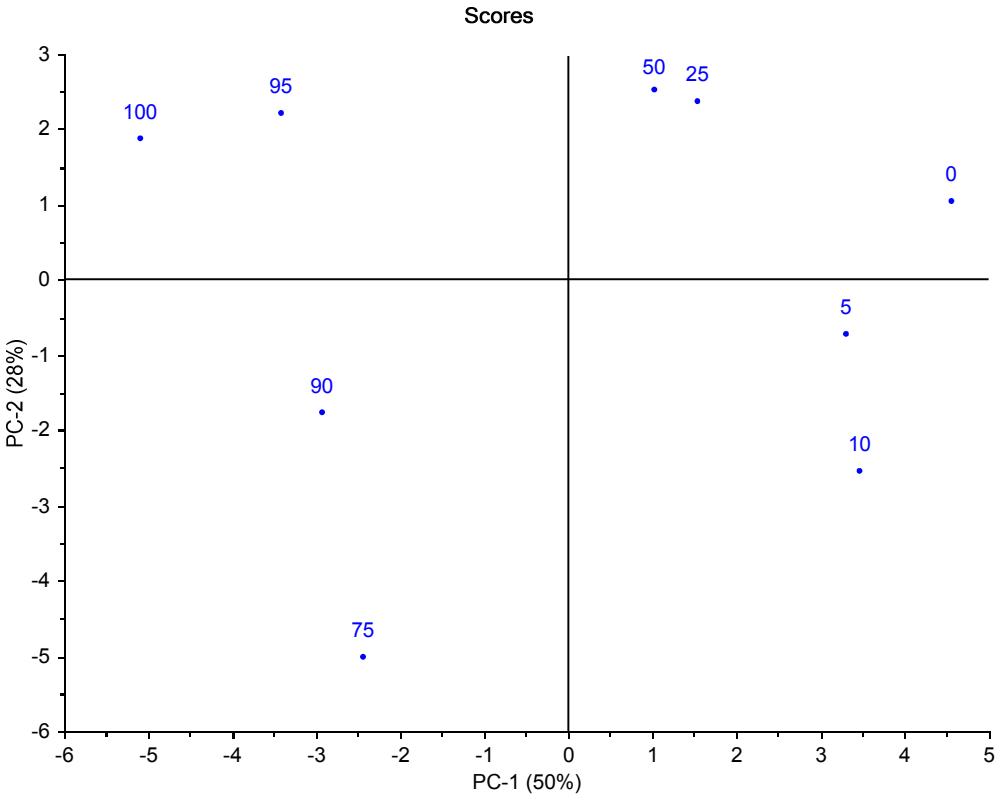


Figure 4.28 FTNIR PCA plot – Red wine

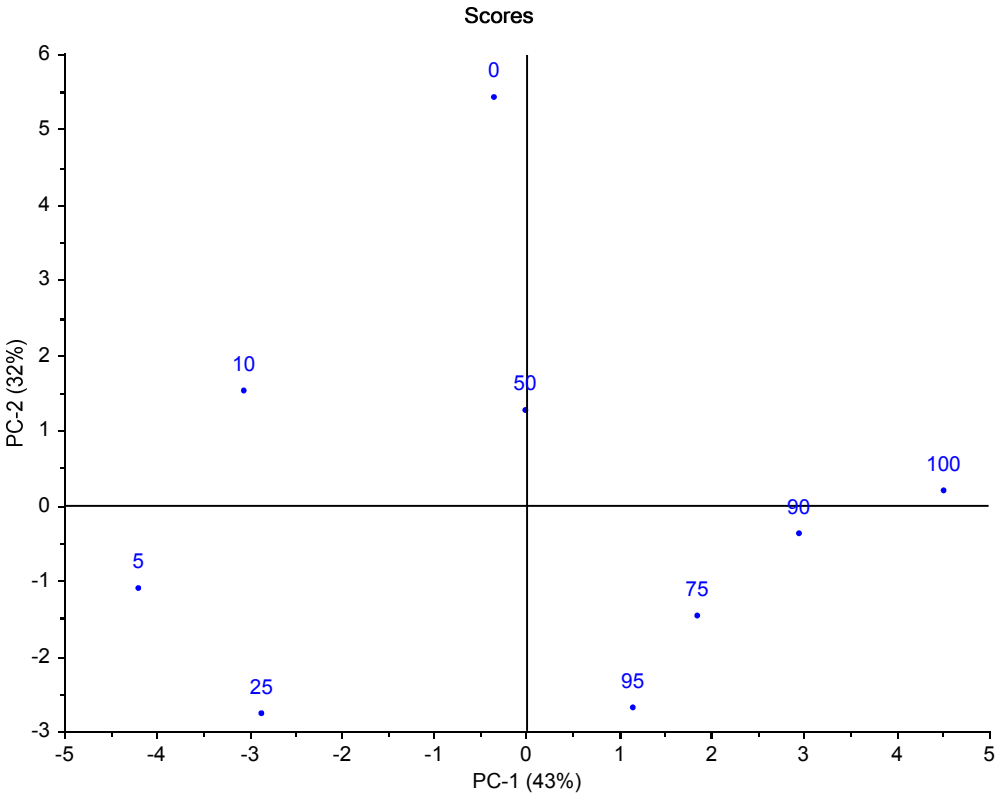


Figure 4.29 FTNIR PCA plot – White wine

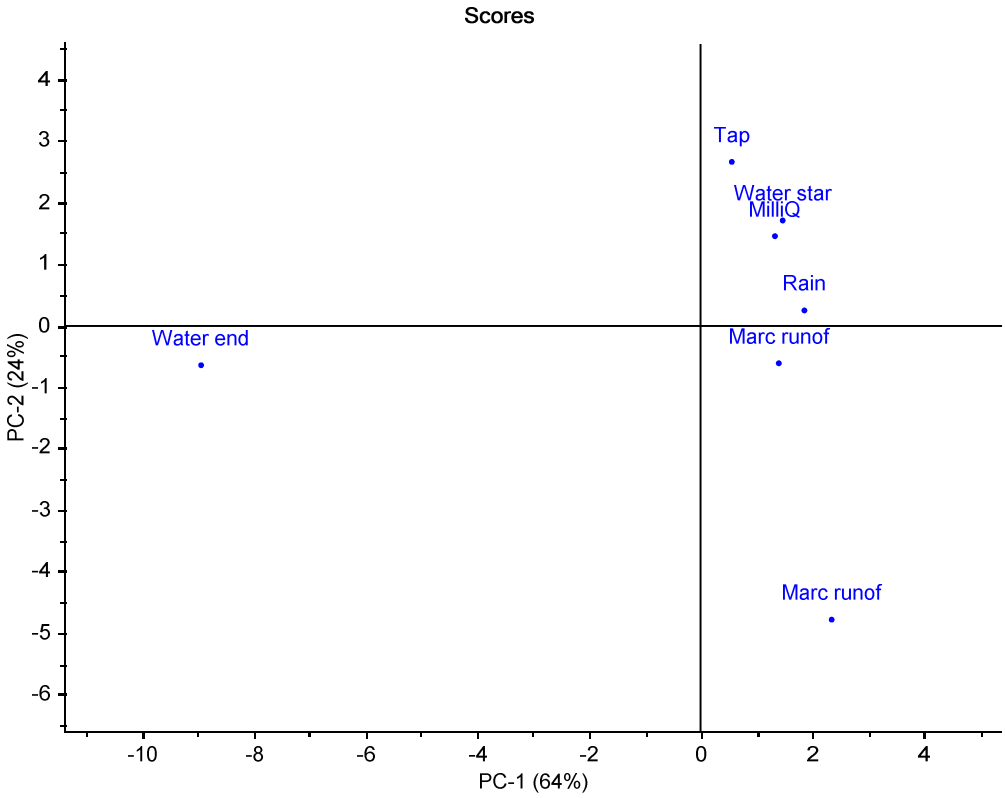


Figure 4.30 FTNIR PCA plot – Water

4.4.5 OUTCOMES

The results of this trial have indicated there are several sensing technologies capable of detecting the degree of mixing between the interfaces. Refractive index, conductivity and UV/Vis spectrophotometer appear to be the most promising sensing technologies. FTNIR may achieve the required sensing resolution, however further data processing will be required (Figure 4.27 to Figure 4.30).

4.4.6 PRACTICAL IMPLEMENATIONS

The implementation of an automatic cut-out device will require the integration of a sensing technology with switching hardware. Mettler Toledo currently offer a product identification/ phase separation sensor known as the InPro 8300 RAMS system. This system operates using a combination of visible and near infrared light, and can store a “fingerprint” for up to 8 unique products. Indicative costs for this sensor is $5,000, however additional hardware integration would be required to integrate this into an automated cut-out.

4.4.7 ENVIROMENTAL EVALUATIONS

Reduced organic loading (as indicated by lower COD) in wastewater could ultimately help to reduce wastewater treatment plant odour. Reduced salt loading (as indicated by lower conductivity) could allow for increased re-use of wastewater in the irrigation of crops or vines.

4.4.8 ECONOMIC EVALUATIONS

Mettler Toledo currently offer a product identification/ phase separation sensor known as the InPro 8300 RAMS system. This system operates using a combination of visible and near infrared light, and can store a

“fingerprint” for up to 8 unique products. An indicative cost for this sensor is $5,000, however additional hardware integration would be required to integrate this into an automated cutout. Economic evaluation of the auto cut sensor is given in Appendix 3.

Total cost outlays for the sensing units are estimated to be approx. $30,000 per unit. This would consist of approximately $6,000 for the sensing apparatus, $6,000 for the 3-way valve and fittings, $10,000 for the customised control system.

The frequency of use will be based on the number of transfers or each wine parcel. A conservative estimate of 5 transfers can be used for the production of every batch of wine, and each transfer will consist of 2 cut-outs (start and end). This leads to a total of 10 cut-outs per batch

The number of units required will be directly proportional to the number of transfers. Each unit is estimated to facilitate a transfer volume of 150kL per shift.

Labour costs will remain largely unchanged, however there may be a reduction in labour effort associated with requiring a cellar to operate the transfer pump whilst a second cellar tastes out the wine at the destination tank. A labour saving of 10 minutes per transfer could be expected.

The unit will require a mains electrical connection, in order to power the sensing device and the valve actuator. Voltage will be stepped down to 24 V, and current requirements will be extremely low (<1 A) Therefore an indicative in-use power rating of 0.025kW is appropriate.

Final implementation is likely to require compressed air to drive the actuator, however total air consumption will be negligible. (It is not consuming air, just using it to hold the valve open – maybe 2 Litre of compressed air per operation)

Making some assumptions about typical transfer lengths, say 50m for small wineries and 250m for a large wineries, then the volume of the corresponding pipe work (50mm diameter) is 100L and 500L respectively. Based on information presented by Deans (2007), up to 50% of the entrained pipe volume can be a mixed wine/water interface. In the case of an end of transfer water “push”, approximately 70% of the interface volume was judged to be acceptable (no dilution detectable), and the residual 30% of the interface was directed to drain. Therefore, accepting 30% of the mixed interface will be directed to drain, this equates to 30L for the small winery, and 150L for the large winery. The volume of wine in this rejected volume was approximately 50% in the Deans’ study, leading to a wine loss and corresponding wastewater addition of 15L for and 75L for a small and large winery respectively. This volume needs to be doubled to take into account that there are 2 push throughs for every transfer operation.

This proposed technology will not change overall water usage.

4.5 Marc bay roofing

4.5.1 OPPORTUNITY

Sheltering of grape marc from rain to prevent/minimize high nutrient run-off entering into the wastewater system.

4.5.2 BACKGROUND

Grape marc is produced as a major organic waste matter in industrial wineries. It is one of the prioritised waste management products. In many cases, grape marc is exposed to rainwater causing high nutrient wastewater, the excessive nitrogen, phosphates and organic loading entry into the wastewater system encouraging bacterial growth. Also, high moisture content in the grape marc increases the difficulty of marc disposal.

Sheltering grape marc results in the prevention or minimization of high nutrient run-off entering the general wastewater system. The impact of rainwater exposure to rain has not been studied in detail. The following laboratory scale experiments aim to determine the impact on pH, organic loading, metals and sugar levels of marc exposed rainwater over time.

4.5.3 EXPERIMENTAL WORK

A laboratory trial was set-up to mimic marc exposure to rain by obtaining 18 Kg of grape marc in a plastic container (43 x 43 x 23 cm). Marc Figure 4.31was then saturated with 4 L of water and slightly compressed in the container. Several small holes were drilled in an X-orientation into a shallow container, to simulate droplets of rain dripping at a rate of approximately 20 mL/min. The run-off was collected every hour, for five hours. The experimental assembly was left overnight at ambient temperature and then the experiment repeated. Experiments were performed at ambient temperatures of (22 °C). Samples underwent pH, Brix, Conductivity, COD and -analysis for selected salts and organic carbon.

By observing the change in organic loading, metals and pH of the marc run-off with increasing time of exposure to the simulated rain to determine prevention of marc run-off entering the wastewater system

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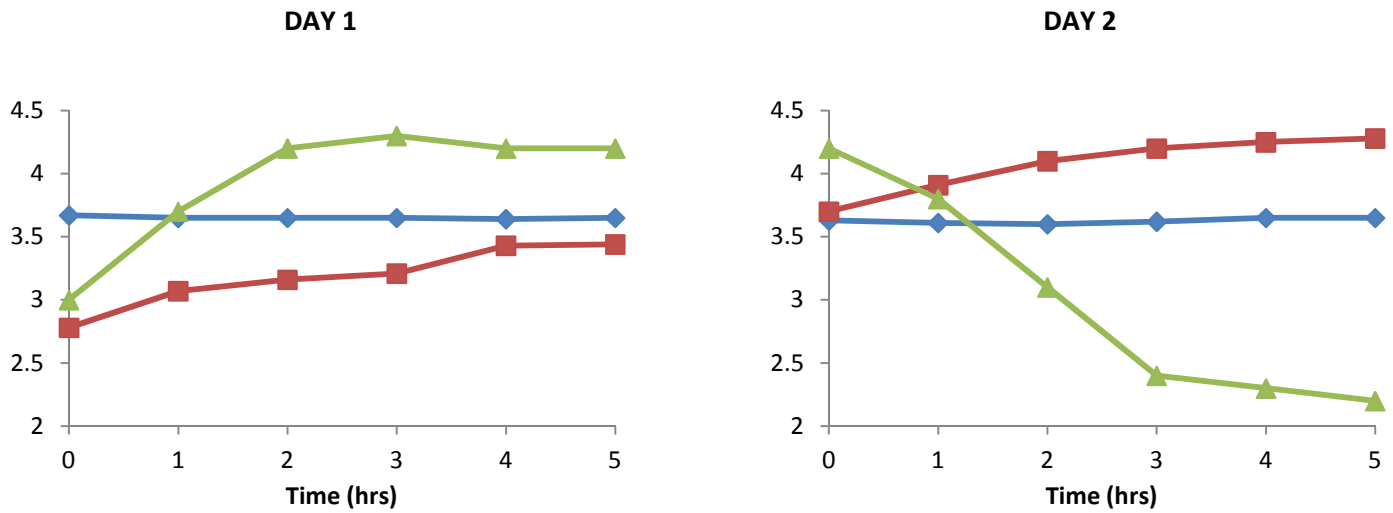


Figure 4.31 Plot observing change in pH, °Brix and Conductivity (mS/cm) levels of marc run-off over time showing results for Day 1 and 2.

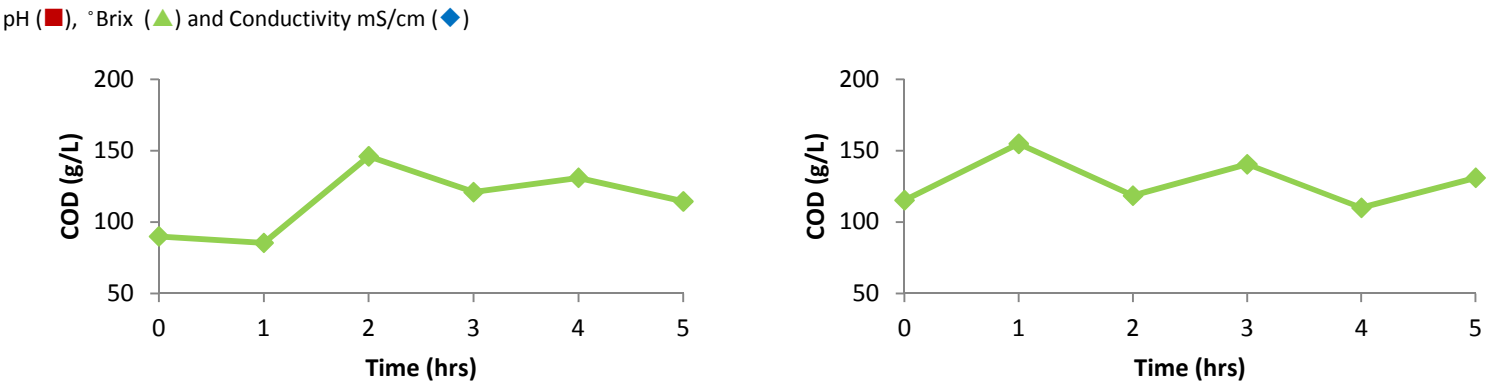


Figure 4.32 Chemical Oxygen Demand (COD) of marc run-off showing results for Day 1 and 2 over time

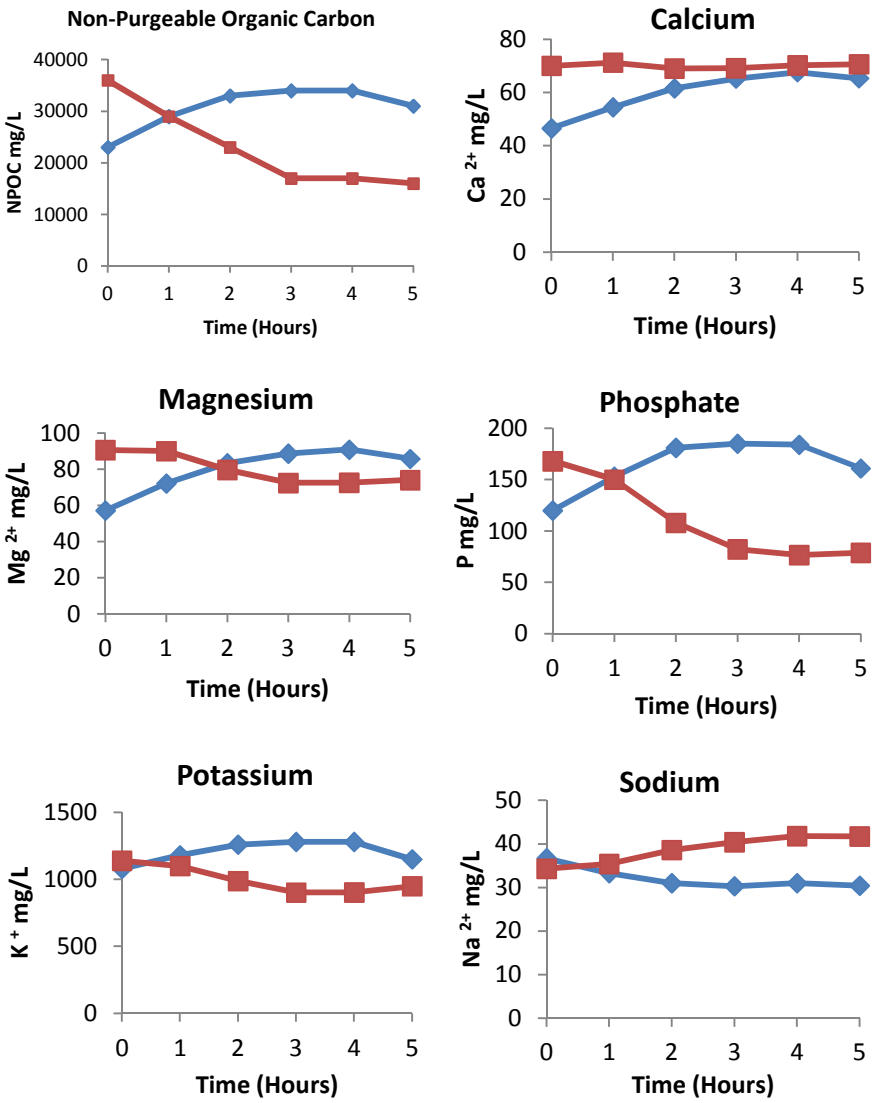


Figure 4.33 Analysis of Marc run-off over time comparing Day 1 and Day 2

Day 1 (■) and Day 2 (◆)

4.5.4 RESULTS

The run-off from the grape marc was observed over two days for a period of five hours over time. The run-off was analysed for pH, COD, Conductivity and Brix over time (Figure 4.32 and Figure 4.32). On the first day, the pH levels increased steadily from pH 2.7 to pH 3.5. On day 2, the pH continued to increase from pH 3.5 to 4.3. The sugar content of the run-off increased from 3% to steady off at 4% after 2 hours of exposure to the simulated rain. The next day the Brix level dropped from 4.3% to 2%, this is suspected to be due to fermentation of the grape marc by yeast or other microorganisms however the levels of metals decreases likely due to dilution (.

Analysis of the run-off showed that there were high levels of salts in the run-off. In particular, K levels were approximately 1000 mg/L. four fold the normal range of effluents (Figure 4.33). Since the volume of marc rainwater run-off is low the result is a highly concentrated wastewater stream.

4.5.5 OUTCOMES

The laboratory scale experiments indicate that the exposure of marc to rain favours microorganism growth and are more likely to generate odours. The analysis of the marc run-off results in a highly concentrated wastewater stream. To minimize or prevent entry of this wastewater stream into the general system, it would be highly advantageous to prevent entry of this stream into the wastewater system or prevent primary exposure of the marc to rain by sheltering.

4.5.6 PRACTICAL IMPLEMENTATION

Sheltering of the grape marc will eliminate the risk of run-off from rain exposure entering the wastewater system. This however will require capital costs (depending on the scale of the winery) and does not eliminate grape marc being prone to microorganism growth due to the high nutrient and moisture content. In the interim in cases where promptly removal of grape marc is not practical, sheltering is a means of minimizing the leaching of nutrients and metals entering the wastewater system.

4.5.7 ENVIRONMENTAL EVALUATION

Reducing entry of the marc run-off into the wastewater system will minimize diminishing the wastewater quality and allow for recycling of the wastewater in the winery. Economic evaluation of marc bay roofing is given in Appendix 5.

4.6 Marc bay roofing

4.6.1 OPPORTUNITY

Improve recovery of wine from lees using cross-flow filtration technology.

4.6.2 BACKGROUND

Lees typically contains around 50%of wine by volume/mass. Settling in tanks typically only allows 20% of that wine to be recovered and the rest is either disposed of with the lees through a waste processing facility (e.g.Tarac) or sent to drain, increasing wastewater load and treatment cost.

Most wineries use rotary drum vacuum technology to improve wine recovery, but this process is inefficient and often results in a downgrade of wine recovered.

Cross-flow filtration of lees could be used to improve recovery of wine from lees for larger wineries and reduce the volume of wine that is disposed of or treated with the lees. This provides a reduction in BOD load, as well as sodium and potassium levels. The quality of wine recovered using this process is typically equivalent to that of the original batch.

The Yalumba Wine Company have previously undertaken a study (Luke Wilson, April 2011, Issue 567) to remove earth filtration from its winemaking processes and incorporate the use of Pall's Oenoflow HS system to recover wine from lees. In comparison to RDV, the Yalumba trial achieved:

- a reduction in perlite use (for lees processing)
- reduction in solid waste volume
- improvements in filtrate quality and consistency
- lower solids content (turbidity) and
- improved wine recovery

4.6.3 PRACTICAL IMPLEMENTATION

The Pall Oenoflow HS system is fully automated, allowing the solids concentration within the system to be accurately controlled to achieve long run times. By automatically controlling the bleed, the filter can operate in a steady state condition, with no degradation to flow or change in the solids concentration, enabling run times of over 48 hours. The cleaning system and flow-path on the filter reduce the likelihood of irreversible blockage of the fibres and the unit facilitates an easy discharge of solids at the end of each batch, enabling the filter to handle high concentrations of wine solids and bentonite.

Utilisation of the cross-flow filter would necessitate the use of additional labour resources to manage the set-up and cleaning of the filter. Electrical power is required to operate the two pumps needed to deliver and segregate the lees through the filter. Membranes would have to be replaced regularly to maintain effectiveness.

4.6.4 ENVIRONMENTAL EVALUATION

The use of cross-flow filtration for lees could lead to improved wine yields and lower volumes of wine lost to drain, reducing COD/BOD and potassium. Additional wastewater generated through cleaning of the filter membranes would need to be treated by the wastewater treatment plant.

4.6.5 ECONOMIC EVALUATION

The details of the economic evaluation of the cross-flow system are given in Table 4.4, Table 4.5, Table 4.6, Table 4.7, Table 4.8 and Figure 4.34.

Table 4.4 Economic evaluation of Cross flow system

DESCRIPTION	SIZE/CAPACITY	INDICATIVE COST ($)	EXPECTED LIFETIME	SOURCE
Cross-flow filtration unit	2,000L/hr	300,000	20 years	Peter Goss (Pall)

It is assumed that an additional $30,000 of equipment/infrastructure is required to support installation.

Annual operational (ongoing) costs

Labour

RESOURCE LEVEL	RATE ($/hr)	REQUIREMENT (hrs/ML wine)	TOTAL ($/KL wine)	ACTIVITIES
Cellar-hand	35	58.8[1]	2.058	Cleaning & removing debris
Cellar manager	65	2	0.13	

[1] Based on 90mins set-up and 45mins cleaning

Consumables

DESCRIPTION	COST ($)	QUANTITY	REQUIREMENT (per KL wine)	TOTAL COST ($/KL wine)
Membranes[1]	2,000/yr	-	-	0.10

[1] no cleaning chemicals required

Utilities

Description	Rate ($)	Quantity (per KL wine)	Total cost ($/KL wine)
Electricity	0.08 per kWh	0.065 kWh[1]	0.005
Water	1.06 per kL	0.0284 kL[2]	0.03

[1] based on requirement of 2 x 2.2kW pumps per filter.

[2] Based on wash water of 966L/kL lees processed.

Wine losses/gains

DESCRIPTION	AMOUNT (L per KL processed)	Cost ($/L)	TOTAL GAIN ($/KL PROCESSED)	ASSUMPTION
Volume gain	26.5	3	79.50	90% recovery
Quality loss	0	3	0	N/A

Treatment costs

DESCRIPTION	AMOUNT (per KL WINE)	TREATMENT COST ($)	TOTAL COST ($/KL WINE)	ASSUMPTION
Wastewater volume(L)		0.02/L		Washing membrane
COD (mg/L)		0.785/kg		
K (mg/L)		46.67/kg		
Na (mg/L)		140.00/kg		

Table 4.5 Lees Management Concept

Lees Management Concept					
Lees is rich in potassium by-products and has an economic value if sent to Tarac, or Australian Tartaric.					
Lees is also very rich in BOD loading and is salty meaning the loading on the wastewater plant is quite high.					
As a baseline, a	15,000	tonne winery will be adopted.			
Assume a	7%	lees generation rate at the winery			
and a	700	l/t extraction rate at the winery			
That winery					
Produces	10,500	kl/yr of wine			
and	735	kl/yr of lees			
less is	75,000	mg/l BOD			
	13,200	mg/l Potassium			
	150,000	mg/l TDS			
If no effort was made to recover lees and it all went into the wastewater system, then the loading would be:					
Volume	735	kl/yr of wastewater	(assume 3,500 mg/l BOD, 280 mg/l K and 1,200 mg/l SS)		
	55,125	kg/yr of BOD load		52,553	extra BOD
	9,702	kg/yr of potassium load		9,496	extra potassium
	110,250	kg/yr of salt load		109,368	extra salt
The impact is:					
Extra BOD load on the wastewater plant or disposal area					
Extra salt load on the disposal area					
Low pH material which affects the wastewater plant, or soil if irrigated directly					
Alcohol in the liquid which can sterilise the bacteria in the wastewater plant, or in the soil.					
Wastewater costs a company					
	$ 12.62	per kl produced			
but we know the extra nutrients cost					
	$ 1.57	per kg of BOD			
	$ 46.67	per kg of K			
	$ 140.00	per kg of Na salt			
If the winery just dumped its entire lees load down the drain without capturing it, the cost is:					
	$ 14,517,023				
or	$ 967.80	per tonne of fruit processed			
or	$ 1.383	per litre of wine			
That does not include the cost to the winery of lost product.					
Assume that	80%	of the lees can be recovered as saleable wine			
at a price of	$ 1.00	per litre			
then, by dumping that lees instead of recovering it, the winery is reducing its wine to market by					
	588	kl/yr	costing them	$ 588,000	per year
Nett cost is	$ 15,105,023	per year			
or	$ 1,007.00	per tonne of fruit processed			
or	$ 1.007	per litre of wine			

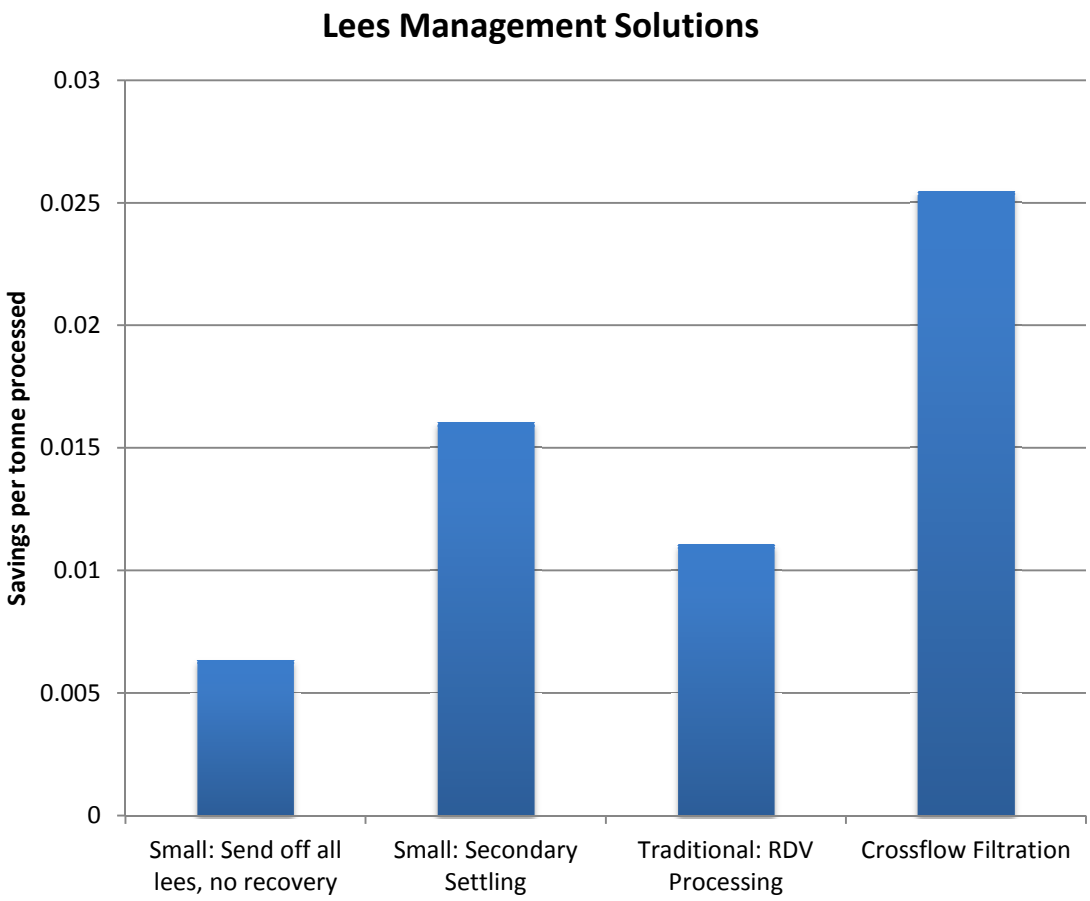


Figure 4.34 Lees Management Solutions

Small winery approach

The average winery currently attempts to capture as much lees as possible, RDV the wine and send the cake to Tarac or AT.

Table 4.6 Economical analysis: capture lees through secondary settling in small winery approach

Background data	
from crush of	15,000 t grapes
likely to create	735 kL/yr of lees
capture rate of	80% off site
need to manage	588 kL/yr of lees
Operating cost	
Pump rate of lees	5,000 L/hr
Time to transfer lees (per kL)	0.20 hr
Need a pump	2.2 kW pump
Power consumption	323.40 kWhr
Power cost per year	$36

Assume time per transfer (kL)	0.1 hr
Labour total	73.5 hr
Absorbed cost of an operator	45 per hr
Labour cost	$3,308
Equipment costs	
Depreciation	$4,000
Maintenance	$80
	$4,080
Cost to the wastewater stream	
Wastewater generation rate	50 L/kL
Wastewater total	37 kL/yr
BOD level	3,500 mg/L
TDS level	1,200 mg/L
Potassium level	280 mg/L
Cost of that to the wastewater system	$ 464
%Loss	70%
Wine recovered	176.4 kL
Value of wine	$1.00 per litre
Value recovered	$176,400 recovered at Tarac
Assume no downgrade	
Less sent to Tarac	411.6 kL
Tarac	$35 per kL gate fee
Lees cost	$14,406
Cost of offsite dumping	
Equipment costs	$4,080
Labour costs	$3,308
Wastewater	$464
Nett Costs	$7851
Net cost	$11.24 per tonne of fruit processed or
	$ 0.016 per litre of wine

The average winery currently attempts to capture as much lees as possible, RDV the wine and the send the cake to Tarac or A.T.

Table 4.7 Economical analysis: Traditional processing of Lees using an RDV

Background data	
From crush of	15,000 t grapes
Likely to create	735 kL/yr of Lees
Capture rate of	80% for processing
Need to manage	588 kL/yr of Lees
Using a	10 m^2 RDV
Which uses	200 kg of DE per cake
Each cake does	5 kL
Number of cakes	118 per year
Annual volume of	23.6 t/yr of DE
Cost of operating RDV	
Setting up RDV for use	90 min
Cleaning the RDV after use	45 min
Flowrate Lees through RDV	3,000 L/hr
Operating time per year	196 hr
Total operator hours	462 hr/yr
Absorbed cost of an Operator	$45/hr
Allowance for winemaker and overheads	15%
The RDV needs two pumps each	2.2 kW pump
Power consumption	862.40 kWhr
Power cost per year	$95
Safety equipment for operators	$500
	$24,477
RDV Depreciation	$10,000
Cost to the wastewater system	
Wastewater generation rate	966 L/kL
Wastewater volume	568 kL/yr
BOD level	8,074 mg/L
TDS level	3,900 mg/L
Potassium level	500 mg/L
Cost of that to the wastewater system	$214,292
Actual DE	49t
AP60 Cost	$0.80 per kg
DE Cost	$39,200

DE sent to Tarac	225 t
Tarac	$35 per t gate fee
Cost of disposal	$7,875
Increased weight	176 t
% loss	40%
Wine recovered	412 kL
Value of wine	$1.00 per litre
Value recovered	$412,000
Need (assuming no downgrade)	$0.72 per L/recovered wine to break even
Cost of RDV processing	
RDV Operation	$24,447
Depreciation	$10,000
Wastewater	$214,292
DE purchase	$39,200
DE disposal	$7,875
Net costs	$295,844
Value recovered	$412,000
Nett cost	$116,156
	or $7.74 per t fruit processed
	or $0.011 per litre of wine

The average winery currently attempts to capture as much as possible, RDV the wine and the send the cake to Tarac or A.T.

Table 4.8 Economical analysis: Processing of Lees using a Crossflow filter

Background data	
From crush of	15,000 t grapes
Likely to create	735 kL/yr of Lees
Capture rate of	80% for processing
Need to manage	588 kL/yr of Lees
Cost of operating the Crossflow	
Setting up crossflow for use	90 min
Cleaning the crossflow after use	45 min
Flowrate Lees through crossflow	2,000 L/hr
Operating time per year	294 hr
Total operator hours	294 hr/yr

Absorbed cost of an Operator	$45/hr
Allowance for winemaker and overheads	15%
The crossflow needs two pumps each	2.2 kW pump
Power consumption	1,293.60 kWhr
Power cost per year	$142
Membrane replacements	$2,000 per year
Safety equipment for operators	No extra safety equipment
	$15,357
Crossflow Depreciation	$30,000 per year
Cost to the wastewater system	
Wastewater generation rate	966 L/kL
Wastewater volume	568 kL/yr
BOD level	8,074 mg/L
TDS level	3,900 mg/L
Potassium level	500 mg/L
Cost of that to the wastewater system	$214,292
% Loss	10%
Wine recovered	$529.2 kL
Value of wine	$1.00 per litre
Value recovered	$529,200
Lees residue (assuming no downgrade)	$58.8 kL
Tarac	$35 per t gate fee
Cost of disposal	$2,058
Cost of Crossflow processing	
XF Operation	$15,357
Depreciation	$30,000
Wastewater	$214,292
Disposal	$2058
Net costs	$261,706
Value recovered	$529,200
Nett cost	$267,494 or $17.83 per tonne fruit processed Or $0.025 per litre wine

4.7 Must solids separation

4.7.1 OPPORTUNITY

Separation of grape solids from waste streams prior to their entry into the general wastewater system.

4.7.2 BACKGROUND

Grape solids are present in waste streams originating from cleaning of crush/de-stem, press and fermentation equipment and tanks. These grape solids can typically remain in contact with the push water for extended periods of time during storage and processing, increasing the pH level, organic loading (COD), sodium/potassium content and sugar level of the resultant wastewater.

Removal of these grapes solids at an early stage, through coarse-grade screens, may provide a reduction in wastewater loading and subsequently lower treatment costs. However, there is no readily available data on the level of impact and benefits that could be achieved using this approach. Scoping experiments were performed to better understand the extraction of compounds from grapes that are relevant to wastewater treatment plant operation and cost.

4.7.3 EXPERIMENTAL WORK

A laboratory scale trial was performed to determine the influence of contact time and agitation on extraction rates from grape solids in water. For each experiment, approx. 100 g of de-stemmed white grapes were gently crushed in a snap-lock plastic bag and then added to a 1 L Schott bottle containing approx. 900 mL of water. Where applicable, agitation was provided by a laboratory shaker table orbiting at ~150 rpm. Experiments were performed in duplicate at ambient conditions (22 °C). Samples of the resultant water were filtered through coarse household-grade sieve and all analyses were performed using standard techniques.

4.7.4 RESULTS

The influence of time and agitation on pH, refractive index (Brix), salt content (sodium/potassium) and COD are presented in Figures 4.35 to 4.38. The pattern of extraction with time was similar for all attributes, with all increasing over the entire treatment period but at a diminishing rate with increasing time. The majority of extraction occurred in the initial eight to ten hour period. Agitation resulted in considerably more extraction than that occurring with static contact.

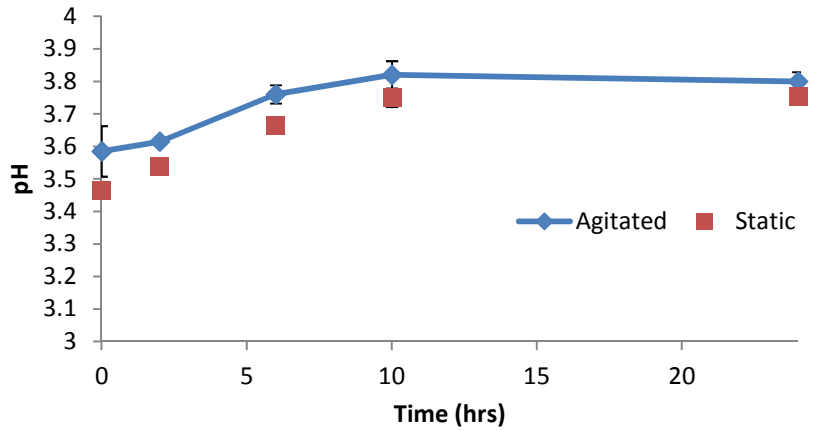


Figure 4.35 Impact of contact time and agitation on pH level

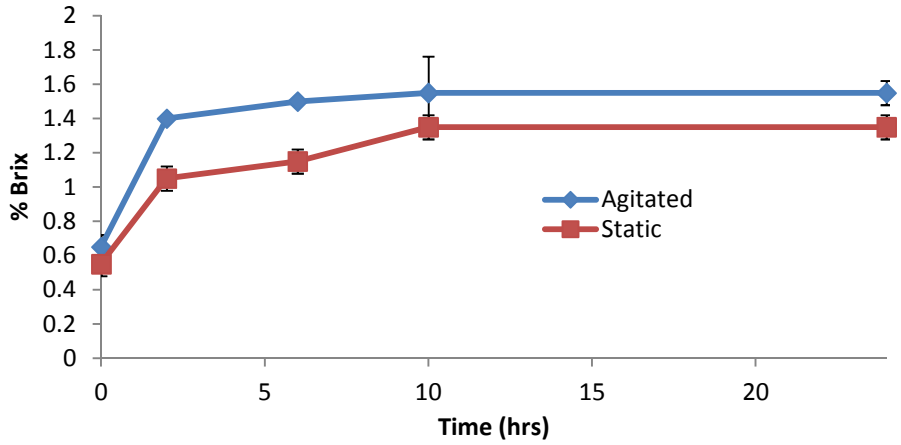


Figure 4.36 Impact of contact time and agitation on Brix

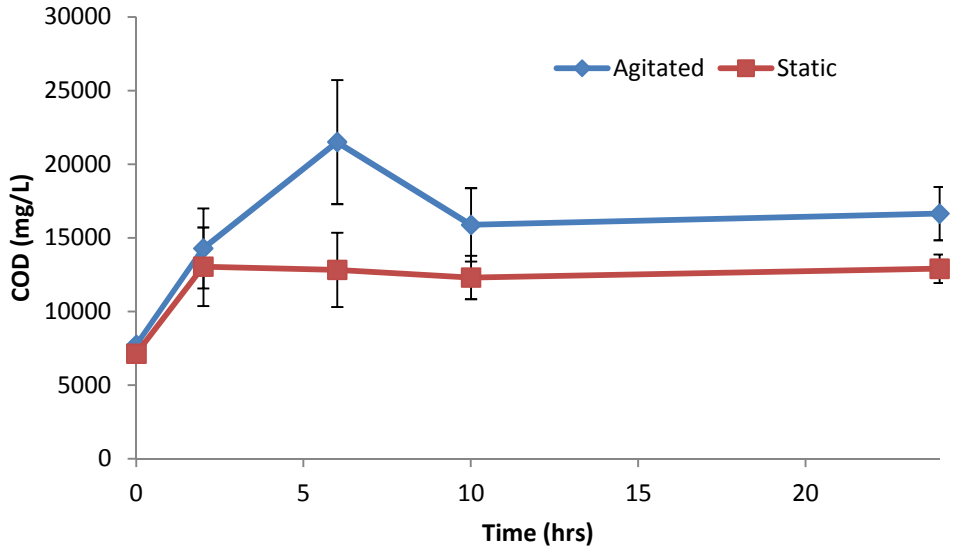


Figure 4.37 Impact of contact time and agitation on COD

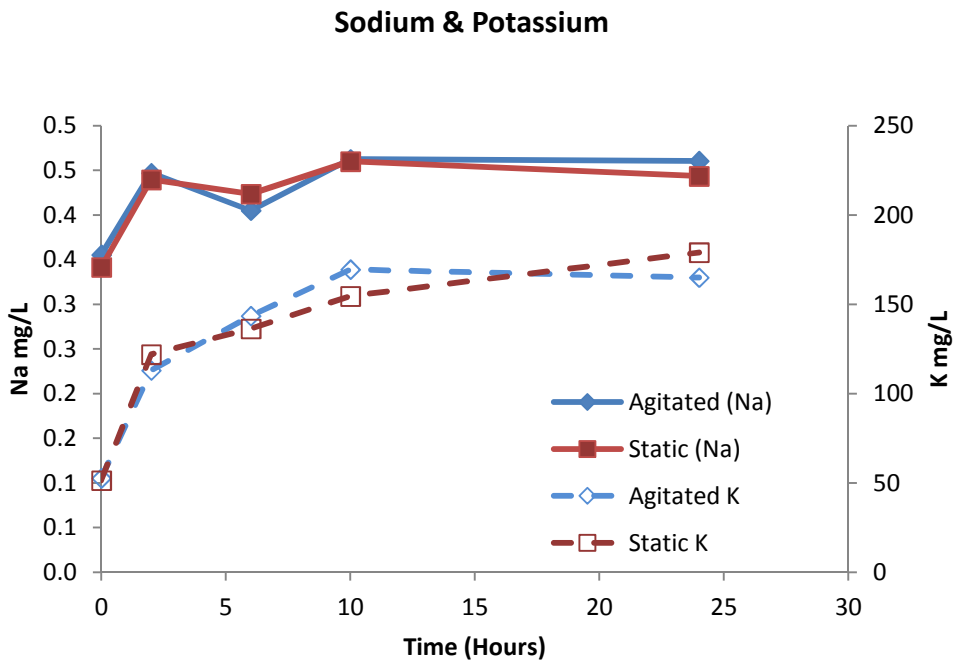


Figure 4.38 Impact of contact time and agitation on sodium and potassium levels

4.7.5 OUTCOMES

Results of the scoping experiments implied that extraction from grape solids in contact with water is rapid over the initial contact period and therefore benefits could be achieved through early separation of grape solids from wastewater.

4.7.6 PRACTICAL IMPLEMENTATION

Early separation of grape solids could be implemented in several ways.

For water with high loadings of large grape solids (e.g. crusher-fermentor push-water), a rotating trommel screen could be employed. An alternative for smaller wineries may be the use of a simple static basket.

For water with low solids loadings, screens/grates across drains could be used. The perforations in grates would have to be appropriately sized, such that they exclude grape solids but at the same time do not foul and prevent water passage. Frequent fouling can lead to excessive cleaning requirements, frustration of cellar hands and ultimately cellar hands lifting grates and hosing solids down the drain, counteracting their function.

Introduction of a trommel screen would involve high capital costs and could require significant spray water to prevent fouling. A static basket would involve much lower capital costs, but may entail significant manual handling and is likely to overflow as perforations are fouled by grape skins during periods of high use. The inclusion of self-cleaning functionality and continuous operation (especially during vintage) may reduce the overall operational impact and cost.

4.7.7 ENVIRONMENTAL EVALUATION

Reduced organic loading (as indicated by lower COD) in wastewater could ultimately help to reduce wastewater treatment plant odour. Reduced salt loading (as indicated by lower conductivity) could allow for increased re-use of wastewater in the irrigation of crops or vines.

4.7.8 ECONOMIC EVALUATION

Economic evaluation of screens and drain covers is given in Table 4.9 and Table 4.10 and the detailed assessment on Trommel screen technology is given in Appendix 6.

Table 4.9 Capital costs

Description	Indicative cost ($)	Expected lifetime	Source
Large/medium winery			
Trommel screen[1]	30,000[2]	15 years[3]	Filtration Solutions (http://www.filtrationscreens.com) Westpro (http://www.westpromachinery.com)
Small winery			
Perforated basket	1,000	10 years estimate	
Drain covers	800 (30cm sq)	15 years	Galvin Engineering (http://www.galvinengineering.com.au) Webforge (http://**w**ww.webforge.com.au*)*

[1] Based on a 760 mm x 900 mm long unit with spray bar and SEW grearedn drive motor. Pore size 1-3mm. Inlet 50mm, outlet 100mm
[2] Based on a 36m^3/hr capacity. Estimated average capacity required for 30KT winery would be 16m^3/hr (calculation).
[3] Longer expected lifetime if used consistently. Recommend a soft start if intermittent use, to reduce torsional stress.

Table 4.10 Annual operational (ongoing) costs

Labour				
Resource level	**Rate ($/hr)**	**Requirement (hrs/mL wine)**	**Total ($/kL wine)**	**Activities**
	Trommel screen			
Cellar-hand	30	1[1]	0.030	Cleaning
Cellar manager	40	0.5[2]	0.020	Set-up & ongoing monitoring
	Drain covers			
Cellar-hand	30	16.5[3]	0.5	Cleaning & removing debris

[1,2] Based on 2 cleaning operations per week when processing approx. 2,000KL wine
[3] Based on cleaning/removal operation every day during week when processing approx. 300KL wine

Consumables				
Description	**Cost ($)**	**Quantity**	**Requirement (per kL wine)**	**Total cost ($/kL wine)**
Cleaning chemicals[1]	-	-	-	-
Lubricants[2]	20	100g	0.1g	0.02

[1] no cleaning chemicals required
[2] Grease required for bearings with trammel screen

Utilities			
Description	**Rate ($)**	**Quantity (per kL wine)**	**Total cost ($/kL wine)**
Electricity[1]	0.3 per kWh	0.05 kWh[2]	0.015
Water	0.5 per L	0.15 L[3]	0.075

[1] 415v supply with rating of 0.75kW for trammel screen.
[2] Based on continuous use during vintage at 126kWh per wk to process approx. 2,500KL wine per week.
[3] Based on 50L wash water per day during vintage (vs~350L/day wine processed) – trammel screen only.

Wine losses

DESCRIPTION	AMOUNT (L PER KL PROCESSED)	COST ($/L)	TOTAL LOSS ($/KL PROCESSED)	ASSUMPTION
Volume loss	0	3	0	No direct losses
Quality loss	0	3	0	N/A

Treatment costs

DESCRIPTION	AMOUNT (PER KL WINE)	TREATMENT COST ($)	TOTAL COST ($/KL wine)	ASSUMPTION
Wastewater volume(L)	0.15	0.02/L	0.003	Washing trommel screen
COD (mg/L)	-5000	0.785/kg	3.925	
K (mg/L)	-75	46.67/kg	3.500	
Na (mg/L)	-0.1	140.00/kg	0.014	

4.8 Cleaning chemical type evaluation

4.8.1 OPPORTUNITY

Substitution of sodium hydroxide for sodium carbonate based cleaning reagents with the intention of reusing the wastewater stream for irrigation.

4.8.2 BACKGROUND

Fermentation vessels can accumulate residue on the interior walls requiring removal prior to reuse. This usually involves the application of caustic cleaning agents that are commonly sodium or potassium based. Each of the caustic reagents has its pros and cons in terms of down-stream application of the wastewater. Sodium based reagents are effective however increases the salinity of the soil and cannot be utilized by crops. Sodium enters the wastewater system due to the use to sodium based caustic cleaning agents. On

the other hand potassium based cleaning reagents are available which subsequently offer the option of the wastewater stream being applied for irrigation purposes (Kumar and Christen 2009).

The effectiveness of potassium and sodium based cleaning reagents were compared. Determining at which concentration the cleaning reagent removed the residue will be used to evaluate and compare the effectiveness of Na and K based cleaning reagents. Three commercial cleaning reagents were evaluated BWP (100% NaOH), Vin K (40% KOH and 10% NaOH) and Vinclean (60% Na_2CO_3), supplied by Dominant Chemicals.

4.8.3 EXPERIMENTAL WORK

20 L fermentors containing white wine residue in the interior wall were used for laboratory scale evaluation of the cleaning reagents. The cleaning reagents were diluted into 5 L of water (as specified in Table 4.11 below) and vessels were exposed increasing concentrations of the cleaning reagent for 10 min at room temperature. Images of the interior of the vessels were taken showing the amount

As there is variability in the amount of wine residue deposit between vessels, the experiment was repeated alternating the vessels used to evaluate the different reagents. The 5 L volume of solution filled approximately 1/3 of the vessel, to repeat the experiment using the same vessels, the bottom of the vessel was filled with water balloons.

Table 4.11 Table of concentrations of active cleaning reagent used and comparative costs

Volume (ML)/ mass (G) of reagent in 5L	**Final cleaning reagent concentration (% V/V)**	**Concentration of active reagent % (V/V)**		
		BWP	Vin K	Vinclean
		93% NaOH	40% KOH 10% NaOH	70% Na_2CO_3
0.5	0.01	0.01	0.005	0.006
1	0.02	0.02	0.01	0.012
2	0.04	0.04	0.02	0.024
5	0.10	0.10	0.05	0.06
Cost $/100 kg		295	298	298

Note: BWP cleaning reagent is more concentrated than Vin K and Vinclean

4.8.4 RESULTS

Caustic Agent	No Reagent	0.5	1
BWP 100% NaOH Rep 1			
	2	5	
			

Figure 4.39 Effectiveness of BWP (NaOH based) commercial cleaning reagent in removing white wine residue in Vessel 2 - 20 L fermentors

Caustic Agent	No Reagent	0.5	1
BWP 100% NaOH Rep2			
	2	5	
			

Figure 4.40 Effectiveness of BWP (NaOH based) commercial cleaning reagent in removing white wine residue in Vessel 4 - 20 L fermentors

Caustic Agent	No Reagent	0.5	1
Vin K 40% KOH, 10% NaOH Rep1			
	2	5	
			

Figure 4.41 Effectiveness of Vin K (4:1 - KOH: NaOH) commercial cleaning reagent in removing white wine residue in Vessel 3 - 20 L fermentors

Caustic Agent	No Reagent	0.5	1
Vin K 40% KOH, 10% NaOH Rep2			
	2	5	
			

Figure 4.42 Effectiveness of Vin K (4:1 - KOH: NaOH) commercial cleaning reagent in removing white wine residue in Vessel 2 - 20 L fermentors

Caustic Agent	No Reagent	0.5	1
Vinclean 60% Na_2CO_3 Rep 1			
	2	**5**	
			

Figure 4.43 Effectiveness of Vinclean (Na_2CO_3) commercial cleaning reagent in removing white wine residue in Vessel 4 - 20 L fermentors

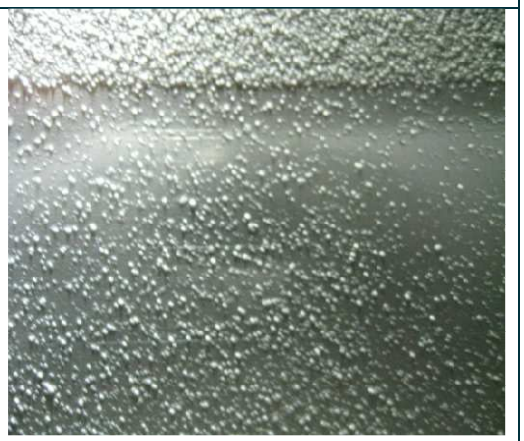
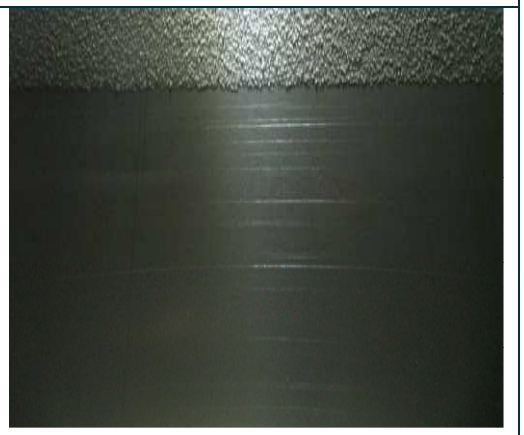
Caustic Agent	No Reagent	0.5	1
Vinclean 60% Na_2CO_3 Rep2			
	2	5	
			

Figure 4.44 Effectiveness of Vinclean (Na_2CO_3) commercial cleaning reagent in removing white wine residue in Vessel 1 - 20 L fermentors

Images of the interior wall of the vessels are shown in Figure 4.39 to Figure 4.44 the gradual removal of the residue with increasing concentrations of cleaning reagents is evident. For the comparison of the various reagents, the vessels were alternated since some had more residue than other which may have biased the results. Taking into consideration BWP is more concentrated (see Table 4.11), than the other two reagents a comparison of the identical vessel and similar cleaning reagents is able to give an indication of effectiveness. For example, by comparing image 1 shown in Figure 4.39 of BWP a similar concentration of the active reagent KOH of Vin K is shown in image 2 of Figure 4.40. Thus, twice the amount of Vin K is required to obtain the same results as half that of BWP.

The cleaning reagents have been ranked below in terms of effectiveness in removing the residue and cost effectiveness. Table 4.12 takes into consideration the concentration of the active ingredient however exclude the effect of other surfactants.

Table 4.12 Effectiveness and cost of cleaning reagents ranked most to least

Effectiveness of cleaning reagent	**BWP > Vinclean > Vin K** **NaOH > Na_2CO_3 > KOH**
Cost of reagent taking into consideration amount of active ingredient	Vin K> Vinclean > BWP KOH> Na_2CO_3 > NaOH

4.8.5 OUTCOMES

There is a requirement for approximately twice the concentrations of potassium based cleaning in comparison to sodium hydroxide based reagents to be used in to remove the same amount of residue (Table 4.13).

Table 4.13 Wastewater treatment cost: $46.67/Kg potassium and $140.00/Kg sodium

REAGENT	CONCENTRATION OF ACTIVE INGREDIENT (% v/v)	VOLUME (mL) OR MASS (g) OF REAGENT PER LITRE REQUIRED	COST $/KL CLEANING SOLUTION	WASTE WATER TRTEATMENT COST $/Kg
BWP	93% NaOH	0.4	1.18	130.20
Vin K	40% KOH, 10% NaOH	1.0	4.47	60.67
Vinclean	70% Na_2CO_3	0.4	1.19	98.0

4.8.6 PRACTICAL IMPLEMENTATION

The effectiveness of sodium carbonate and sodium hydroxide based reagents in removing wine residue appear to be very similar. However taking into account downstream implications of sodium in the wastewater system, it would be preferable to use sodium carbonate based cleaning reagents to decrease the concentrations of sodium in the wastewater.

4.8.7 ENVIRONMNTAL EVALUATION

Substitution of sodium hydroxide based cleaning reagents for sodium carbonate based agents may result in decreased sodium loading in the wastewater and improved soil salinity.

4.9 Cleaning chemical type evaluation

4.9.1 OPPORTUNITY

Reuse of cleaning chemicals.

4.9.2 BACKGROUND

The use of caustic cleaning solutions is widespread within the wine industry. Caustic cleaning agents are relatively cheap and very effective. In most cases, Sodium Hydroxide (NaOH) is the active ingredient although some wineries use Potassium Hydroxide (KOH) or Sodium Bicarbonate (Na_2CO_3).

Although effective as cleaning agents, caustic cleaners pose significant problems for wastewater treatment facilities. Even the more advanced waste treatment facilities are generally unable to remove sodium and potassium salts that are introduced from these cleaning agents.

One way to reduce the amount of salt entering waste treatment systems is to limit the disposal of cleaning agents to the drain. Reusing or recycling cleaning chemicals whenever possible, and effectively eliminating their introduction to the wastewater treatment plant, will have a big impact on the final quality of water leaving the waste treatment system. This is not a new idea and a number of Australian wineries are currently adopting recycling practices; the general approach is as follows.

- Establish a central storage tank to hold the caustic cleaning chemical. Some sites maintain this tank with 2% active OH as titratable hydroxide.
- Draw the required amount of caustic solution from the central holding tank into a movable container.
- Transport the mobile container to the tank and use it to clean the tank in the normal manner.
- Empty the used cleaning solution back into the mobile tank.
- Empty the mobile tank back into the main storage tank.

In some cases, it may be more effective to fit fixed caustic delivery lines throughout the winery (Figure 4.45). This may be the only option if access to various sections of the winery is limited and it is not possible to use a portable cleaning rig.



Figure 4.45 Fixed Caustic and Cleaning Water lines for recycling



Figure 4.46 Caustic solution storage tanks at Yalumba's Oxford Landing Winery

The main storage tank (Figure 4.46), used to supply caustic for each cleaning process will need to be monitored at regular intervals to ensure that the concentration remains adequate. Additional doses of caustic material will need to be added to maintain effectiveness.

As the salt level builds up, the tank will eventually need to be emptied. This can be done by:

- Disposal into the wineries waste treatment facility (although this will have significant risks and hidden costs);
- Disposal at a waste processing facility (about $140 per kL);
- Disposal into an evaporation pond or basin.

Caustic solutions are more effective at higher temperatures. If cleaning processes are completed at elevated temperatures the cleaning process will take less time and lower amounts of caustic material will be needed. In recent years, a number of wineries have begun developing systems which enable them to both recycle and heat caustic cleaning agents. One such example is the mobile tank cleaning unit (TCU) developed by Yalumba and in operation at the Oxford Landing Winery (Figure 4.47). This apparatus, fitted to a mobile skid, contains storage tanks for rinse water, caustic cleaner and an acid neutraliser as well as a heat exchanger. Hot water increases the performance of the cleaning chemicals used, however, care needs to be taken to ensure that equipment is not damaged by the use of elevated temperatures.



Figure 4.47 Tank cleaning unit in operation

4.9.3 PRACTICAL IMPLEMENTATION

In order to establish a caustic recycling system within a winery the winery will first need to decide if they want to use a portable cleaning rig or adopt a fixed line system. This choice will have a large impact on the overall cost and complexity of commissioning.

The wineries will also need to establish a suitable set of storage tanks. In some cases it may be appropriate to have both a caustic storage tank and an acidic tank holding neutralising product such as citric cleaner.

If using a portable cleaning rig, this will also need to be designed built and commissioned.

4.9.4 ENVIRONMENTAL EVALUATION

Reducing the disposal of caustic material to the waste treatment system is likely to have significant impact on reducing salt loads associated with the treatment plant. Overall the environmental impact will be assessed by evaluating the reduction in salts entering the treatment facility.

4.9.5 ECONOMIC EVALUATION

Some capital equipment will be needed to develop this as a method within a winery. This includes:

- Concrete bunded pad for tanks - $20,000
- Large storage tanks with appropriate fittings - $20,000
- Stainless steel Mobile pumping Skid - $20,000
- Paletcon pumping skid - $ 2,000

Purchasing costs and the treatment costs associated with three main cleaning agents is given in Table 4.14.

Table 4.14 Price of caustic cleaner including purchase costs and treatment costs

Reagent	Concentration of active ingredient (% V/V)	Cost $/KL cleaning solution	Waste water treatment cost $/KG
BWP	93% NaOH	1.18	130.20
Vin K	40% KOH, 10% NaOH	4.47	60.67
Vinclean	70% Na_2CO_3	1.19	98.0

Wineries who have implemented caustic recovery systems may realise about 60% reduction in caustic use.

Ryecroft saved about 2 tonnes per year of sodium hydroxide entering their waste treatment system.

4.10 Selection of case-studies

The second phase of this project involves case studies which will investigate in more detail the following three technologies identified as being most beneficial to Australian wineries.

1. The reuse of cleaning chemicals and the design/development of a speciality cleaning system which will allow chemical reuse and heating. This will include the development of methods to assess caustic concentration and top-up/ disposal requirements.
2. The implementation of a lees separation techniques including an evaluation of various newly developed lees cross-flow filtration systems; and
3. The development of method(s) to reduce the number of transfers performed in wineries. This project is expected to combine elements of scheduling, ullage management and blending techniques.

5 Case-study 1: Re-use of caustic cleaning agents

5.1 Introduction

Cleaning is one of the most repeated tasks in a winery. It is time consuming, tedious, costly and potentially dangerous. Due to the nature of fouling within a winery, the majority of the cleaning processes are expedited by the use of caustic cleaning agents, most commonly sodium hydroxide.

There is an increasing focus on the minimisation of caustic material within wineries. This is primarily driven by the following factors:

- Chemical cost;
- Occupational health and safety requirements;
- Waste water quality implications; and
- The potential re-use of winery waste water in irrigation applications.

This report is intended to outline a method to enable the re-use of caustic cleaning chemicals. This will be done by considering the following three important categories:

- Occupational health and safety;
- Economic cost; and
- Environmental benefits.

5.1.1 SALTY WINERY WASTE WATER

Winery waste water is often high in sodium and potassium salts. At high concentrations these salts may be harmful for the environment or limit the opportunity associated with water re-use (Operating Guidelines, Peter Day, 2011). There are limited practical treatment options available to reduce the salt concentrations in waste water and therefore the following management options are suggested in the Operational Guidelines: Winery Wastewater Management & Recycling handbook:

- Cleaner Production – Eliminate salt from the winery waste water.
- Dilution – Salt concentrations can be reduced through dilution with alternative fresh water.

The Operational Guidelines also suggest evaporation, treatment using reverse osmosis or discharge to sewer as suitable management options.

Sodium salinity in winery waste water is predominantly the results of caustic washing processes within the winery, but may also be the result of Ion exchange process wastes. Potassium based salinity may be attributed to product loss (grapes are high in potassium) or through the use of potassium based caustic cleaning agents. In some wine growing locations, fresh water is supplied to the winery with relatively high salt concentrations.

5.2 Case-study: Caustic recovery

5.2.1 CAUSTIC RECOVERY 0 THE BASIC PREMISE

The purpose of a caustic recovery system is to minimise caustic waste. This is achieved by having a central caustic solution storage tank (Figure 5.1). Caustic solution is drawn from this tank, used for winery cleaning operations and then returned to the same tank. The size of the caustic storage tank needs to be sufficiently large such that multiple withdrawals of caustic can occur without radically compromising the caustic

concentration. This central storage tank is routinely monitored and additional caustic material is added as required.

Caustic recovery is effective, as in most cleaning applications, the used caustic material has not been completely exhausted. Returning it to a central storage tank allows it to be reused in further cleaning applications.

There are two main of variants of caustic recovery, they differ only in how the caustic solution is delivered to the area needing to be cleaned. The simplest variant uses mobile pallet containers transported by forklift or pallet jack. In circumstances where the use of a forklift is more difficult, due to access constraints, a network of pipes can be established and the caustic material is then pumped to its desired location. The cost of this additional plumbing, normally completed using stainless steel pipes, makes the use of pallet containers more appealing to most wineries.

The general approach is as follows.

- Establish a central storage tank to hold the caustic cleaning chemical. Generally the tank is maintained with 1-2% active OH as titratable hydroxide.
- Draw the required amount of caustic solution from the central holding tank into a movable container.
- Transport the mobile container to the tank and use it to clean the tank in the normal manner.
- Empty the used cleaning solution back into the mobile tank.
- Empty the mobile tank back into the main storage tank.



Figure 5.1 Caustic solution storage tanks

The main storage tank will need to be monitored at regular intervals and have additional doses of caustic material added to maintain effectiveness.

Some sites that have already adopted caustic recovery systems report that the need to empty or completely refresh the tank does not occur frequently. Every time a tank is cleaned, there is some loss in caustic volume, due to small spills, pipe volumes and holdup of droplets on tank walls etc. This small loss in volume at each clean reduces the need to empty the holding tank as frequently.

As the salt level builds up the tank will eventually need to be emptied. This can be done by:

- Disposal into the wineries waste water treatment facility (although this may have significant risks and hidden costs);
- Disposal at a specialised waste processing facility such as Tarac (about $140 per kL plus transport costs); and
- Disposal into an evaporation pond or basin.

5.2.2 TANK CLEANING PROCESS

Tank cleaning is common winery process. The following approach is generally adopted.

1. Tank is completely drained by opening the lowest drain valve;
2. The lowest valve is then connected to a pump inlet;
3. The pump outlet is connected to a spray ball (Figure 5.2), inserted into the top of the tank (often fixed pipe lines are used to connect the pump outlet and the spray ball, but this can be done with flexible hoses also).
4. Caustic based cleaning agents are added to the tank;
5. Al hatches and inspection point are closed, but not normally sealed;
6. The pump is switched on causing caustic cleaning solution to circulate through the spray ball (Figure 5.3).
7. Cleaning time vary depending on how dirty the tank is and how effectively the cleaning chemical works.



Figure 5.2 Spray ball used for tank cleaning



Figure 5.3 Pump used to circulate caustic cleaner through spray ball

5.2.3 CURRENT WATER QUALITY

Although there are technologies available for salt removal, such as reverse osmosis, they are not commonly used within wineries. For this reason it is more effective to prevent salts from entering the waste water treatment system. Re-use of caustic cleaning solutions diverts this highly saline stream away from the treatment system.

Limiting waste water effluent salinity is particularly important if waste water is to be reused for irrigation.

At the cases study winery, following treatment, waste water is stored in a large dam. It is then used to irrigate a local vineyard. Water samples were collected from this storage dam in June and July 2012. Chemical analyses were performed on these samples with the following results type of cleaning solution

Sodium hydroxide is the most widely used caustic cleaning agent within the Australian wine industry, however, sodium salts are not readily absorbed by plant material. Therefore, if saline waste water is used in irrigation applications the sodium content continues to build up in the soil. This has led a number of wineries to switch to potassium based cleaning agents. Potassium salts are more readily absorbed by plants and so are more likely to be removed from the soil.

Table 5.1 Waste water analysis

SAMPLE	COD (mg/L)	pH	E.C. (dS/m)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)	SAR[1]
Stored Irrigation Water – Sample 1	0	8.2	1.456	19.5	121	13.4	195	5.1
Stored Irrigation Water – Sample 2	60	8.3	1.456	22.2	131	14.4	208	5.3
Inlet Waste Water	5000	7.0	1.6	28.9	142	12.9	252	9.7

Together with electrical conductivity, the dimensionless sodium adsorption ratio (SAR) helps to determine the impact of waste water on soil quality. Current values suggest that the stored irrigation water will have no impact on soil infiltration. This is means that current practices, without re-using caustic cleaning solutions are not affecting the quality of irrigation water. However, the samples were taken during the winter months, after significant rainfall events and therefore represent best case scenarios. At the end of vintage, after dry summer months it is likely that both the SAR and salt level of the stored irrigation water will be significantly higher in the absence of leaching rainfall events.

Potassium uptake, although greater then sodium uptake, is also limited meaning that potassium levels should also be monitored. Winery waste water is typically high in potassium salts (excluding cleaning chemicals) as these salts exist in grapes. Observe in the above analysis results that potassium salts are about 130mg/L in the waste water even in the absence of potassium based cleaning product being used (Table 5.1).

5.2.4 CURRENT CLEANING PRACTICES

In order to evaluate the benefit of a caustic recover system, current cleaning practices at the case study winery were observed. Particular focus was placed on identifying the amount of active hydroxide remaining in the cleaning solutions normally disposed into the waste water treatment facility.

Currently the standard practice in the winery is to target a 1% w/w caustic concentration for normal tank cleaning operations. Some very intensive cleaning operations may require higher concentrations.

Pre and post cleaning samples were collected from a number of different tanks and bottling line cleans. The results are summarised in Table 5.2.

The results above show that excluding sample 411, the average concentration of NaOH disposed to drain is 0.75%. However, in some cases the concentration is significantly higher, such as with sample 411.

The results above suggest that current cleaning practices are only utilising 15-30% of the hydroxide in the cleaning solution. The implementation of a recovery system will allow for further utilisation, reducing the overall consumption of NaOH. Based on these current utilisation rates, a conservative estimate would be that re-use would lead to a 50% reduction in sodium hydroxide consumption.

Table 5.2 Sample analysis - caustic concentration before and after cleaning process

SAMPLE #	COMMENT	%NAOH
100	Tank Cleaning - Inlet	0.85
101	Tank Cleaning - Outlet	0.91
201	Tank Cleaning - Inlet	0.31
202	Tank Cleaning - Outlet	0.91
203	Re-use of sample 202, with 4.5 kg of caustic added to 1000L of water.	0.71
301	Tank Cleaning - Inlet	0.8
302	Tank Cleaning - Outlet	0.86
401	Re-use of caustic solution for 202 before cleaning	0.73
402	Re-use of caustic solution 202 after cleaning. Tank was very dirty cleaning process was completed over 8 hours	0
411	Re-use of 402 with an extra 25kg of caustic. Hot water clean.	2.97
501	300L of water, 2-3 kg of caustic relatively clean tank	0.11
502	After 45 mins.	0.56
602	Post bottling cleaning.	0.69

5.2.5 UNIFORMITY OF CONCENTRATION

Although the case study winery has a target concentration of 1% NaOH when cleaning winery tanks, achieving this specification is very difficult as it relies on cellar hands to accurately estimate how much water they are adding to the bottom of a tank.

The consequence of this is that some cleaning solutions may be much weaker than 1% NaOH, requiring longer cleaning times, while others may be much higher. These higher concentration solutions may pose more of an OH&S risk, than would be expected with a 1% solution.

The move towards a caustic recovery system would enable the concentration of cleaning solutions to be more tightly controlled minimising both OH&S issues and tank cleaning times.

5.2.6 MANAGEMENT AND MAINTENANCE

The caustic recovery tank is intended to be maintained in such a way that it always contains an effective cleaning agent. The tank will require monitoring and additions of sodium hydroxide at intervals (possibly weekly). The following process is proposed.

1. The onsite laboratory prepares sample containers with a known amount of hydrochloric acid. Concentration and volume will depend on a specified minimum tank caustic concentration
2. The sample container is then filled with a caustic solution sampled directly from the storage tank.
3. Litmus paper is used to check the pH of the mixed sample.
4. If the litmus test indicates an acidic solution, a fresh bag of solid caustic is added to the tank.
5. The tank is then pumped over for 20 minutes to mix it in.

Occasionally it may be necessary to purge the caustic storage tank. With existing infrastructure there are two potential ways that this could be done:

1. Discharge it to the onsite waste water treatment system.
2. Employ an external waste treatment company to take it away (e.g. Tarac).

Current water analysis suggests that sodium concentration is not a major issue in the holding dam and therefore the first option may be most cost effective. It would be prudent to ensure that the discharge to the waste water treatment system is done slowly and in a controlled manner, so as to not upset the biological activity of the treatment system. If possible the discharge should be done at or near a significant rainfall event. This would assist in the dilution of the caustic material.

5.3 Cost-benefit analysis

The ultimate implementation of new practices and technologies rests on a financial justification. This case study considered carefully the costs and benefits of installing and using a caustic recovery system. The economic analysis considered the capital costs to establish the recycling system and the savings from reduced caustic use and a reduction in labour requirements associated with caustic solution preparation prior to every tank cleaning operation.

The economic analysis does not consider:

- OH&S benefits associated with caustic recovery;
- Environmental performance improvement; or
- Long term soil health improvement.

These items have been excluded from the economic analysis due to difficultly in establishing or correlating economic values to these benefits.

It is estimated that this project will require a capital investment of $12,825 (Table 5.3). This includes a suitable, chemical resistant poly tank ($3,325) electrical installations ($2,500), safety bollards and additional safety equipment including signage ($2,000), the decommissioning and reconfiguration of used winery pumps ($3,000) and the purchase of two pallet containers ($2,000).

Table 5.3 Simple Economic Evaluation

EXPECTED COSTS		EXPECTED SAVINGS	
Tank	$3,325	Reduced Caustic	$5,940
Electrical Installations	$2,500	Reduced Labour	$5,200
Safety Bollard etc	$2,000		
Pumping equipment	$3,000		
Pallet Containers	$2,000		
Total	$12,825		$11,140
Payback Period (years)	1.15		

The main savings associated with the recovery system come from reduced caustic purchases ($5,940 pa) and reduced labour costs are difficult to calculate but have been conservatively estimated ($5,200 pa). Total annual savings are estimated as $11,140.

Using a simple (excluding the time value of money) payback method, the payback period is just over 1 year (Table 5.3).

5.4 Occupational health and safety

Sodium hydroxide is classified as a dangerous good. It is a corrosive chemical and causes burns by all exposure routes. Within the winery sodium hydroxide is one of the most dangerous chemicals and must be handled with due care.

Sodium hydroxide is delivered to the winery as a solid material in 20kg bags. Although delivered as a solid, it is normally used as a solution. The addition of water to solid sodium hydroxide causes a vigorous exothermic reaction generating heat, often in sufficient quantities to boil the water. This hot, highly concentrated solution is extremely corrosive. Carrying open top buckets of this solution around the winery is a potential hazard that would be removed through the use of a caustic recovery system. Caustic soda solution does not look dangerous, being clear and odourless, like water. In addition, it does not cause immediate pain when it comes in contact with the skin, however, even brief contact may cause marked irritation or a chemical burn. Unlike some acids that coagulate protein to form a barrier upon contact, caustic soda solution will continue to attack and penetrate the eyes or skin, causing significant injury (Dow Chemicals, 2012).

Lower concentrations of sodium hydroxide such as the 1% w/w used in tank cleaning operations are still considered dangerous and should be handled carefully. However, 1% solutions pose a significantly reduced risk to much higher concentration solutions or solids.

Dow Chemicals, one of the world's leading chemical producers recommends the following Protective Clothing and Equipment (PPE) when using caustic soda solutions (Figure 5.4):

- Persons handling caustic soda solution must always wear close-fitting chemical worker's safety goggles and chemical resistant gloves.
- Additional clothing and equipment may be required, depending on the job. It is the responsibility of the facility using caustic soda solution to perform a job safety analysis to determine the proper Personal Protective Equipment (PPE) for the task being performed.

Personal Protective Equipment may include:

- Hard hat.
- Chemical resistant apron.
- Full face shield (in addition to chemical worker's safety goggles).
- Chemical resistant boots.
- Chemical protective suit (jacket and pants). The jacket should be buttoned up to the neck, the trousers worn outside the boots, and the shirt sleeves sealed at the glove unless a job safety analysis determines it is acceptable for the sleeve to be worn over the glove.
- Full chemical protective suit with hood and an air supplied respirator.



Figure 5.4 DOW Chemical PPE Recommendations

One of the key features associated with a caustic re-use system is the improvement to occupational health and safety by eliminating the requirement to transport high concentration solutions around the winery. Traditionally OHS issues associated with caustic material are addressed via the use of extensive PPE, as described above. A better approach is to eliminate the exposure to high concentration scenarios. By creating a central storage point for caustic solutions, most cleaning operations will not expose staff to high concentration caustic mixes.

With a caustic recovery system the only time when potentially higher caustic concentrations occur is when filling, or refreshing the storage tank. As this is no longer a routine task (expected to occur less than once per week), it is likely to be easier to control compliance around safety.

Individual regional jurisdictions may have specific requirements associated with storage, preparation and use of dangerous goods. You are advised to seek specific advice from your local authorities before beginning an installation process.

5.5 Environmental considerations

The case study winery has an advanced waste water treatment plant. The system is 'state of the art' yet it will not treat or remove meaningful amounts of sodium salts. Like most winery waste water treatment plants, the unit relies on biological methods to treat the waste water. This generally works well in removing sugars, ethanol and suspended solids. However, it is not able to remove sodium or potassium salts commonly associated with caustic cleaning chemicals. The implementation of a caustic recycling system will reduce the levels of sodium salts in the wineries waste water.

Sodium hydroxide is a dangerous good even at low concentration it poses a risk to both human health and the environment. Before installing a caustic recovery system care should be taken to ensure that adequate containment methods are in place to reduce the risk from spills or tank failures.

Individual regions may have different legal requirements associated with the storage of dangerous goods and you are advised to consult local authorities before beginning an installation process. You are advised to also consult the Dangerous Goods (Storage and Handling) Regulations, 2000.

5.6 Conclusion

This case-study was undertaken to demonstrate that there are a number of benefits associated with moving to caustic recovery system. These are economic benefits but also OH&S and environmental benefits.

It is expected that the introduction of a caustic recovery system will reduce caustic purchases by 50%. This is expected to save the case study winery between $4,680 and $5,940 dollars per year. In addition the labour costs associated with tank cleaning operations is expected to decrease by at least $5,200 per year.

Caustic recovery has environmental benefits by reducing the total salt discharged into the recycled wastewater hence making it more suitable for vineyard irrigation. Potentially the most important aspect of the project is the improvement to OH&S. The use of a caustic recovery system is expected to minimise the presence or need of high strength caustic solutions within the winery, removing a significant hazard.

6 Case-study 2: In-winery product movements

6.1 Introduction

Wine is moved between tanks to facilitate many winery processes, including:

- separating liquid from settled solids (racking),
- using equipment (e.g. a centrifuge or filter),
- relocating wine for the convenience of future operations (e.g. to a tank near packaging),
- blending wines from different tanks, and
- moving wine into different sized tanks or topping-up tanks to prevent ullages.

Each movement uses labour, water, cleaning chemicals and produces wastewater. These resources are used at the start and end of a wine movement and also for the tank cleaning operation that often accompanies a movement. Wine is also lost and/or diluted with water.

In a typical wine movement, a line first needs to be set-up between the source and destination tank. This line is usually a combination of fixed piping and flexible hoses. Finding the necessary fittings and making the connections can be time-consuming. Water is used to check the connections and flush the line. A caustic solution will sometimes be used initially for cleaning (this may be drained immediately to wastewater or recovered for reuse). Wine will then be introduced, pushing the water from the line. Adjacent to the destination tank, that water will be allowed to drain to wastewater until the wine arrives, at which time the cellar hand will 'cut' – i.e. open the valve to the destination tank and close the drain valve. After the source tank has been emptied, or the required volume of wine has been moved, water is used to push the final wine in the line through to the destination tank. When the water arrives at the destination tank, the cellar hand will cut – i.e. open the drain valve to wastewater and close the valve to the destination tank. The cellar hand makes the assessment on when to cut based on tasting and/or a colour change observed through a sight glass. A detailed description of a product movement at one winery is provided in Appendix A.

For the wine-water push at the start of a movement and the water-wine push at the end of a movement there will be some mixing at the interface between wine and water. There is very limited information available on the magnitude of this mixing. The only example available in the literature to the authors' knowledge is for one water-wine push through a 500 m length of 3" line including a plate heat exchanger (Deans 2006). In this instance the wine-water interface was 1186 L, and with the cut performed by the cellar-hand, 179 L of wine was lost to wastewater and the wine was diluted with 189 L of water. In this new study, experiments were performed on simple pump movements in order to address the knowledge gap.

The most effective way to avoid the negative aspects of movements is to perform less of them. This is easier said than done. Wineries do not perform a movement unless there is a reason to do so at that time. To systematically work towards performing less movements it is necessary to better understand the number of wine movements actually performed and what the drivers behind these movements are. In large wineries producing many different and interdependent products, the number of movements in a product's lifetime is often not well understood. For this reason, a case study was performed at one large winery to develop an improved understanding of product movements. The approach was to mine product movement data in the winery's label integrity program (LIP) database.

The results from experiments on the size of the wine-water interface/wine losses at the start and end of a wine movement and the case study on wine movements at one large winery are presented in this report.

6.2 Methodology

6.2.1 WINE-WATER INTERFACE AT THE START AND END OF WINE MOVEMENTS

An in-line conductivity probe was used to assess the interface between wine and water during basic tank to tank wine movements at one winery (Figure 6.1). Wine contains dissolved salts giving it a much higher conductivity than water. Lines were a combination of 3" fixed pipe and 3" flexible hose. The procedure for movements is described in Appendix A, with the only difference being that a conductivity meter and a flow meter were installed in-line at the nearest possible point to the destination tank. This section of the arrangement is shown in **Error! Reference source not found.**.

Conductivity was measured using a TB457 4-electrode conductivity cell (ABB) connected to an AX400 transmitter (ABB). The transmitter was configured to output its readings via a 0-20 mA analogue current loop. The analogue output signal updated at 1 Hz. Fluid flow rate was measured using an FM Magflo MAG6000 electromagnetic flow meter (Siemens). Measurements were also output via a 0-20 mA analogue current loop. The two current loops were measured independently by measuring the voltage drop over 250 ohm resistors in the loops. The 0 – 5 V signals were measured at 50 Hz and 10 bit resolution by an Atmega168-20AU microprocessor (Atmel) on an 'Arduino' development board, programmed to average the voltages over 5 times and record data at 10 Hz.



Figure 6.1 In-line flow meter and conductivity meter for assessing the wine-water transition

6.2.2 NUMBER OF WINE MOVEMENTS AT A LARGE WINERY

A two phase approach was used to analyse the winery's LIP database. Firstly, winery-wide red and white (including rosé) wine movements were investigated statistically, and secondly, two specific blends (a red and a white wine) were followed in the database through their production lifetime.

For the winery-wide statistics, relevant wine movement records for 2009-2011 were extracted from the database. In order to estimate the average number of movements performed on a red or white wine during its lifetime from the extracted list of movements, equations 1 and 2 were applied for each operation type

(e.g. centrifuge, pump[1], etc.) in each of three production stages ('Varietal', 'Blended' and 'Finished'[2]) for wine vinified in 2009.

$$\overline{N}_{simple} = \frac{\sum_{i=1}^{n} v_i}{V_{wine}} \quad (1)$$

$$\overline{N}_{size-weighted} = \frac{\sum_{i=1}^{n}\left[v_i\left(\frac{v_i n}{\sum_{i=1}^{n} v_i}\right)\right]}{V_{wine}} \quad (2)$$

$\overline{N}_{simple}$:	Simple average number of movements.
$\overline{N}_{size-weighted}$:	Size-weighted average number of movements.
v_i:	Volume of individual movement i.
n:	Total number of movements.
V_{wine}:	Volume of wine produced[3].

Equation 1 provides a simple estimate of the average number of movements, essentially the number of times each drop of wine has gone through a movement operation type. Equation 2 provides a size-weighted estimate. The size-weighted average is likely to have a closer relationship with the actual number of movements performed at the winery as the simple average will be skewed by large volume movements.

Each movement between two specific tanks had an individual record in the database. For example, if one 100 kL tank was centrifuged sequentially into two 50 kL tanks, there would be two records. It could be argued that with respect to the effort involved this should be described as one instead of two movements (the truth probably lies somewhere in between – there still needed to be 2 clean destination tanks). To provide an indication of the level of grouping for each operation type, a movement to jobs ratio was calculated either by grouping movements that were from the same tank on the same day or by grouping movements that were on the same operations note.

6.2.3 NUMBER OF WINE MOVEMENTS AT A LARGE WINERY

The terminology used when discussing product movements in wineries can be confusing. For example the term 'transfer' is sometimes used to refer only to product movements that do not use processing equipment, while other times those movements may also be included as transfers. Similarly, small product movements to top-up tanks may or may not be included. For clarity, in this report the term transfer will not be used at all. The following key terminology will be employed, consistent with the methodology already described.

[1]The winery uses a splitter/blender for some operations. This is represented in the database by pump movements into and out of a hypothetical tank. In this report, the pump movements out of the splitter/blender have been excluded to prevent double counting. Loading into tankers for inter-winery transport, filling export containers, and packaging were also excluded.
[2]Varietal: Prior to blending into a specific product class, Blended: Designated as a specific product class, Finished: Post-stabilisation.
[3]The winery receives and distributes wine at various stages of completion. The volume of wine produced was calculated as the sum of wine packaged on site, transferred to another winery/packaging facility or exported in bulk. Incoming wine was subtracted from this volume when it could confidently be classified as Finished based on status codes as it was reasoned that most of the required operations would have already been performed on those quantities of wine.

Movement: The overarching term to describe any product movement between 2 specific tanks, irrespective of whether processing equipment was used or not, and the volume moved.

Pump: A movement that does not use processing equipment (the term 'pump movement' will also sometimes be used).

A range of codes were used interchangeably in the winery's database to describe the same physical operation. For example 'pump' was used by some staff, while 'rack' was used by others for the same physical operation. For this study, operations under codes representing the same operation were combined into the single most common code. For example, all 'rack' and 'pump' operations were combined as 'pump' operations.

The case study winery, like many others, was divided into a number of tank farms. To analyse interactions, tanks were divided into sectors and labelled. Labels consisted of a letter prefix (A-J), the volume or range of capacities of tanks in that sector, and the number of tanks in that sector. Sectors with letters closer together in the alphabet were generally closer together when looking at them on a site layout. There were some minor exceptions to the use of letter prefixes. Packaging tank sectors were given a 'Pac' prefix, a sector used for loading export containers was given an 'Exp' prefix, portable pallecon tanks were given a 'P' prefix and portable stainless steel tanks were given an 'S' prefix.

6.3 Results and discussion

6.3.1 WINE-WATER INTERFACE AT THE START AND END OF WINE MOVEMENTS

A transition observed from wine to water during the water push-through at the end of a wine movement is presented in Figure 6.3. A plot of best fit was added based on the general diffusivity equation of Danckwerts (1953)[4]. Wine loss to wastewater in the instance of a cut at the middle of the interface was also calculated according to Danckwerts (1953)[5]. The results from experimentally observed interfaces at the start or end of wine movements are presented in Table 6.1.

[4]Wine fraction = $\frac{1}{2}\left[1\text{-erf}\left(\frac{x}{2\sqrt{D\theta}}\right)\right]$, where: D is the diffusivity coefficient (determined by adjusting for best-fit with experimental data), x is distance (m) referred to coordinates moving at flow velocity, and θ is the average residence time (s).

[5]Wine loss (L) if cut at mid-interface = $1000A_x\sqrt{\frac{D\theta}{\pi}}$, where A_x is the pipe cross-sectional area (m^2). This also equals the water added to the wine.

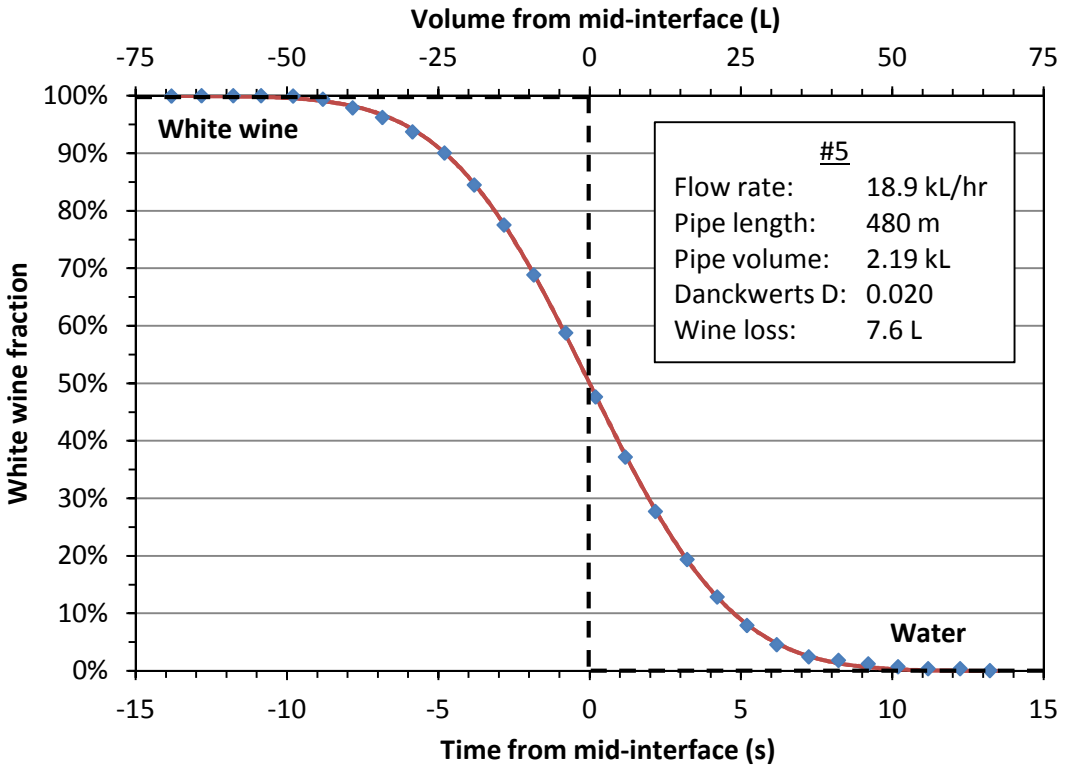


Figure 6.2 Transition from wine to water during water push-through at the end of a wine movement

Table 6.1 Experimentally observed transition interfaces

#	DESCRIPTION	FLOW RATE (KL/HR)	PIPE LENGTH (M)	PIPE VOLUME (KL)	DANCKWERTS D	WINE LOSS (L)
1	Water - Red wine	25.2	153	0.697	0.015	3.1
2	Red wine - Water	21.7	153	0.697	0.026	4.4
3	White wine - Water	18.9	184	0.839	0.019	4.5
4	Water - White wine	22.0	480	2.19	0.016	6.1
5	White wine - water	18.0	480	2.19	0.020	7.6

In these experiments the wine-water interface was rather small. Assuming a cut at mid-interface the highest wine loss into the wastewater was only 7.6 L, and this was for a 480 m long wine movement. This is in contrast to the result reported by Deans (2006) where wine loss was 184 L for a mid-interface cut. The reason for this difference is likely to be that their experiment included an in-line plate heat exchanger and this device was responsible for significant spreading of the wine-water interface. Considerable interface spreading is something that is also likely to occur in other equipment, like centrifuges and filters, as they have a hold-up volume where the interface fluids will mix. Deans (2006) did not report the flow rate employed, but it may also have been relatively slow given the higher pressure drop associated with a plate heat exchanger. The influence of flow rate on interface size is hinted at in Table 6.1 where there is a lower diffusivity coefficient with a flow rate of 25.2 kL/hr compared with at 21.7 kL/hr, and a lower diffusivity coefficient with a flow rate of 22.0 kL/hr compared with at 18.0 kL/hr. In a pipe, the central core of fluid moves faster than fluid near the pipe wall, resulting in interface spreading. This effect is more pronounced

with lower flow rates (particularly if those flow rates are slow enough to result in laminar flow). With faster flow rates, there will be increased eddy mixing between the two fluids, however this is evidently a less significant influence. Faster pushes are therefore generally more desirable.

The effect of pipe length on transition profile and wine loss is considered Figure 6.3 using the average experimentally determined diffusivity coefficient. When the cut was performed at the mid-interface, wine loss ranged from just 1.0 L for a 10 m pipe length to 7.4 L with a 500 m pipe length. Therefore shorter movements are generally more desirable than longer movements.

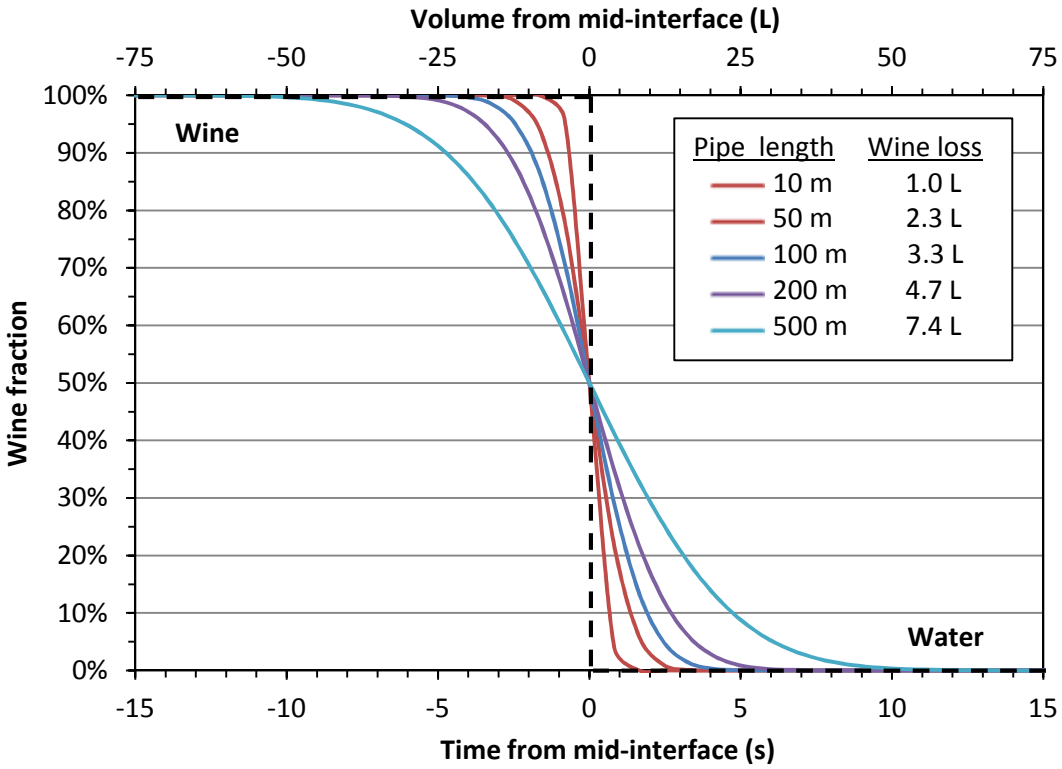


Figure 6.3 Transition and wine loss assuming a cut at mid-interface for different length 3" pipe movements (Flow rate: 20 kL/hr, Danckwerts D: 0.020)

Up until now, only a cut at mid-interface has been considered. In reality, it seems more likely that cuts will be made slightly after mid-interface as the cellar-hand would be unsure of the interface size and would want to be sure that it had passed. Table 6.2 illustrates the influence of an early or late cut on wine losses to wastewater and water addition to wine for a push flow rate of 20 kL/hr and a pipe length of 100 m. If the cellar-hand cut 3 seconds after mid-interface both at the start of the wine movement and at the end of the wine movement, the net effect would be the same volume in the destination tank, but 16.8 L of wine lost to wastewater and 16.8 L of water added to the wine. In modern wine production, there is also likely to be increased occasions where cuts are missed, as it is generally too expensive to use two people to perform most pushes/cuts, so often a single person has to both start the push at the source tank and perform the cut at the destination tank.

Table 6.2 Influence of an early or late cut on wine losses and water additions (3" pipe, Flow rate: 20 kL/hr, Danckwerts D: 0.020, Pipe length: 100 m)

Cut-time (s)[a]:	-30	-5	-3	-2	-1	0	1	2	3	5	30
Start of product movement (Wine push-through of water)											
Wine fraction at time:	0%	0%	2%	9%	25%	50%	75%	91%	98%	100 %	100 %
Wine lost to wastewater (L):	0.0	0.0	0.1	0.3	1.2	3.3	6.8	11.5	16.7	27.8	167
Water added to wine (L):	167	27.8	16.7	11.5	6.8	3.3	1.2	0.3	0.1	0.0	0.0
End of product movement (Water push-through of wine)											
Wine fraction at time:	100 %	100 %	98%	91%	75%	50%	25%	9%	2%	0%	0%
Wine lost to wastewater (L):	167	27.8	16.7	11.5	6.8	3.3	1.2	0.3	0.1	0.0	0.0
Water added to wine (L):	0.0	0.0	0.1	0.3	1.2	3.3	6.8	11.5	16.7	27.8	167

[a]Relative to mid-interface.

Instrumentation could aid cellar hands with cuts to avoid accidentally missing the transition by a large amount, however, there are practicalities that mean this is unlikely to be viable. Winemaking uses many different tanks, so any device would need to either be fitted to every tank or be light-weight and portable so that it could be easily attached. Furthermore, it would need to be left in-line during the entire wine movement, unless extra valves were used to create a bypass.

In summary, short movements are preferable to longer movements and faster pushes are preferable to slower pushes. Stopping flow while the wine-water interface is in the pipe is also undesirable as it is likely to cause increased interface mixing. Beyond this, practical winery opportunities for improving the way individual wine movements are performed seem rather limited. The larger opportunity is in altering wine production so as to reduce the number of wine movements that need to be performed. This has the potential to reduce water use, wine loss and also has the added benefit of reducing labour requirements.

6.3.2 AVERAGE NUMBER OF MOVEMENTS

The average number of post-fermentation wine movements for red and white wines using the simple estimate and the size-weighted estimate are presented in Figure 6.4 and Figure 6.5, respectively. Using the simple estimate, on average there were 10.6 movements for red wines and 8.6 movements for white wines. Using the size-weighted estimate, there were on average 25.6 movements for red wines and 16.9 movements for white wines.

Pump movements were the dominant movement type (50% or 60%, on a simple or size-weighted basis, respectively). The remainder involved processing equipment, mainly related to clarification. The operations

involving processing equipment are likely to have a disproportionately large influence on wine losses to wastewater as a consequence of larger wine-water interface sizes.

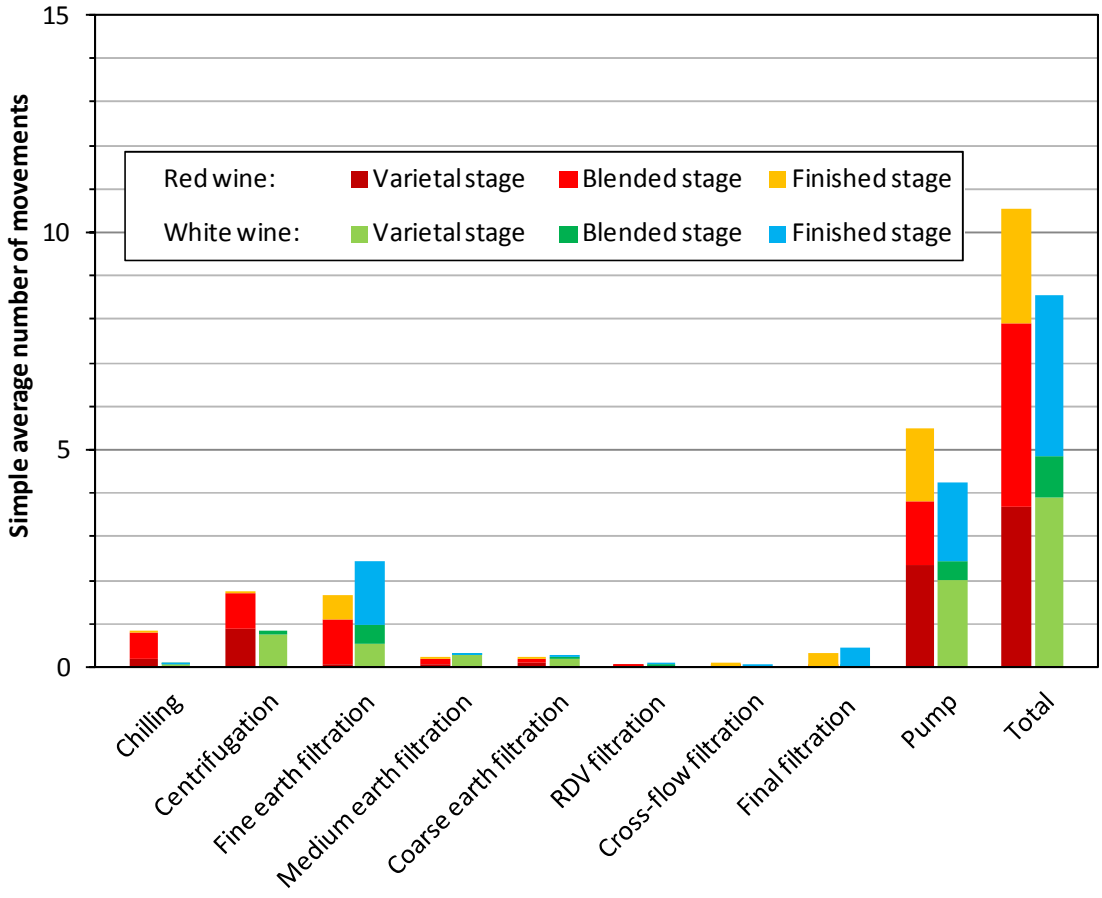


Figure 6.4 Simple average number of movements during wine lifetime (separated by operation type and production stage, 2009 vintage wine)

Excluding final filtration, red wines were clarified by centrifugation or filtration an average of 3.9 times on a simple estimate basis or 7.7 times on a size-weighted basis. Similarly white wines were clarified by centrifugation or filtration an average of 3.8 times on a simple estimate basis or 5.5 times on a size-weighted basis. This large number of clarifications is worthy of further investigation by the case study winery. There may be opportunities to reduce this number by coupling additions and therefore clarifications steps, relaxing requirements for clarity during storage, or substituting earth filtration systems with cross-flow filtration systems that may be able to achieve the same level of clarification in fewer passes.

There were significantly more movements during the average red wine lifetime than during the average white wine lifetime. This is partially explained by malolactic fermentation being more commonly practiced with red wine and the final filtration equipment/packaging centre being located a considerable distance from the main red wine production zone and therefore typically requiring an additional intermediate pump movement prior to final filtration.

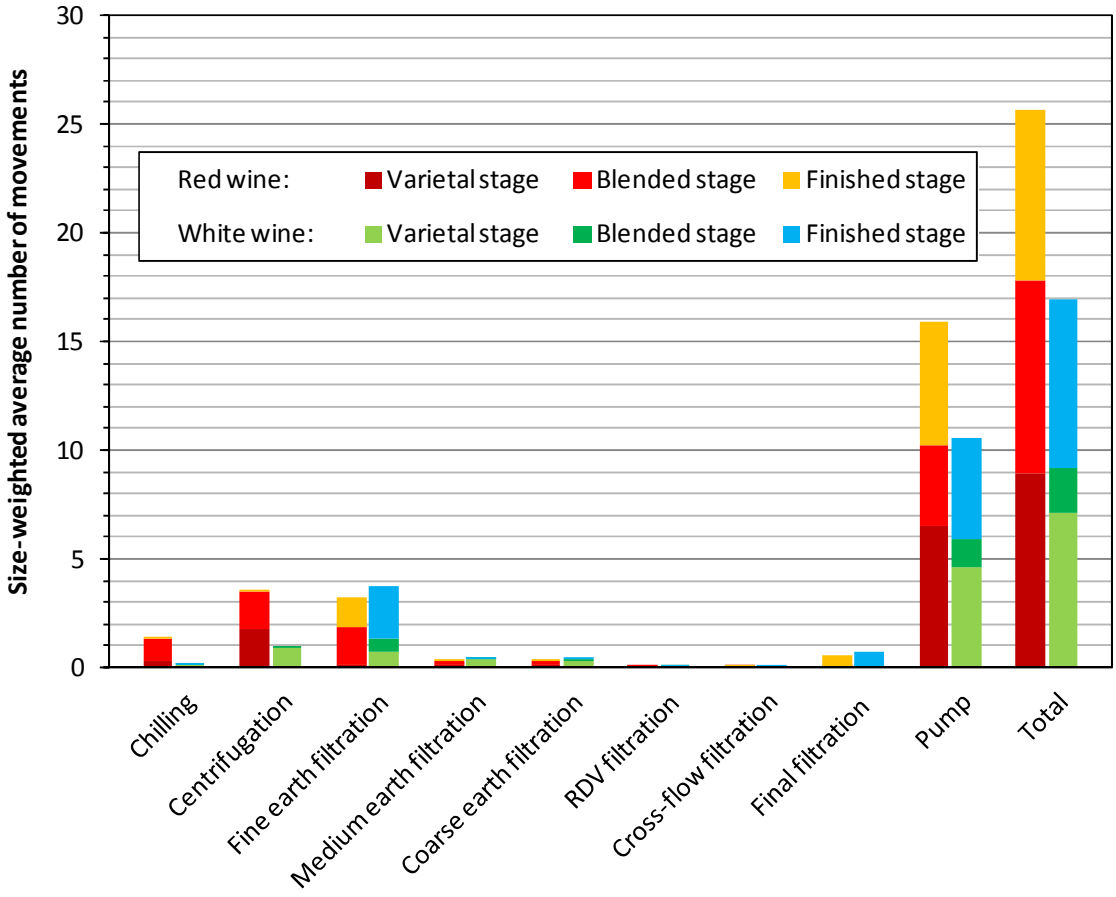


Figure 6.5 Size-weighted average number of movements during wine lifetime (separated by operation type and production stage, 2009 vintage wine)

For the specific red wine blend the number of wine movements when directly following a product from tank to tank ranged from 10 to 22, while it ranged from 8 to 24 for the specific white blend. It should be noted that in the estimation of the average number of wine movements (Figure 6.4 and Figure 6.5), movements that would often not be included when directly following a product from tank to tank have been included, e.g. moving small leftover volumes of wine, topping-up tanks, etc.

The operations flow sheets presented Figure 6.6 and Figure 6.7 demonstrate the complexity of interactions between different tanks and products at this winery. Broadly speaking, after fermentation there were a large number of tanks/wines that over time fan inwards towards a blend and then fan outwards to different packaging formats or destinations. This is also generally consistent with Figure 6.4 and Figure 6.5 where are significant numbers of movements associated with the Varietal and Finished production stages.

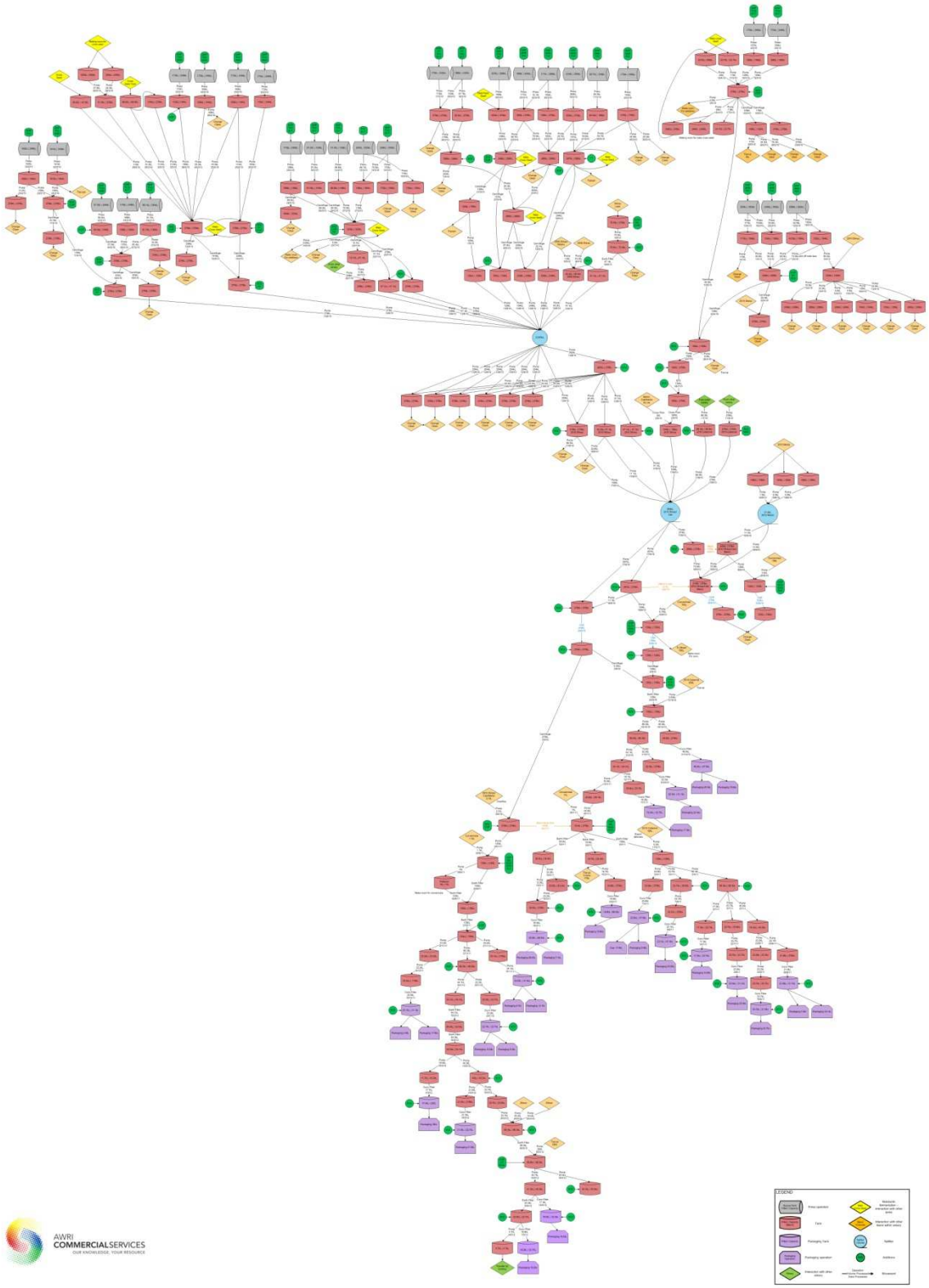


Figure 6.6 Operations flow sheet for specific red wine blend



Figure 6.7 Operations flow sheet for specific white wine blend

6.3.3 NUMBER OF MOVEMENTS PER JOB

The number of movements per job is presented in Figure 6.8 for each operation type. Grouping movements into jobs by operations note resulted in higher values than if they were grouped by being from the same tank on the same day. This may be because multiple tanks could be included on the same operations note (e.g. centrifuge tanks 1-5 into tanks 6-10). Overall there were 1.9 movements per job if they were grouped by operations note.

Generally speaking, increased grouping of movements using common equipment and nearby tanks will result in increased efficiencies and reduced changeover costs. There can be other advantages as well. For example, gross clarification steps like centrifugation have the potential to create an ullage when using source and destination tanks of the same capacity, as a consequence of the solids being removed. This influence is minimised if multiple tanks of the same product are clarified sequentially as each destination tank can be topped with wine from the next source tank.

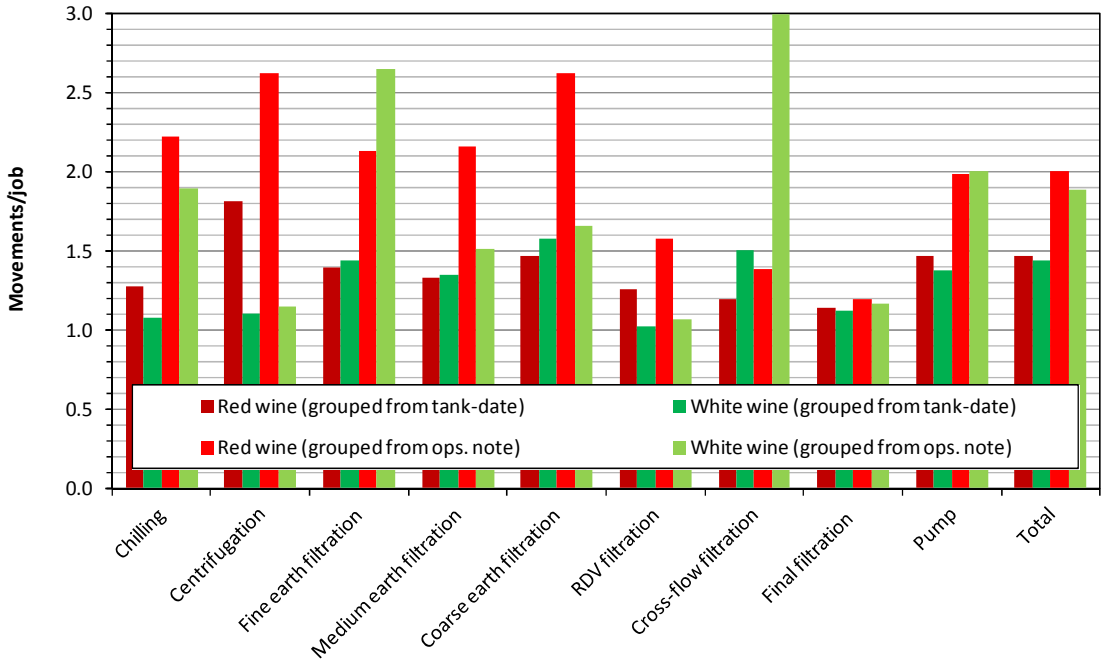


Figure 6.8 Number of movements per job (movements grouped into jobs either based on being from the same tank on the same day or from being on the same operations note, 2009 vintage wine)

6.3.4 PUMP MOVEMENT SIZE AND EXPORT LEFTOVERS

Pump movements were the dominant movement type. The size distribution of pump movements on a number and volume basis are presented in Figure 6.9. It is apparent that for both red and white wines the largest volume of wine is pumped in 250-300 kL lots, but by number, more than 60% of pump movements were in volumes of less than 50 kL. This 0-50 kL category is further sub-divided in Figure 6.9. 24% of red wine pump movements and 12% of white wine pump movements were in volumes less than 2 kL. This was of interest because generally there will be some fixed costs (labour, water, wastewater) associated with starting and finishing a wine movement and it is therefore more efficient to wherever possible perform movements in large volumes. This result was investigated through discussions with winery staff and studying the number of 0-2 kL pump movements coming from or going to tanks in different sectors of the winery (Figure 6.10).

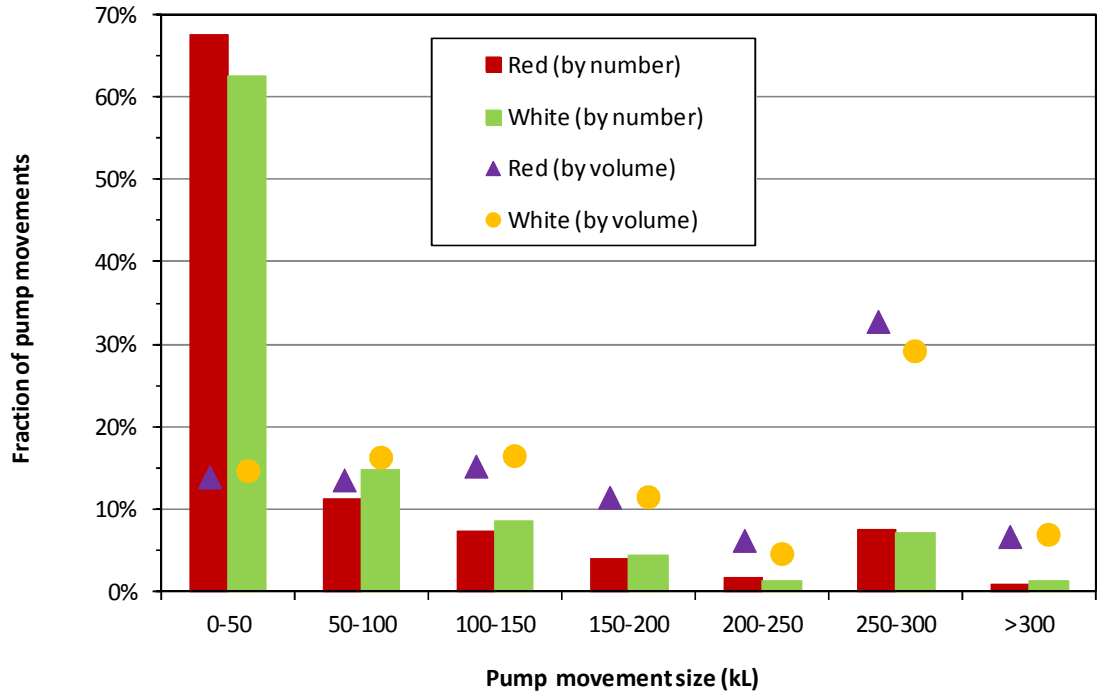


Figure 6.9 Distribution of pump movements by size (2009-2011, number and volume basis)

On average there were fourteen 0-2 kL pump movements from each tank in winery sector Exp-140-280x20 each year (Figure 6.11). Tanks in this sector were used to load bulk export containers. The large number of small movements from these tanks was associated with managing leftovers. Shipping is expensive so the bulk export containers need to be full. When wine was pumped to these export loading tanks, a little bit extra would be moved, as flow meters/tank dips were not sufficiently accurate to move the exact amount. On completion of loading of the export containers, the leftovers from the tank would then need to be moved.

These 0-2 kL volumes are typically too small to make it practical to pump them through the general winery pipe network. Therefore portable 1 kL pallecons or 2-6 kL stainless steel tanks are used. The pump movement into a portable tank from a fixed tank is fairly similar to that between two fixed tanks, except that the distance between the source tank and the portable tank is usually much shorter. The subsequent pump movement from the portable tank to a fixed winery tank can be somewhat different. If the portable tank can be moved close enough to the destination tank, a progressing cavity pump may be used to move the wine out the top of the portable tank into the racking valve of the destination tank without even requiring a water push (wine can be pushed by air with these pumps). These movements are therefore likely to use less water and produce less wastewater than movements between two fixed tanks. There is however a labour requirement in performing operations involving portable tanks: moving the wine into the portable tank, transporting that portable tank, and then moving the wine out of the portable tank. When a small volume of wine is separated in this manner ideally a similar type and grade of product needs to be found that it can be blended back in with. The ease of doing this will depend on the time of year and how much blending is being performed at that time. There is always a risk with small quantities of wine that they may be forgotten about or not be bothered with at all and just drained to wastewater.

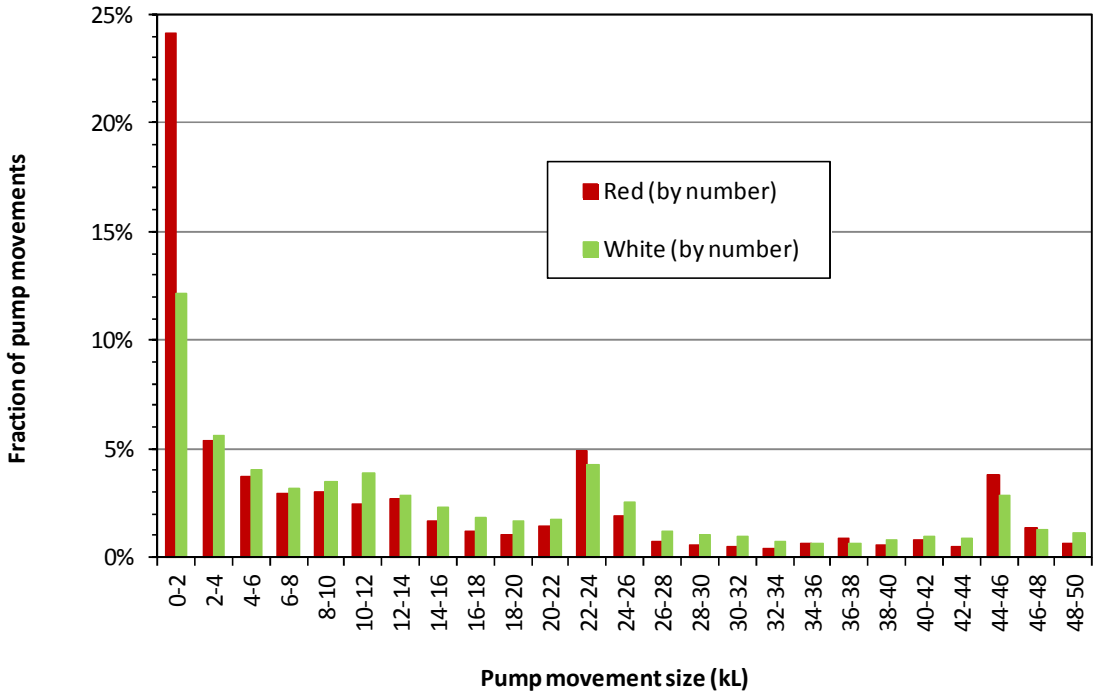


Figure 6.10 Distribution of pump movements by size (2009-2011, number basis, 0-50 kL)

There does not appear to be an immediate solution to the issue of managing export leftovers, as it is unlikely to be possible to improve the accuracy of volume measurement. However, now that the magnitude of this issue has been highlighted, perhaps different strategies to deal with these leftovers can be investigated. This may also be a problem in many other wineries given that bulk wine exports now make up more than 50% of Australian wine exports (Wine Australia 2012).

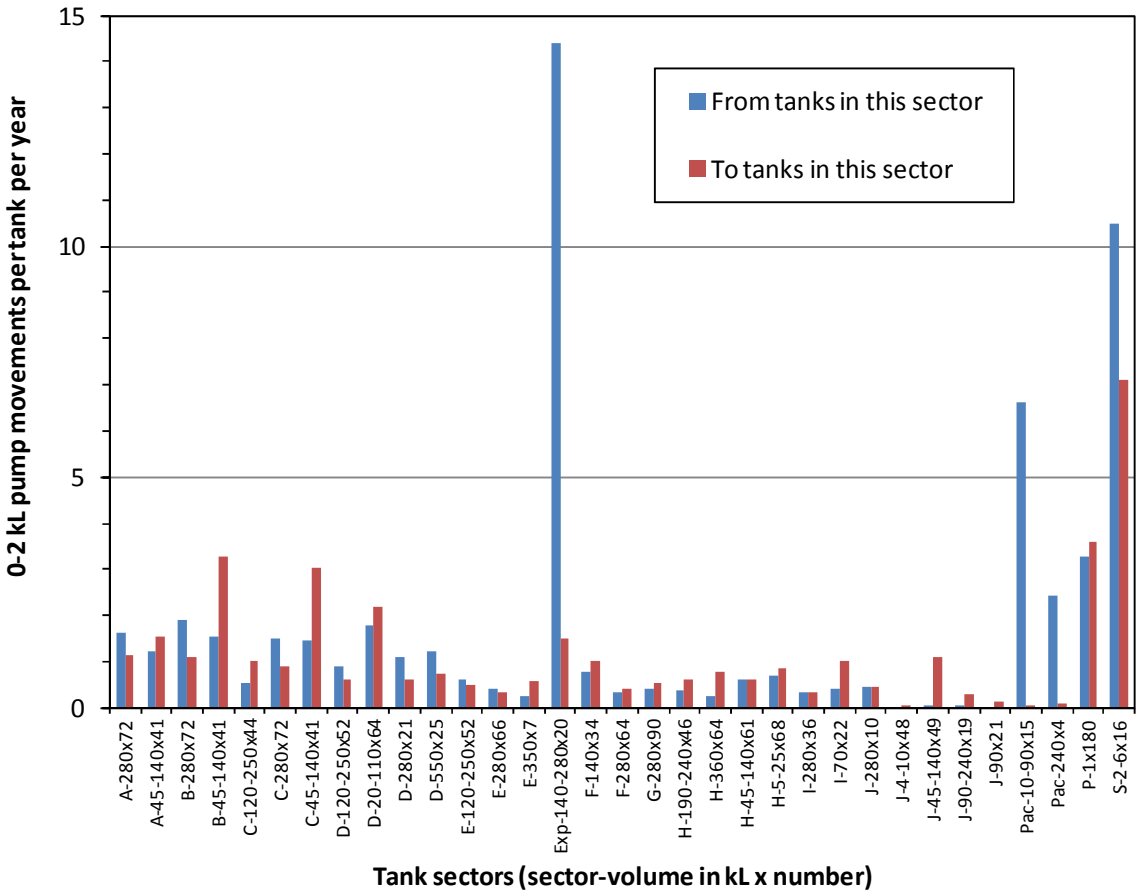


Figure 6.11 Pump movements per tank per year from or to tanks in different winery sectors (2009-2011, 0-2 kL only)

6.3.5 PUMP MOVEMENT STAGE AND PACKAGAING-RELATED BREAKDOWNS

In Section 6.3.4, movements were separated between three production stages. On a size-weighted average basis there were 5.7 red wine pump movements and 4.7 white wine pump movements during the Finished production stage. This was a surprisingly large number given that most core processing operations were performed during earlier production stages.

Packaging-related breakdowns and the associated ullage prevention are likely to be one reason for this. This can be seen in Figure 6.12 where towards the bottom of the operation flow sheets the streams fan out as different portions of wine are taken for packaging and the remaining wine has to repeatedly be divided between other tanks to prevent ullages. An excerpt from is provided in Figure 6.12 illustrating this stage of the process.

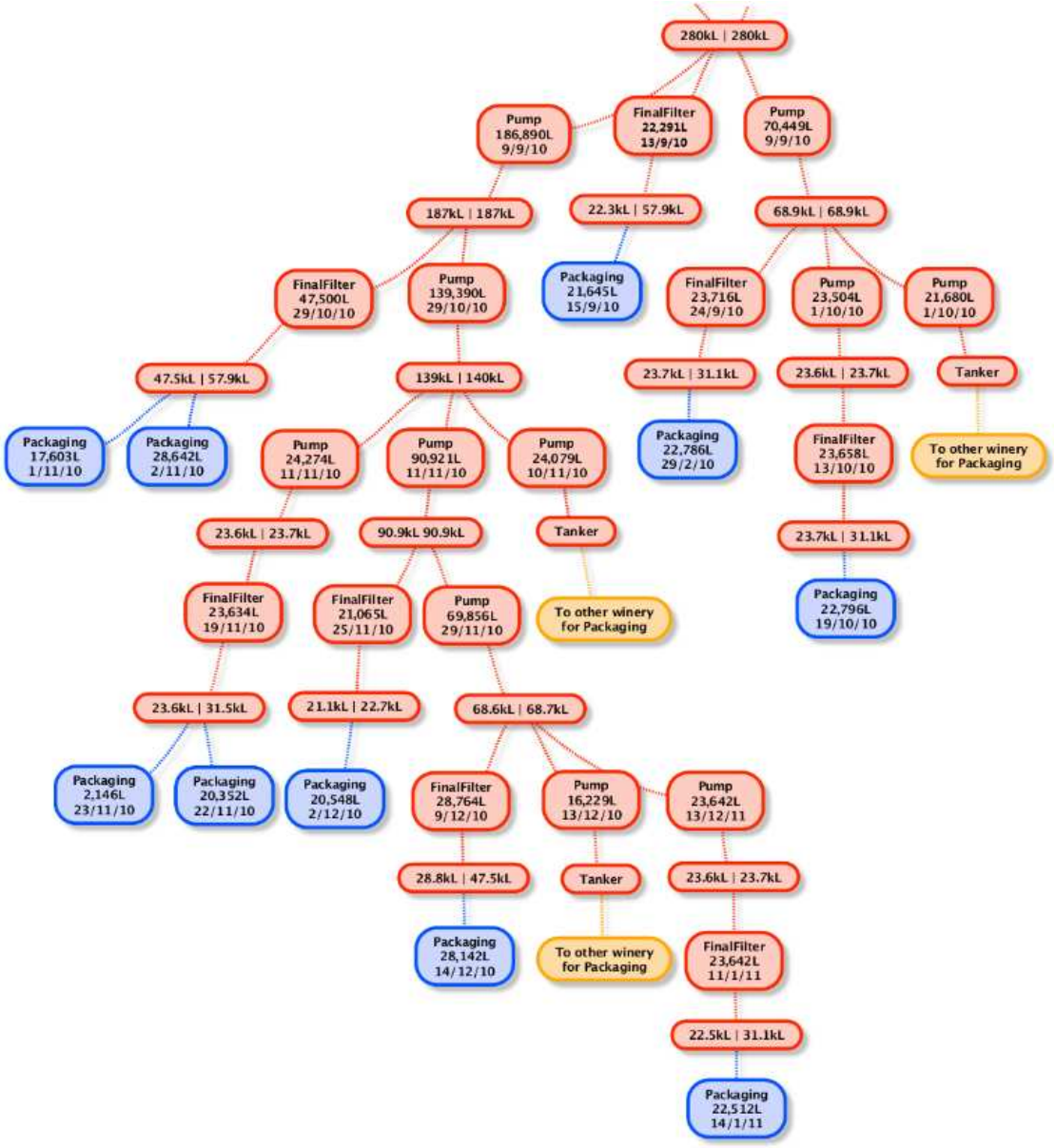


Figure 6.12 Breakdowns associated with packaging for the specific white wine product

Winemakers at the winery were questioned about the effectiveness of existing inert gas diffuser systems in place for ullage management. They had varying opinions but like winemakers at many other wineries, the overall sentiment was that nothing was as good for maintaining wine quality as keeping tanks full. There are really three reasons to prevent ullages: making best use of available tank capacity, preventing wine quality degradation and preventing tank headspace corrosion issues in tanks made from some grades of stainless steel. Making best use of tank capacity is likely to be of considerable importance during vintage, but later in the year the negative quality implications of ullages are likely to be the major driver. There may be opportunities to reduce wine movements if improved ullage management technologies were available that allowed wine to be kept in partially filled tanks without risk to wine quality.

The size of packaging runs at the winery is reported in Figure 6.13, both on a number and volume basis. This is an estimate based on information available in the LIP database. Packaging runs that cross shifts were recorded in the database as separate entries. In an effort to eliminate this artefact, entries for a given blend class were grouped together into single larger volume packaging runs if they were on the same or consecutive days. By number, packaging runs were dominated by small volumes comparative to most tanks at the winery. This corresponds generally with the observed large number of breakdowns observed for

Finished wine. It is also expected that the small packaging runs would be relatively expensive from a packaging perspective because of costs associated with changeovers.

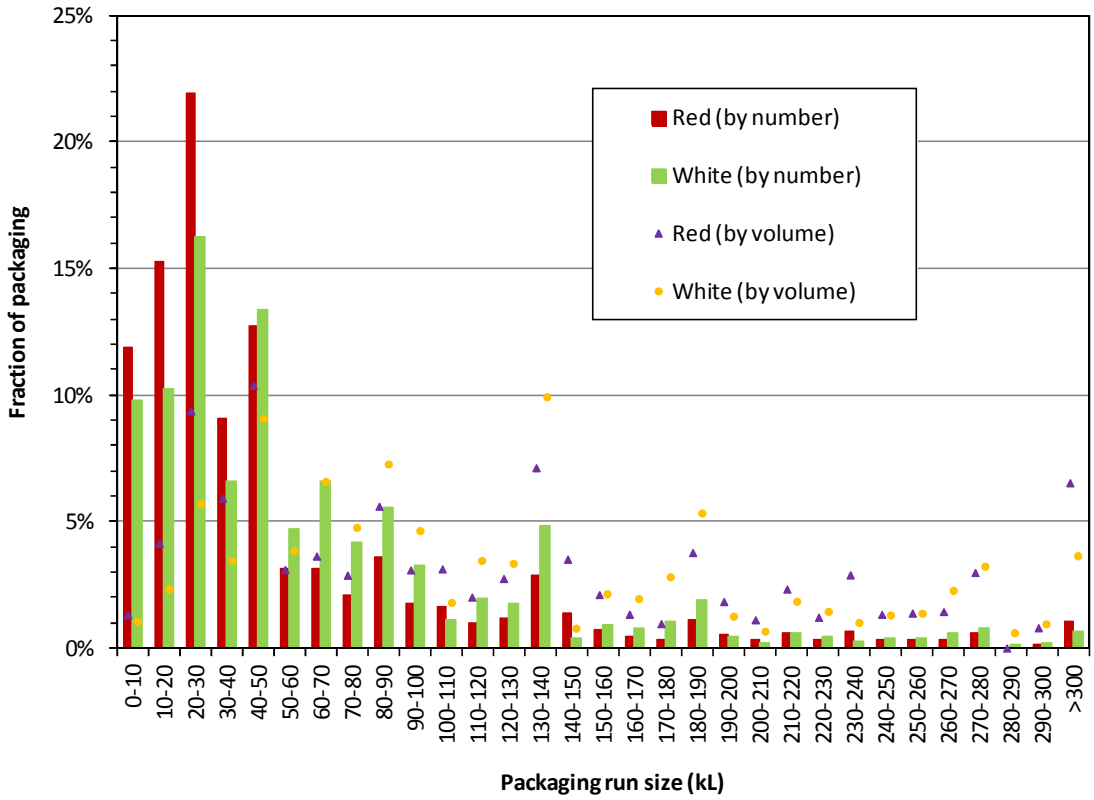


Figure 6.13 Distribution of packaging runs by size (2009-2011, number and volume basis)

6.3.6 WINERY ZONING

The number of movements going to and coming from tanks in different tank sectors per year is presented in Figure 6.14. The fraction of movements into destination tanks in a given sector from different sectors is shown in Figure 6.14. The key observation from Figure 6.15 is that most tank sectors had their greatest interaction with themselves, but even this was typically less than 20%, with maximum values of approximately 40% for the sectors containing the largest winery tanks (360 kL or 550 kL tanks) or a very large number of 280 kL tanks. There were a small number of exceptions. 92% of the movements into the portable 2-6 kL stainless steel tanks (S-2-6x16) were leftovers from the export loading tanks (Exp-140-280x20). Another exception was that 30% of the movements into the winery's largest 550 kL tanks were from the splitter/blender devices.

Theoretically in an ideal simple linear facility it would be expected that each tank sector would have a major connectivity with one other sector, corresponding with the next step in the process. This was not observed. The largest interaction for most tank sectors was with themself, which may simply mean that the next step in the process was within the same tank sector. However, as already mentioned even the internal sector interactions were typically lower than 20%. This may indicate an opportunity for improved zoning for wine storage and operations at this winery. It must be cautioned that this is a very simple macro analysis based on wine movement information available in the LIP database, and relatively arbitrarily assigned tank sectors – interactions could be between the edge of one sector and the edge of the next sector. Wine production has some peculiarities that are not found in the production processes for many manufactured goods, such as a need to hold large inventories given that raw materials are only available for a short period of time. Nevertheless, it is likely that there are opportunities for improved production zoning in this and other large wineries that may result in both fewer and shorter product movements.

Paths taken by the specific red and white wine blends are mapped in Figure 6.16 to Figure 6.20. These demonstrate the complex path that wine can take at the winery. The number of movements and the distance travelled 'as the crow flies' are reported. The true distances travelled are likely to be considerably longer as the available pipe work will be much more tortuous. There were large variations in the number of movements and the distance travelled for the same blend. An interesting feature of these maps is the path that wine often takes to access fixed processing equipment. In this and many other wineries there are areas with centrifuges, filtration equipment and heat exchangers, to which product is passed to and then back to a destination tank. This is responsible for some of the jagged back and forth arrows to zones in between the blocks in Figure 6.16 to Figure 6.20.

This winery was relatively well separated between white wine and red wine production zones but there were still a few facilities/equipment in the white wine zone that were used for red wine production. Packaging was in the white wine production zone. Red wines were usually moved to an intermediate tank in the white wine production zone prior to final filtration into the packaging tanks. The topic of whether this intermediate movement could be eliminated and the wine filtered directly in the same movement into the packaging tanks was discussed with winery staff. Problems with doing this directly included that there were limited pipes between the red and white production zones and the filtration process is much slower than a normal pump movement. Therefore it is easier to have an intermediate pump movement to a tank closer to the filtration equipment. Having the source tank closer to the filtration equipment also makes managing filtration easier.

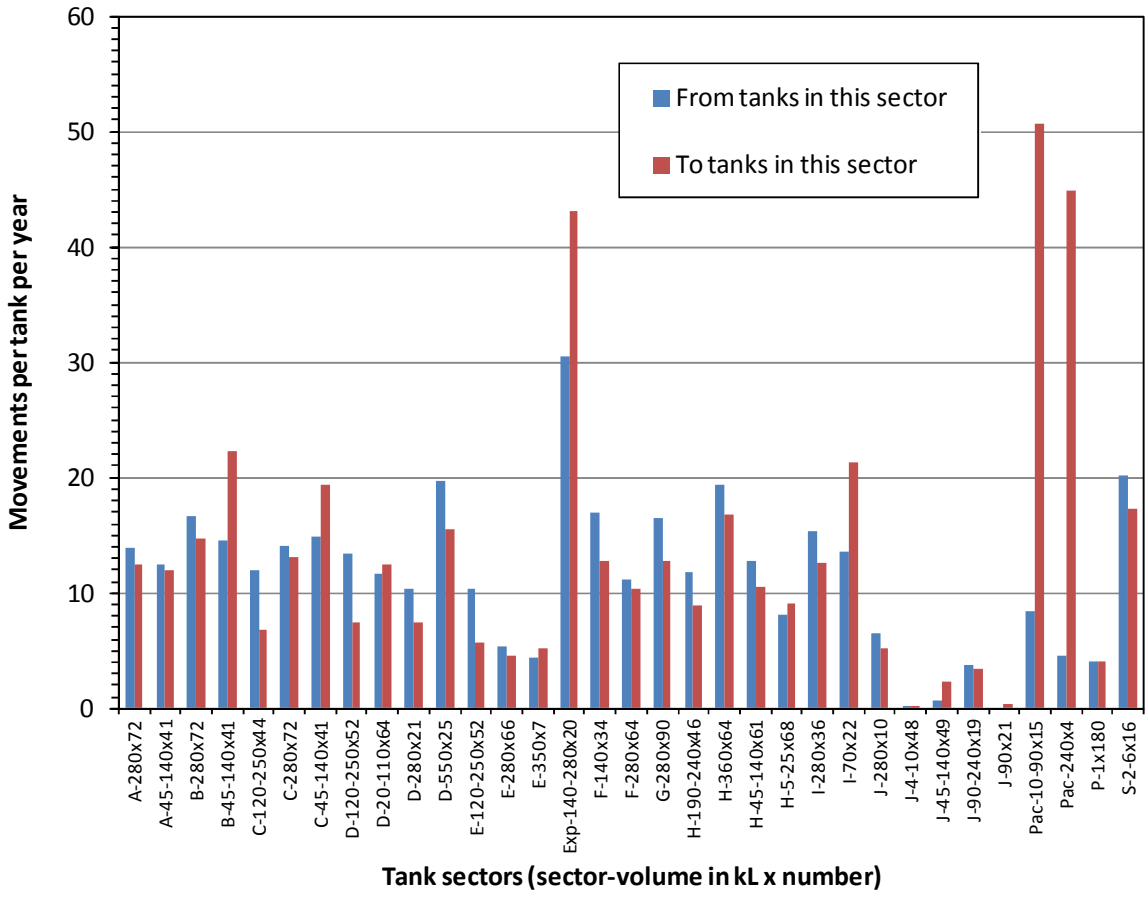


Figure 6.14 Movements per tank per year from or to tanks in different winery sectors (2009-2011)

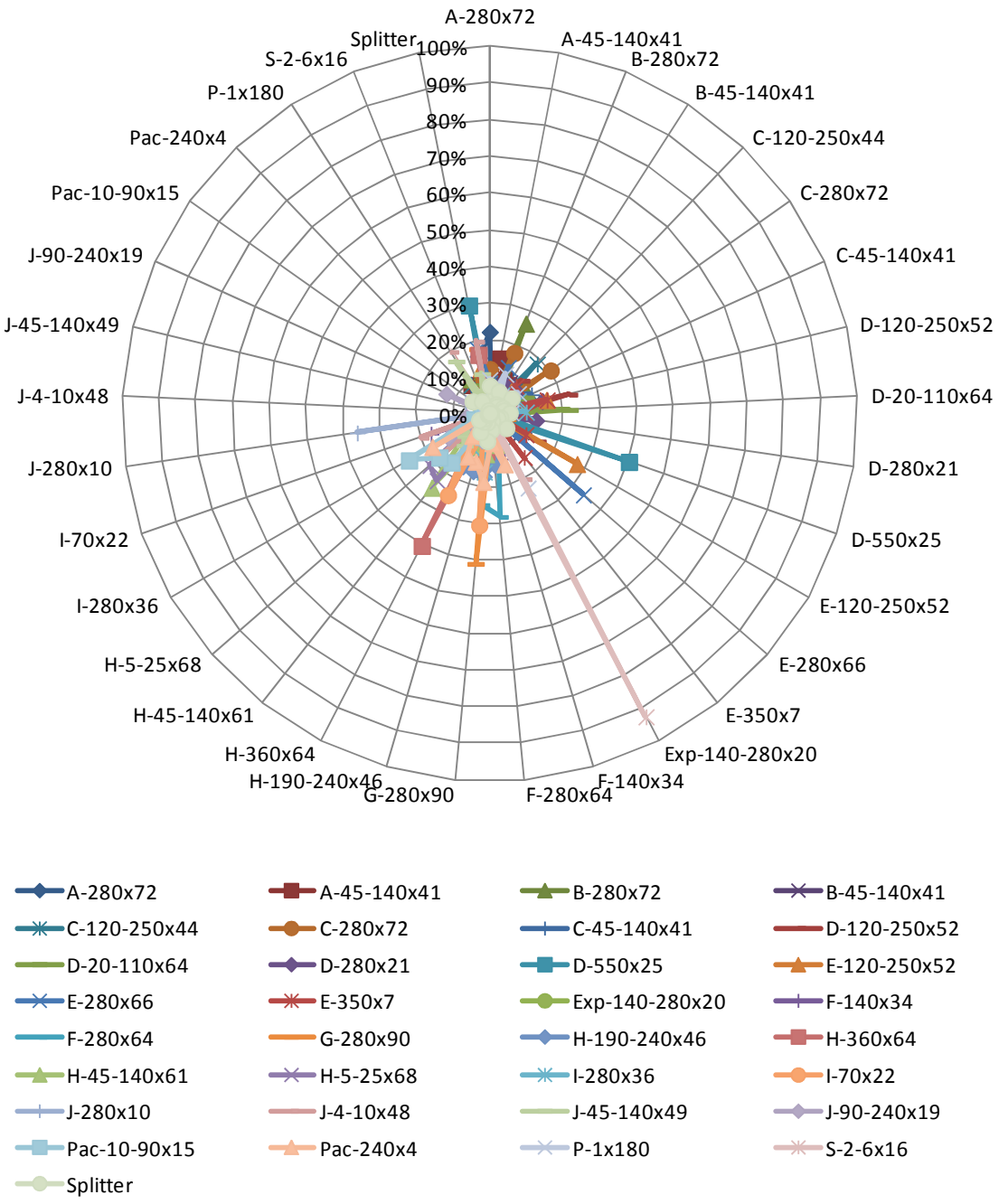


Figure 6.15 Fraction of total movements into destination tank sectors (shown in legend) from given source tank sectors (shown around plot) for 2009-2011.

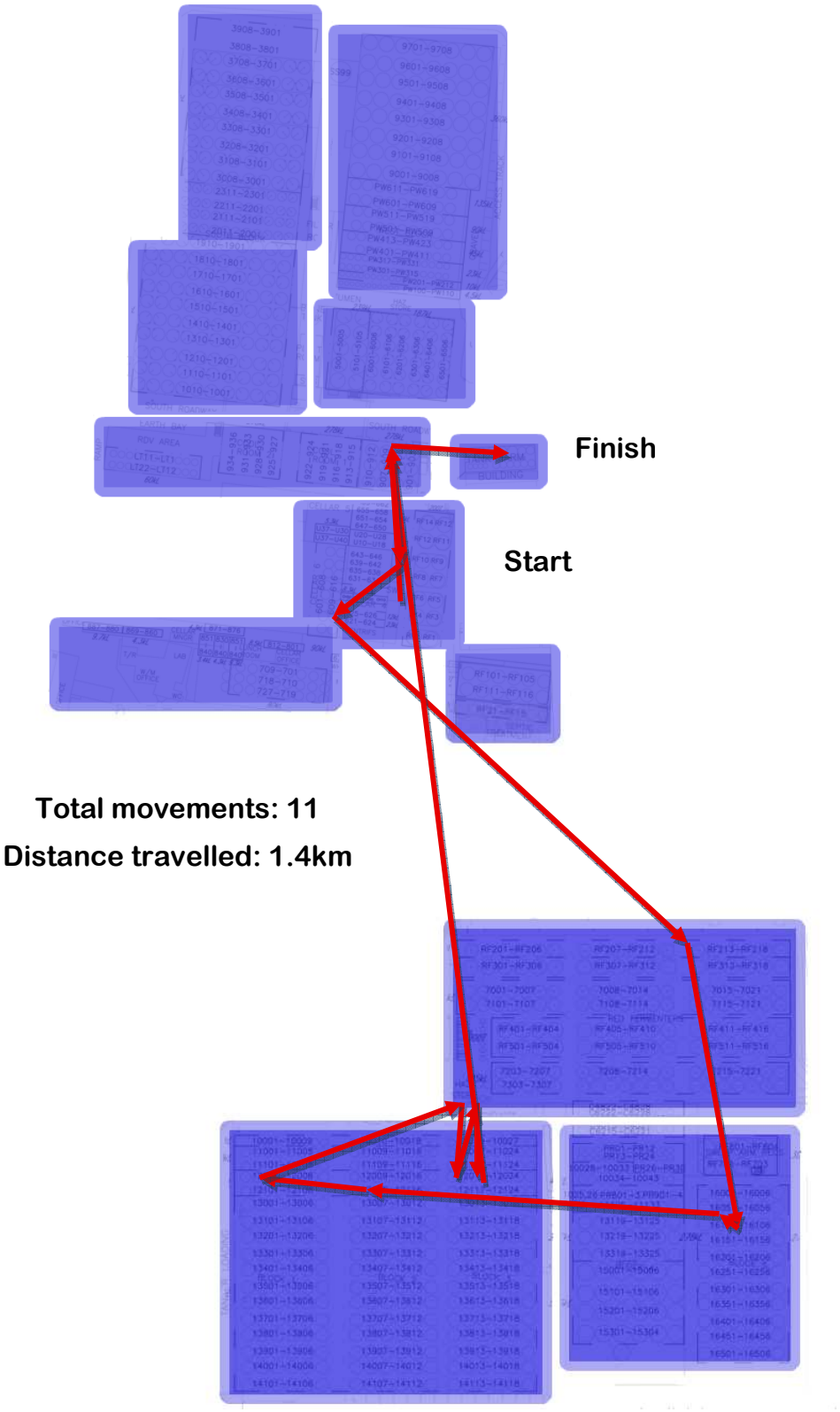


Figure 6.16 Product flow map for specific red wine blend

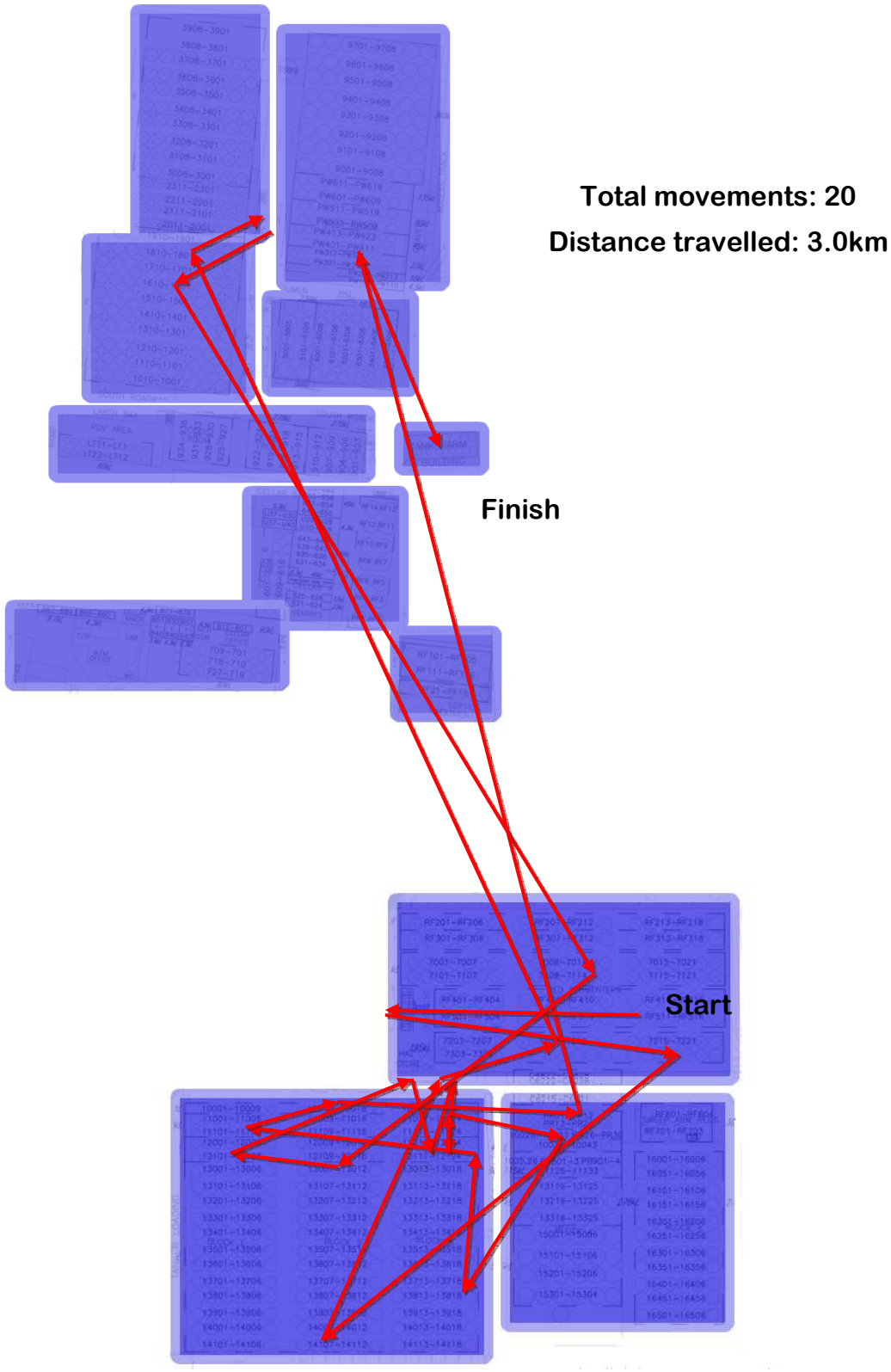


Figure 6.17 Product flow map for specific red wine blend

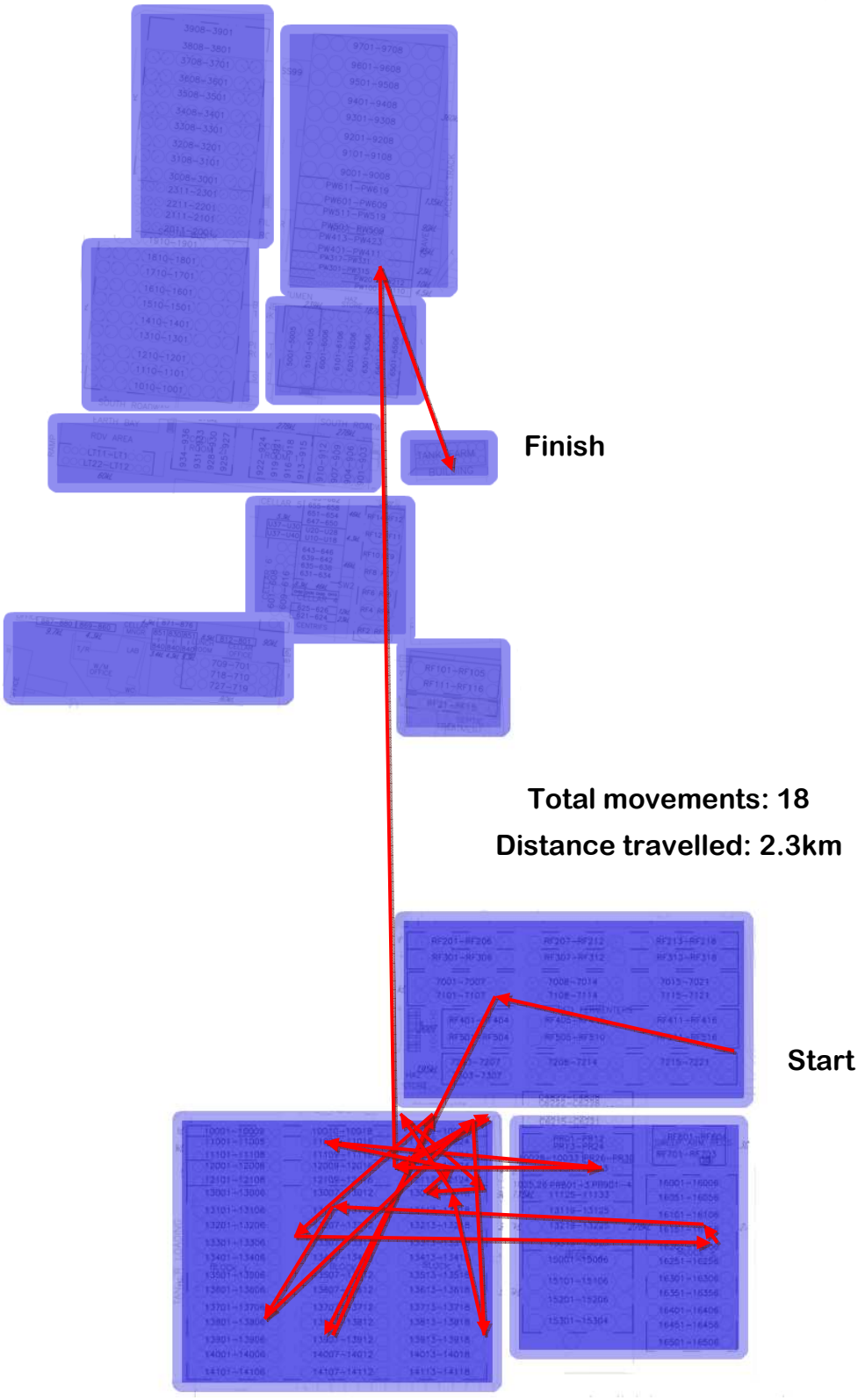


Figure 6.18 Product flow map for specific red wine blend

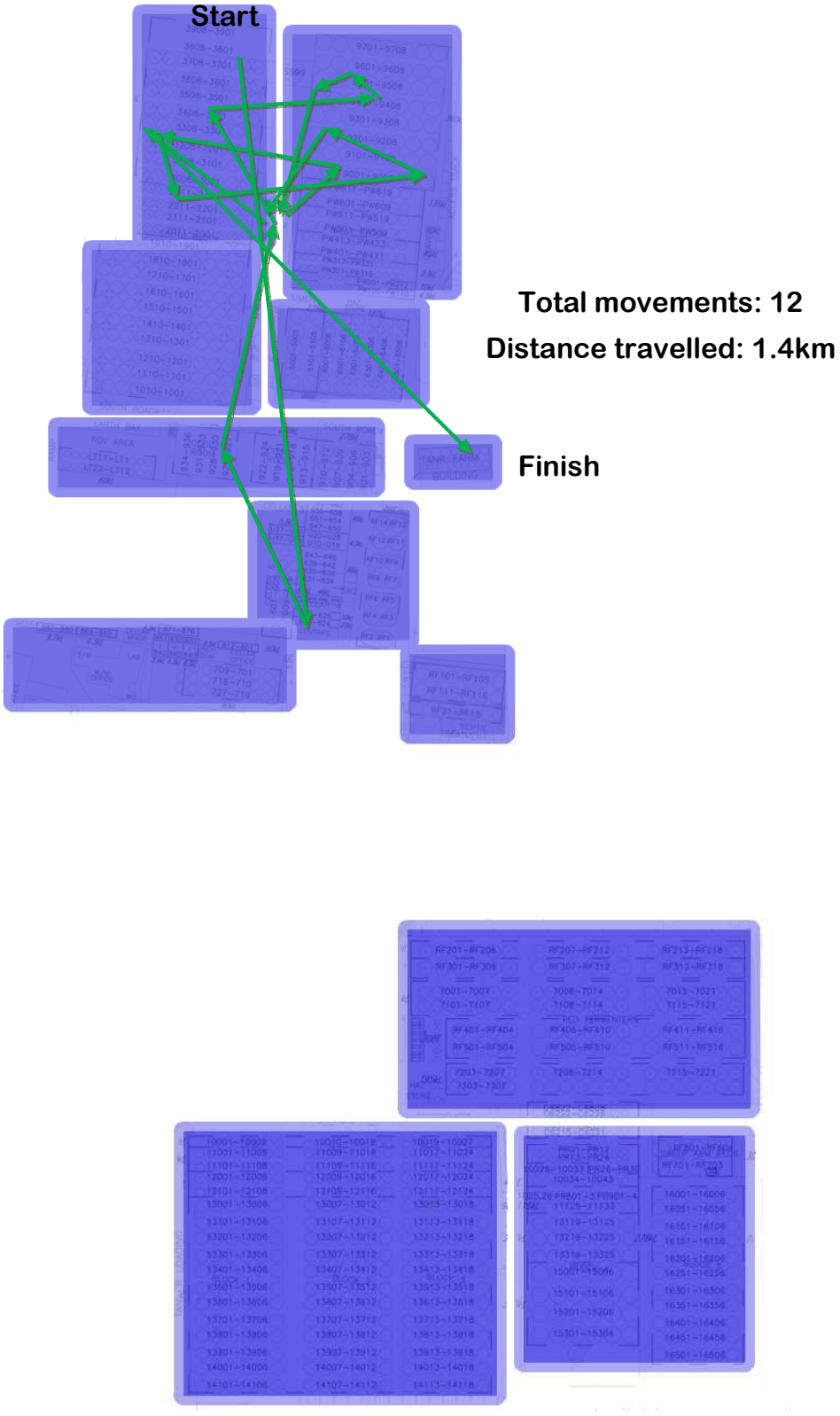


Figure 6.19 Product flow map for specific white wine blend

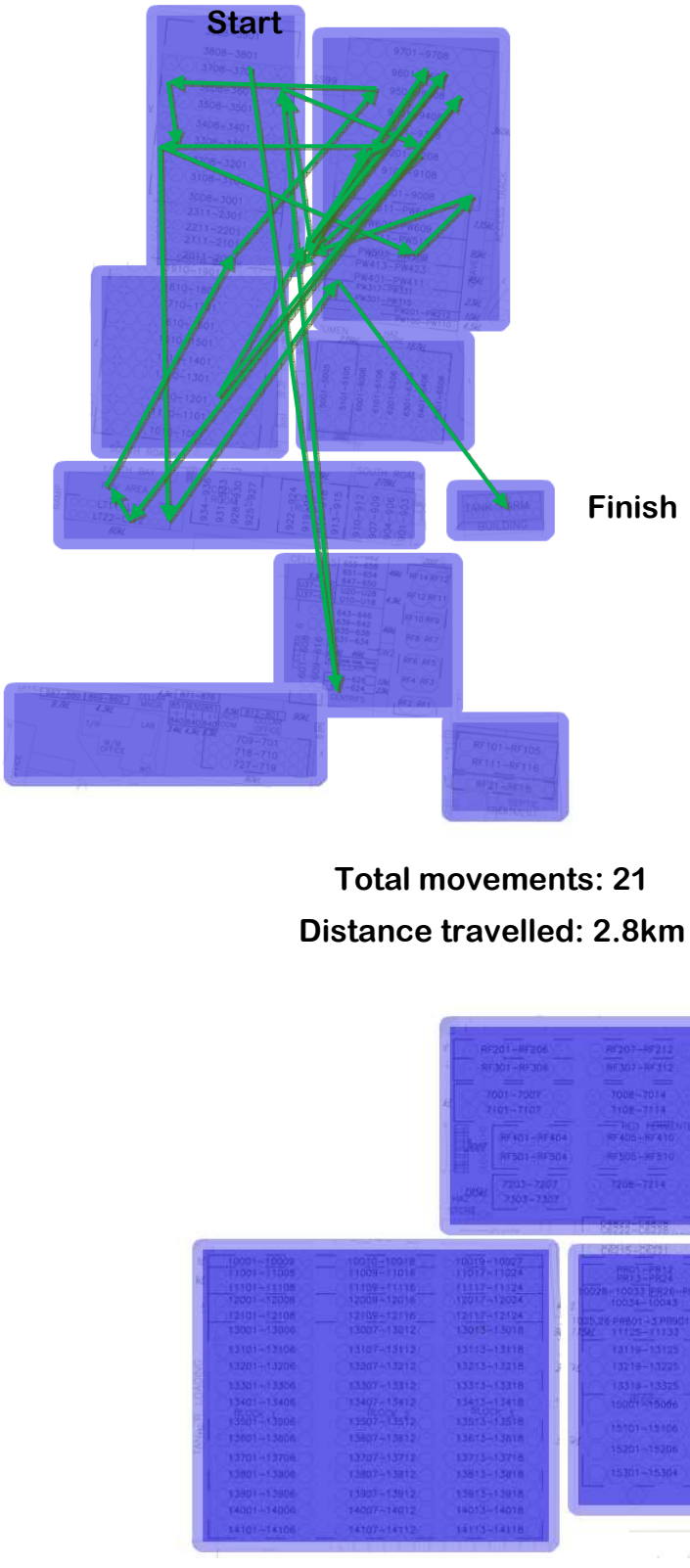


Figure 6.20 Product flow map for specific white wine blend

6.3.7 BLENDING WINE RECOVERED FROM LEES

In the specific white wine followed there was an interesting example of blending relating to the reincorporation of wine recovered from bentonites lees (Figure 6.21). Initially there had been 4 full tanks of

the same wine (3 × 356 kL and 1 × 280 kL). To incorporate wine recovered from bentonite lees into these tanks, a corresponding amount of wine was removed from each tank into Tank A. It would have seemed simpler to just move all 68.3 kL of recovered wine in a single movement to Tank A. The reason that the more complex strategy was chosen, seems likely to have been to ensure that no individual tank would contain too high a percentage of the potentially lower quality wine that had been recovered from bentonite lees. The strategy adopted was probably optimal in the circumstances but highlights the potentially large number of movements associated with reincorporating small quantities of lower quality wine recovered from lees.

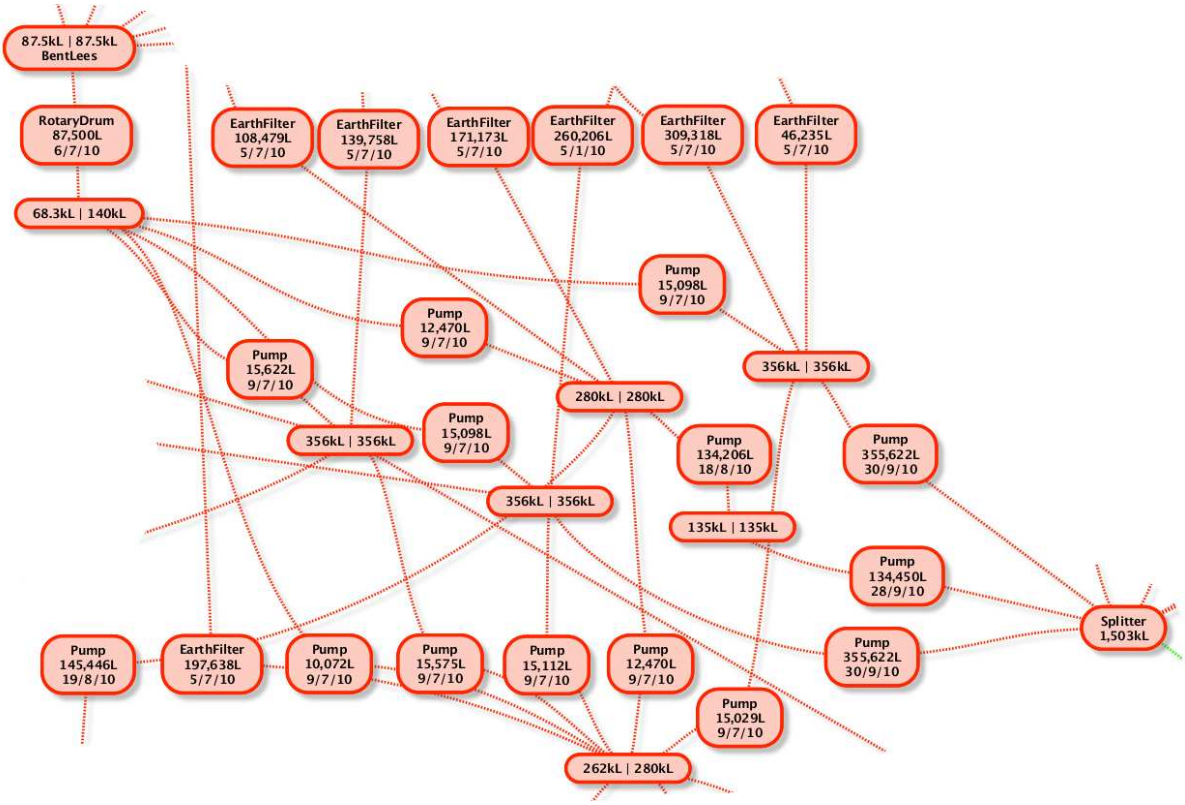


Figure 6.21 Removing wine from tanks to accommodate wine recovered from lees

6.3.8 WINE LOSSES TO WASTEWATER

The winery collected measurements of the alcohol concentration in the winery wastewater and of wastewater volume. Based on these measurements for 2011, an average wine alcohol concentration of 13%, and either the volume of wine from the grape crush or the volume of wine exiting the winery in 2011, the potential wine lost to wastewater was estimated to be 4-5%. It should be noted that a range of operations at the winery will contribute to this, and some of the potential wine may never have been viable as saleable wine - such as fermented grape skins or low quality wine lees flushed to wastewater.

In wineries, tallies of product losses are sometimes kept based on net dips in the source and destination tanks across the winery. This will give a very different result to that reported above, partly as a consequence of some wine losses being offset by water addition.

6.3.9 PRODUCTION RULES AND OPTIMISATION SOFTWARE

It is apparent from the previous sections that this winery is complex with many different interacting products. It is therefore difficult to find simple solutions to optimise the process. However, the potential gains are large.

At least one company (SolveIT software) has sold scheduling optimisation software into the wine industry. In an article presented at the 14th Australian Wine Industry Technical Conference Michalewicz et al. (2011) suggested that through the use of their Tank Farm Optimiser they are able to reduce overall movements by 5%-10%, reduce labour (particularly overtime) requirements as a result of simpler and clustered movements, and free up tank capacity. Their system generates optimised tank farm plans and production schedules given the physical constraints of the tank farm, incoming grapes, juice, wine, packaging plans and other user defined business rules. The user is able to make manual changes, set the rules and constraints and re-optimise after making changes.

Software of this nature is not really off the shelf and requires significant configuration for each facility. Therefore it is expensive, anecdotally costing $1.5 -$2 million for a large winery installation. This is likely to make it difficult to justify for many wineries.

In wineries, decision-making is often quite distributed with a number of different winemakers having significant control over different areas and cellar-hands sometimes having power to choose which tanks they use themselves. Optimisation software is likely to require a cultural change in many wineries from distributed to centralised decision-making. This cultural change is actually likely to be beneficial to process efficiency if it can be achieved. It is likely that some of the benefits would actually be achieved from that cultural change even without the software.

A possible approach to improvement without software purchase is to extensively engage all winery staff on a process optimisation project. Winemakers, scheduling and cellar staff probably already has ideas about what is efficient and what isn't. There are likely rules that particular staff already uses, and it is worthwhile formalising these so it is transparent and everybody follows the same system. After initial consultations a project manager could propose a draft scheme. This may include a winery tank map annotated with areas that are to be preferentially used for specific purposes, accompanied by a list of other production rules. This could be revised through further stages of consultation. While it is difficult to make time for things like this in a production environment, it could be a worthwhile exercise if performed in a well structured and inclusive manner.

6.3.10 SUPPLY CHAIN COLLABORATION AND FORECASTING

The opportunity to optimise the in-winery process is influenced by a knowledge of the grapes (and juice and wine) that will enter the winery and the wine that is going to leave the winery. Collaboration through the supply chain is obviously critical. The longer time people have to prepare and the better suited production is to the production facility the more efficient operations will be.

It is apparent from the distribution of packaging run sizes and the breakdown of tanks to facilitate packaging that this winery is often working with much smaller batches than it was originally designed around, creating additional product movements and work. This is probably a common theme in the wine industry as wine companies and their customers look to reduce packaged wine inventories. If longer term forecasting can be improved through working with customers, it may be possible to group orders from different customers into fewer and larger packaging runs. The same principle applies to reducing movements of export leftovers. If more export containers can be loaded in a single run there will be fewer parcels of leftovers.

The issues with packaging run size were already understood by staff at the winery but it is obviously a very complex issue involving many internal staff and customers. It is worthwhile pursuing though.

6.4 Conclusion and recommendations

- Wine movements involving processing equipment (e.g. a centrifuge, filter, plate heat exchanger, etc.) are likely to result in larger wine losses to wastewater and dilution of wine with water than those not involving processing equipment.

- Wine losses and dilution will generally be smaller for shorter movements.
- Wine losses and dilution will generally be smaller with higher push flow rates.
- The practical opportunities to improve the manner in which an individual wine movement is performed are judged to be rather limited. The biggest improvement opportunity is in working to reduce the absolute number of movements.
- At the case study winery, using a simple estimate, there were on average 10.6 movements for red wines and 8.6 movements for white wines. Using a size-weighted estimate, there were on average 25.6 movements for red wines and 16.9 movements for white wines.
- Excluding final filtration, red wines were clarified by centrifugation or filtration an average of 3.9 times on a simple estimate basis or 7.7 times on a size-weighted basis. Similarly white wines were clarified by centrifugation or filtration an average of 3.8 times on a simple estimate basis or 5.5 times on a size-weighted basis. This large number of clarifications is worthy of further investigation by the case study winery. There may be opportunities to reduce this number by coupling additions and therefore clarifications steps, relaxing requirements for clarity during storage, or substituting earth filtration systems with cross-flow filtration systems that may be able to achieve the same level of clarification in fewer passes.
- Some wine movements will be performed at the same time and will therefore involve less effort. If movements at the winery were grouped into jobs based on a common operations note, there were 1.9 movements per job.

- Pump movements were the dominant movement type and a large number of these were small volume movements. 24% of red wine and 12% of white wine pump movements were less than 2 kL. Moving leftovers after filling export containers was a major contributor to this result. This is likely to be a common issue at many wineries given that bulk wine exports now make up more than half of all Australian wine exports.
- Approximately 40% of pump movements occurred at the Finished production stage. This was surprising given that most core operations had been completed by this time. A contributor to this was small packaging runs that required reorganisation of leftover wine from a tank to prevent remaining wine being ullaged. It would be advantageous if improved low cost techniques to prevent wine quality loss during ullaged storage could be developed so that the only driver in keeping tanks full was to free up storage capacity.
- Scheduling / tank farm optimisation software has the potential at this and other large wineries to significantly reduce movement numbers and distances. This non-standard software may be too expensive for all but the largest and most complex wineries and is also likely to require cultural change at many wineries.
- Decision-making in many wineries is quite distributed, with cellar-hands sometimes making decisions on which tanks to use. There is an opportunity in some large wineries to reduce product movements through standardisation and formalisation of production rules (e.g. specific winery zones to be used for different operations). Extensive preliminary consultation with production staff would be required if this was to be effective.
- There may also be an opportunity for some wineries to reduce product movements through working with customers to improve forecasting of product requirements, with the goal of being able to group orders from different customers into larger packaging runs. The same principle applies to reducing movements of export leftovers. If more export containers can be loaded in a single run there will be fewer parcels of leftovers.

- An aspirational long-term goal to reduce product movements is to have techniques in place that allow wines to be kept in their most base state and then be able to blend, stabilise, clarify and package them into a high quality consistent product to order in one action.

7 Case-study 3: In-winery product movements

7.1 Introduction

Efficiently recovering value from wine and juice lees, which typically comprises solid content of 20-35%, is a task that provides a significant challenge to wineries of all sizes.

Wine lees typically contain around 50% of wine by volume/mass. Simply allowing the juice/wine to settling in tank typically only allows 20% of that wine to be recovered and without further processing the rest is either disposed of with the lees through a waste processing facility (e.g.Tarac) or sent to drain, increasing wastewater load and treatment cost whilst forgoing the value associated with the entrained juice or wine volume.

Typically most wineries that do process their lees utilise rotary drum vacuum (RDV or RVD) technology to recover a significant quantity of this juice or wine, however whilst RVD can handle high solids levels, the filtration process itself will generally result in a quality downgrade of product recovered, and it produces an additional solid waste stream. Additionally there are the well know OH&S issues surrounding the use of diatomaceous earth, which in itself has driven a shift towards using perlite as a filter medium.

Newly developed cross-flow filtration systems capable of handling the high solids levels associated with lees, and the associated difficulties posed by bentonite additions, have the potential to improve recovery of wine from the lees, whilst reducing the environmental impacts of water use, wastewater loading and the generation of an additional solid waste stream associated with earth based filtration.

This investigation seeks to provide a high level assessment of the potential for various new lees processing technologies to improve both the economic and environmental impact of lees processing. The technologies evaluated include the Pall HS Oenoflow and the TMCI Padovan Dynamos rotary cross-flow filters. Additional technologies such as the Bucher-Vaslin Flavy Leestar technology are also applicable for lees filtration, however this technology was not available for assessment.

7.2 Case-study: Benchmarking the Pall High Solids Cross-flow filter against Rotary Vacuum Drum filtration

7.2.1 BACKGROUND AND METHODOLOGY

A large winery had recently installed a new Pall Oenoflow HS (high solids) cross-flow filter unit for the purpose of processing their lees in order to achieve greater economic and environmental performance. Figure 7.1 shows an image of the filter whilst Figure 7.2 shows the schematic of the operation. The HS filter differs from a conventional cross-flow filter through the use of wide bore hollow fibres, which enables the processing of lees that would otherwise lead to blockage of conventional narrow bore filter modules, especially during the processing of Bentonite lees. Figure 7.3 shows a picture of the cross section of a filter module during a cleaning cycle.



Figure 7.1 Pall Oenoflow HS cross-flow filter.

Image source - http://www.pall.com/main/Food-and-Beverage/Product.page?id=53865

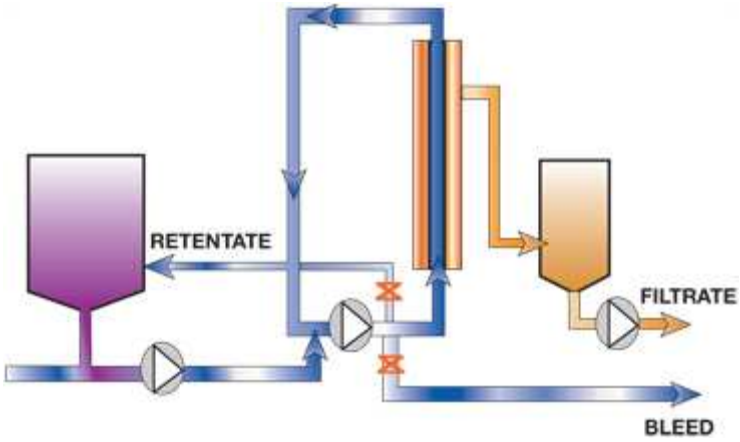


Figure 7.2 Schematic representation of the Pall Oenoflow HS filter.

Image source - http://www.pall.com/main/Food-and-Beverage/Product.page?id=53865



Figure 7.3 View of the wide bore fibres at the end of a single filtration module. Photo is shown during a cleaning operation.

The timing of the installation and commissioning of the HS cross-flow provided the opportunity to assess this relatively new technology and benchmark its performance against conventional RVD filtration.

The facilitating winery made available a 107kL batch of mixed red lees, with a 35% solids ratio as determined by their internal spin tests. This batch of lees was split, with approximately 76kL to be processed by the Pall HS cross-flow and 31kL to be processed using RVD, using a TMCI Padovan 10m^2 Taylo 10 filter.

Both operations were audited to determine the following metrics:

- Product recovery and quality
- Water use
- Wastewater quantity and quality
- Solid waste generated
- Energy use
- Consumable use
- Labour requirements
- Processing time

To obtain data on the water and power consumption, metering was undertaken where possible. Both the RVD and the cross-flow where equipped with logging power (current) meters, and the RVD was equipped with flow rate meters on its water supply. The water consumption associated with the cross-flow was all during the cleaning operations, and this is dependent on the type of cleaning undertaken. For this assessment, the nominal cleaning volumes recommended by the manufacturer were used as it was not possible to break into the fixed lines to measure the quantities directly.

7.2.2 RESULTS AND DISCUSSION

The 76kL batch of lees for the cross-flow was scheduled to run as a single batch, however winery operational requirements required that the run be interrupted after 12 hours of processing to complete

another priority job, before returning to complete the original batch of lees. Therefore the cross-flow processing consisted of 2 separate runs, with the subsequent calculations performed to ensure the outcomes were representative of a single run, i.e. to avoid double counting of cleaning cycles for example.

The cross-flow operation can be summarised as follow

- The processing rate of the unit was consistent throughout the run, yielding an average processing rate of 2.5kL per hour.
- The turbidity of the filtered wine (filtrate) was 7 NTU.
- There was minimal labour requirement to manage the running of the filter after the initial connections and start up, other than occasional supervision to confirm correct operation.
- The power consumption of the filter was essentially constant during the operation between 50 - 55 amps per phase.
- At the completion of the batch, the filter was cleaned using the following cycles
    - Hot water rinse requiring approximately 800L of 55°C+ hot water.
    - Back-flush with cold water requiring approximately 400L and 10 minutes,
    - Hot water rinse requiring approximately 800L of 55°C+ hot water.
    - Caustic clean requiring approximately 800L of hot water and 40L of 50% caustic applied through inline dosing.

All of this cleaning water was dumped to drain. The analysis of the waste water is shown in Table 7.1.

Table 7.1 Water analysis results from cross-flow cleaning operation.

Sample	Waste volume (L)	COD (mg/L)	TDS	TSS	pH	EC (dS/m)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)
Tap water	-	280	208	0	8.6	0.39	20	5	8	41
1st hot water rinse	800	319900	1368	849	3.6	2.60	63	861	27	45
Back-flush	400	104250	702	122	3.8	1.30	38	299	12	42
2nd hot water rinse	800	9675	210	0	5.8	0.41	17	22	6	40
Caustic sample	800	12875	546	70	12.9	31.89	31	22	4	3410

At the completion of the cross-flow operation, the retentate volume was 25,683 L. These lees were measured at 78% solids, and would be scheduled to be filtered using RVD to extract the last remaining and recoverable wine volume.

The RVD operation can be summarised as follows:

- Approximately 600kg of perlite was mixed with 3000L of water to create the slurry. Of this slurry volume, approximately 1000L was to be used to coat the drum, whilst the rest would remain in suspension for any subsequent RVD operations.
- The RVD was given a rinse down with water before precoating commenced.
- The drum was precoated to a filter cake thickness of approximately 8cm.
- This preparation process required approximately 2.5 hours.

- The filter cake was dried for approximately 30 minutes before the lees were introduced.
- The RVD then operated for approximately 12 hours to process the 31kL, completing the run during night-shift. Supervision was required essentially for the entire operation.
- At the commencement of dayshift, the remaining 2.5cm of filter cake was manually scraped off and collected in the solid waste bins. This represented best practice and minimised water use for cleaning.
- Any remaining filter cake was hosed off and the entire RVD unit was flushed and hosed down, requiring 1,800L of water. A caustic clean was not conducted as part of this operation.
- The overall water usage for the RVD can be broken down as follows.
    - Upfront rinse – 550L
    - Percolating – 1,000L
    - Vacuum pump – 27,600L
    - Cleaning – 1,800L
    - Total – 30,950L

From these, it is clear that the vacuum pump is by far the greatest user of water, responsible for almost 90% of the water consumption. The vacuum pump consumed water at a steady rate of approximately 20L/min for the entire duration that the pump was active. Further to this, analysis of composite samples of the vacuum pump drain water shows that contamination levels are low, as can be seen in Table 7.2. Therefore there are opportunities to reduce the overall water consumption through re-using this water.

Table 7.2 Water analysis results from RVD operations

Sample	COD (mg/L)	TDS	TSS	pH	E.C. (dS/m)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)
Mains water	280	177	0	8.4	0.51	24	5	10	62
Wine	211500	590	95	3.5	2.6	50	945	144	61
Lees	195500	540	28460	3.5	2.6	50	957	146	62
Vac. pump sample 1	220	177	0	8.1	0.51	24	5	10	62
Vac. pump sample 2	1330	175	0	8.1	0.51	24	6	10	61
Vac. pump sample 3	4630	164	0	8.0	0.51	24	6	10	61
Vac. pump sample 4	4400	119	0	8.0	0.52	25	7	10	63
Vac. pump sample 5	730	167	0	8.0	0.51	25	5	10	63
Vac. pump sample 6	1170	176	0	8.3	0.52	25	6	10	62
RVD liquid waste	23000	252	140178	3.6	2.66	41	875	27	73

Table 7.3 Summary of results from Pall HS cross-flow and RVD filtration

	PALL HS CROSS-FLOW	RVD
Lees processed (kL)	76	31
Wine recovered (kL)	50	28
Wine recovery	66%	90%
Water use (L)	2,000	30,950
Waste water generated (L)	2,000	~30,000
Water use (L/kL)	**26**	**998**
Power use (kWh)	875	400
Power use (kWh/kL)	**12**	**13**
Additives	N/A [1]	~200kg Perlite
Solid waste (t)	-	~10
Labour (hrs)	**5**	**17**
Processing time (hrs)	33	17
Ave processing rate (kL/hr)	2.3	1.8
Recovered wine NTU	**7**	**159**
Free/Total SO2 (mg/L)	19/69	5/53

[1] Caustic not considered as RVD was not caustic cleaned

Additionally to the metrics reported in Table 7.3, winemaker assessment reported that the wine recovered using the cross-flow was “cleaner, smells better, & would be able to be blended straight back to 4lt whereas is RVD recovered wine was not so good”.

The significant findings from this benchmarking are:

- Specific water consumption (L per kL of lees processed) is approximately 38 times greater for RVD processing than cross-flow. It is important to understand that as RVD water consumption is being driven by the liquid ring vacuum pump, the consumption will be proportional to batch size. Conversely, the water consumption associated with cross-flow operation is contained to cleaning operations, so within operating capabilities of the machine, the specific water consumption will decrease as the batch size increases.
- Power use is comparable between the technologies.
- RVD yielded great product recovery, although the turbidity of the filtrate was significantly lower, and the sensory properties we negatively impacted. This in turn provides the key input to determining the economic performance of the filtration technologies.
- The SO_2 level of the wine filtered by cross-flow was notably higher than the RVD wine, indicating that the exposure to oxygen was significantly lower.
- Processing rates were roughly equivalent, however the cross-flow required significantly lower labour input, therefore leading to lower operational costs.

Overall, it is evident that the Pall HS cross-flow offers clear environmental benefits in terms of reduced water consumption and corresponding wastewater volumes. The economic impact will be strongly impacted by the value of the lees being processed and the downgrade that would typically result from RVD processing. This particular evaluation was not conducive to assess the true value that can be recovered, as the product being filtered was mixed lees with the recovered product being destined to be blended for bag-in-box wine. When operating in its envisaged role, the HS cross-flow would be processing lees and returning the recovered wine directly to the original batch, therefore mitigating any downgrade in value. The economic advantages will be highly dependent on processed volumes and wine values, however a very generic example is provided in Table 7.4 to demonstrate the possibilities. This theoretical assessment of a large winery processing 500kL per annum uses the wine recovery percentages achieved in this evaluation, and demonstrates that the recovered value of wine alone, ignoring any improved efficiencies in operations. Given the Pall HS Oenoflow capital costs are typically in the range of AUD$500,000 - $1,000,000 dependent on size and installation requirements, the potential for relatively short payback periods does exist if the machine can be used to maximum value.

Table 7.4 Example of potential increased recovered wine value

	HS CROSS-FLOW	RVD
Lees Volume (L)	500,000	
Wine recovery (%)	66%	90%
Wine recovery (L)	330,000	450,000
Recovered wine value ($/L)	2	0.5
Recovered value	$660,000	$225,000

7.3 Side investigation – Potential for Rotary Drum filtration water re-use

7.3.1 METHODOLOGY

At present, Rotary Vacuum Drum (RVD or RDV) filtration is the primary method for processing wine lees across the Australian wine industry. RVD filtration is known to be a significant user of water as shown in the previous case study, however the intent of this investigation was to provide a benchmark as to water usage and assess the potential benefits of simple water re-use strategies.

Inherent by design, the RVD filter requires a vacuum to be generated to hold the filter cake to the rotating drum, and therefore each RVD unit is equipped with a vacuum pump. Almost universally, the RVD technology is supplied with a liquid ring vacuum pump, which uses liquid (water) to create a seal enabling vacuum to be achieved. Typically this water is used once and then dumped to drain. Therefore there is significant opportunity associated with the reuse of the vacuum pump water, and some prior analysis of this has been conducted and reported through the GWRDC case study on Vacuum pumps.

As demonstrated in Section 7.2.2 of this report, the precoating of the drum and the subsequent cleaning at the completion of the run do contribute to water usage, it is the vacuum pump water consumption that generally dominates.

The vacuum pump water usage was audited in two separate wineries using the equivalent RVD filters. The RVD filter used was a $6m^2$ (Taylo 6) supplied by Padovan. The first winery diverted the vacuum pump water to drain, whereas the second winery incorporated basic water re-use system. White tank bottoms (juice) were processed in both cases.

7.3.2 RESULTS AND DISCUSSION

The vacuum pump water consumption at winery 1 was measured to be 11.2 L/min, all of which was diverted to drain. The measured temperature rise between inlet and outlet was 7^{o}C.

Winery 2 used a basic recirculation system to reduce the water requirements of the RVD. Figure 7.4 shows the recirculation system, which comprises an approximately 50L plastic crate which provides a reservoir of water consisting of a mix of recycled water from the vacuum pump and freshly introduced mains water. Mains water is fed into the system, controlled by a float valve to maintain the level. To manage both the temperature and the contamination of the water, the drain valve at the bottom of the crate is used to bleed off some of the water at the appropriate rate. A 240V pump is used to supply the vacuum pump with water, and this water is then returned to the reservoir once it has passed through the pump.

The image in Figure 7.4 shows essentially the worst case condition throughout the particular tank bottom being filtered, as there is significant foaming occurring. This only occurred during the latter part of the run and can be largely attributed to the lees already undergoing fermentation.



Figure 7.4 A basic vacuum pump water recycling unit for a 6m^2 RVD filter. Note – significant frothing occurred due to fermentation occurring in the juice lees.

With this recycling system in place, the vacuum pump water consumption was reduced to 5.6 L/min, which equates to a reduction of 50%. In this particular case, the measured temperature rise between inlet and outlet as 12^{o}C, so somewhat higher than the single use scenario.

In the case of a nominal 12 hour RVD batch, the water saving equates to approximately a reduction from 8,000L to 4,000L of water required to generate a vacuum.

Clearly this is a basic implementation, and further opportunities do exist to improve the water re-use ratio's by the introduction of switching technology to divert the vacuum pump water to drain based on pH or conductivity measurements for example, and recycle when level are within an acceptable range.

Alternatively, a larger volume reservoir, for example 10,000L, may well be sufficient to operate an RDV for a period of a week, following which the water will be dumped to drain and refilled with mains water.

In whatever water recirculation scenario to be investigated, it is important to understand that water temperature plays a significant role in determining the efficiency of a liquid ring vacuum pump, and that a relatively small rise in water temperature that can result from re-circulation can result in a considerable reduction in vacuum pump capacity of 20%. This may necessitate the integration of refrigeration capability in some cases.

Alternatives to vacuum pumps using a conventional liquid seal are available, and dry vacuum pumps as previously reported (Sydney Water) can offer payback periods of less than 1.5 years in high use scenarios.

7.4 Case-study: Proof-of-Performance trial of new rotary lees filter from TMCI Padovan

7.4.1 INTRODUCTION AND METHODOLOGY

TMCI Padovan have a strong history and market position in RVD filters, and recently have released an innovative cross flow filter suitable for high solid content. This filter, known as the Dynamos, utilises rotating ceramic discs that operate in accordance with the cross-flow principle, however the rotation is claimed to offer a greater self cleaning capabilities which enables the filter to operate on liquids with very high solids content (Figure 7.5). Also, the unit does not require a pump to generate pressure in order to achieve filtration, as this is achieved by the relative motion between the rotating discs and the (relatively) stationary liquid. The benefit of this is significantly reduced energy consumption when compared to conventional cross-flow and lower temperature pickup across the ceramic membrane.

The Dynamos rotary cross flow filter is available in models ranging from 5 m^2 to 40 m^2, with the 40 m^2 unit will be capable of producing on average 1,200 –1,500 litres/hour of filtrate.

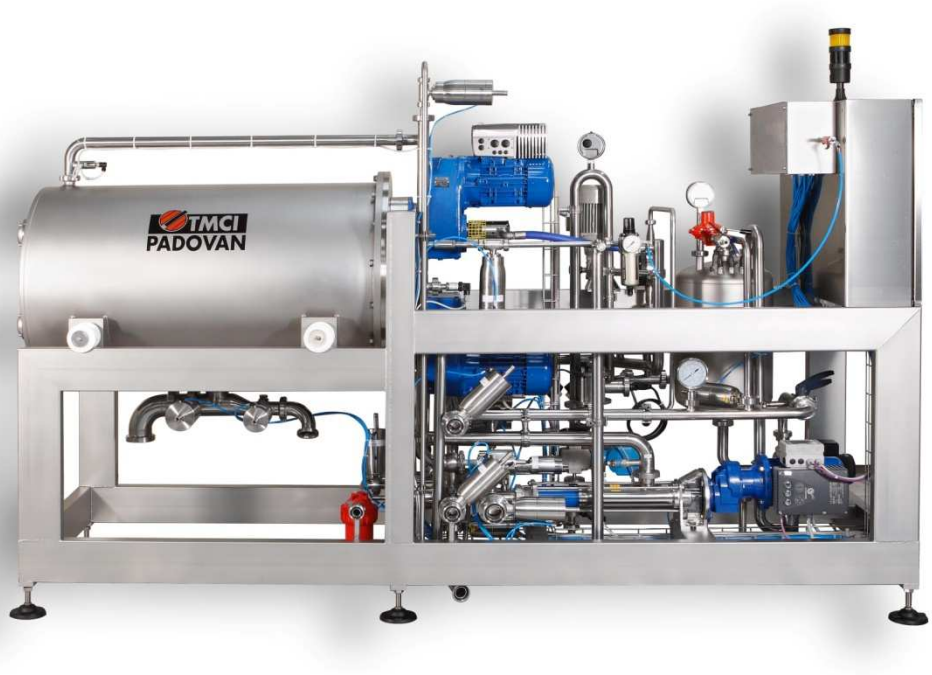


Figure 7.5 Image of the 10m^2 TMCI Padovan Dynamos rotary cross-flow filter. Image courtesy of TMCI Padovan.

The principle of operation of the rotary cross-flow filter is best described by Figure 7.6. Here it can be seen that the Lees (retentate) is recirculated through the chamber of the filter which contains the rotating ceramic discs. The wine/juice (filtrate) permeates through the ceramic discs and is extracted through the central shaft(s) and collected in the extraction tank, and from there it is discharged to its destination tank. Back flushing does occur at preset intervals to clear any blockages that may form on the discs themselves. The filtrate in the extraction tank is used to send a pulse of filtrate back through the system.

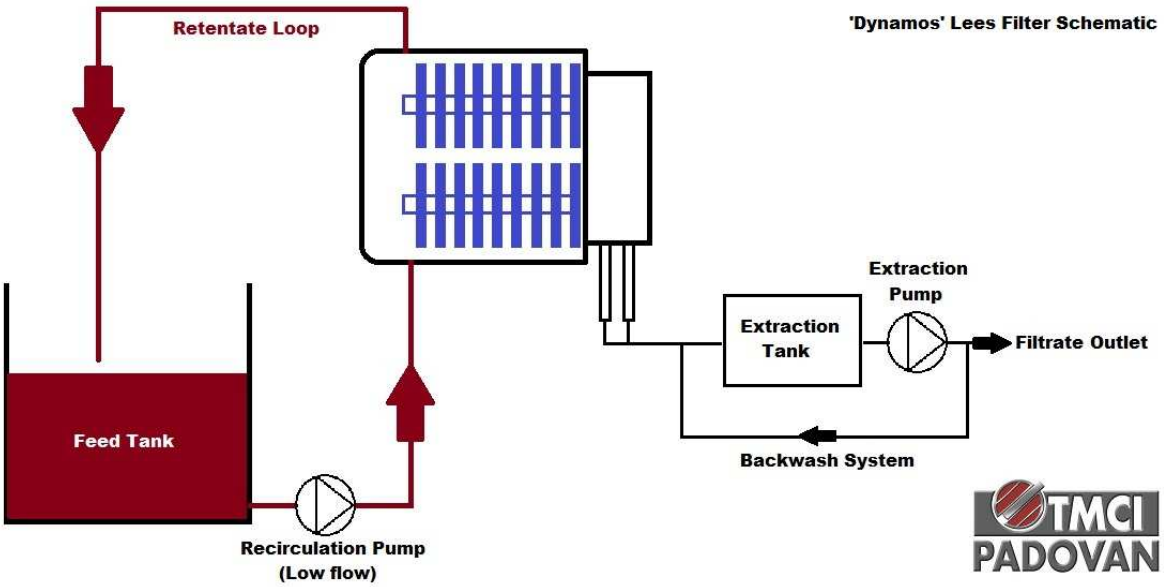


Figure 7.6 Schematic of the operation for the Dynamos rotary cross-flow filter. Image courtesy of TMCI Padovan.

For the purpose of this trial, Padovan made a small (1m^2) trial machine available in Australia for a short period. Whilst the processing rate associated with this machine would be very low and impact on the

commercially viability of the filter, it was proficient to conduct a basic proof-of-performance assessment on the technology itself. Being a trial unit, it was a semi-automatic machines, however all commercial machines are fully automated.

The facilitating winery made available a small 470L parcel of Sauvignon blanc tank bottoms to be filtered, in parallel to the winery conducting RVD filtration on remaining volume of tank bottoms.

7.4.2 RESULTS AND DISCUSSION

The Dynamos filter achieved an average processing rate of 30L/hour, and from the 470 L of lees provided, the filter yielded approximately 250 L of juice. Table 7.5 shows the analysis results of the lees pre and post filtration. It can be seen that the Dynamos filter yielded filtrate with a turbidity of 0.5 NTU whilst the same lees processed using RVD filtration had a turbidity of 25 NTU.

The Dynamos filter operated at a recovery ratio of 53%, however it is important to note that due to the size of trial machine only small batches were filtered, however in reality the larger the batch size the higher the percentage of filtrate recovery the machine can achieve. In contrast, 1,739L was processed by RVD, with 1,082L of filtered wine recovered. This equates to a recovery 62%.

Table 7.5 Example of potential increased recovered wine value

	JUICE LEES	DYNAMOS FILTERED JUICE	RDV FILTERED JUICE	RETENTATE FROM DYNAMOS
Alcohol	-	0.3	0.3	-
Glucose + Fructose	191	202	218	-
Optical density at 420 nm	-	0.065	0.205	-
pH	3.25	3.25	3.24	-
Specific gravity	-	1.0875	1.0917	-
Sulfur Dioxide (free)	28	26	26	-
Sulfur Dioxide (total)	78	82	88	-
Titratable acid pH 7.0	7.7	7.1	7.3	-
Titratable acid pH 8.2	8.1	7.4	7.6	-
Turbidity	-	0.5	24.9	-
Total solids	28%	N/A	0.2%	69%

The machine also performed very well in the sense that it created very little temperature pick-up, measured to be less than 4 degrees above ambient. Whist specific attention was not applied to the dissolved oxygen pickup during this trial, it is envisaged that this would be extremely low due to the closed nature of the system, provided the feed tank was blanketed with an inert gas.

As per a conventional cross-flow, the only driver of water consumption and wastewater generation is the cleaning requirements. Whilst time constraints meant that a full clean could not be conducted during the trial, the associated cleaning effort is low and requires minimal water consumption. The specified cleaning cycles comprise the following:

- Cold water flush. Fill unit with 100L of water and then dump, repeat 3 times.
- When CIP is required at product changeover of every ~ 4 days of operation, fill unit and recirculate with 100L of 0.5% caustic followed by 0.2-0.03% hydrogen peroxide.

- Neutralise with 100L water and 1% acid.
- Rinse with 100L of water.

Again, on the trial machine with the very small batch size, the specific water use would be disproportionately higher than a commercial machine operating on typical batch sizes.

Whilst power consumption wasn't specifically measured, it is clear from the power rating of the onboard motors that it would be low. For the 1m^2 machine, the motor to rotate the discs is rated 1.5kW, and the recirculation pump is also rated at 1.5 kW.

Overall, the Dynamos filter demonstrated it was capable of filtering lees with high solids content, and producing juice or wine to a bottle ready turbidity of <1 NTU. Whilst in the tank bottom scenario evaluated, filtered juice to 0.5 NTU may be far below requirements, in the case of wine lees, it does offer the potential to eliminate any final filtration processes that would otherwise be required. It also enables wineries, specifically the smaller wineries to use the filter for all their wine, rather than just the lees. Additionally, the technology is claimed to be able to process bentonite as per the Pall HS cross-flow, but it has the advantage that it can also process PVPP which is known to still cause blockages in wide bore cross-flows.

The technology therefore offers an alternative for wineries, especially the small and medium sized ones, to enable improved recovery from lees and reduced environmental and operational costs.

7.5 Conclusion

This investigation has evaluated technologies including the Pall HS Oenoflow and the TMCI Padovan Dynamos cross-flow filters, and has demonstrated these technologies, and potentially others such as the Bucher-Vaslin Flavy Leestar, can provide the opportunity to improve both the economic and environmental impact of current practice lees processing, with very significant reductions in water consumption and improvements is filtration proficiency and corresponding product quality.

Whilst there are no one-size-fits-all findings generated from this investigation, there is scope for individual wineries to define their lees processing requirements, and in-turn the report will assist in quantifying the potential benefits available from these new processing technologies.

Additionally, the investigation has quantified the water consumption associated with rotary drum vacuum processing, and has demonstrated that low technology opportunities do exist to significantly reduce water consumption of existing technologies.

8 Case-study 4: Winery salt balance

During the vintage of 2012, selected trial work was conducted at the Wirra Wirra winery, located in the McLaren Vale wine region of South Australia approximately five km southeast of the township of McLaren Vale.

The overall focus of the trial work was on the sources and amelioration of salts entering the wastewater stream at the winery. The following elements of the operation of the winery were investigated to identify sources and opportunities for salt removal in winery operations:

1. An overall winery salt balance
2. Detailed investigation of salt inputs at grape receival
3. Detailed review of performance of waste recovery at the centrifuge over two large centrifuge runs
4. Detailed review of tank washing wastes, for heavily tartrated tanks

The overall winery mass balance examined the following elements of the mass balance at the winery:

1. Determining an accurate estimate of the potable water used in production and the subsequent salt load from that source
2. Analysis of all salt purchases at the winery
3. Analysis of incoming grapes to obtain an estimate of the potassium derived from grapes
4. Investigation of the potential for salt concentration through the wastewater treatment train and in the storage lagoon

8.1 Identifying the sources of salts

A whole of winery salt balance has been used to estimate the sources of salt (Na and K) in the wastewater at Wirra Wirra. Figure 8.1 shows the elements of the whole-of-winery salt balance.

The elements of the whole-of-winery salt are:

1. Deliberate imports
    a. Non-potable water sources, which includes:
        i. Bore water
        ii. Recycled wastewater
    b. Potable water
    c. Wine and Juice from contract winemaking and contract crushing
    d. Grapes
    e. Winemaking additives
    f. Cleaning Agents
2. Accidental/unintentional imports
    a. Rainwater
    b. Atmospheric deposition onto roofs and paved areas, particularly in seaside environments
3. Solid and sludge exports
    a. Sludges from wastewater treatment
    b. Sludges from centrifuges
    c. Waste marc
    d. Mixed solid wastes (e.g. broken pallets, packaging, broken glass)

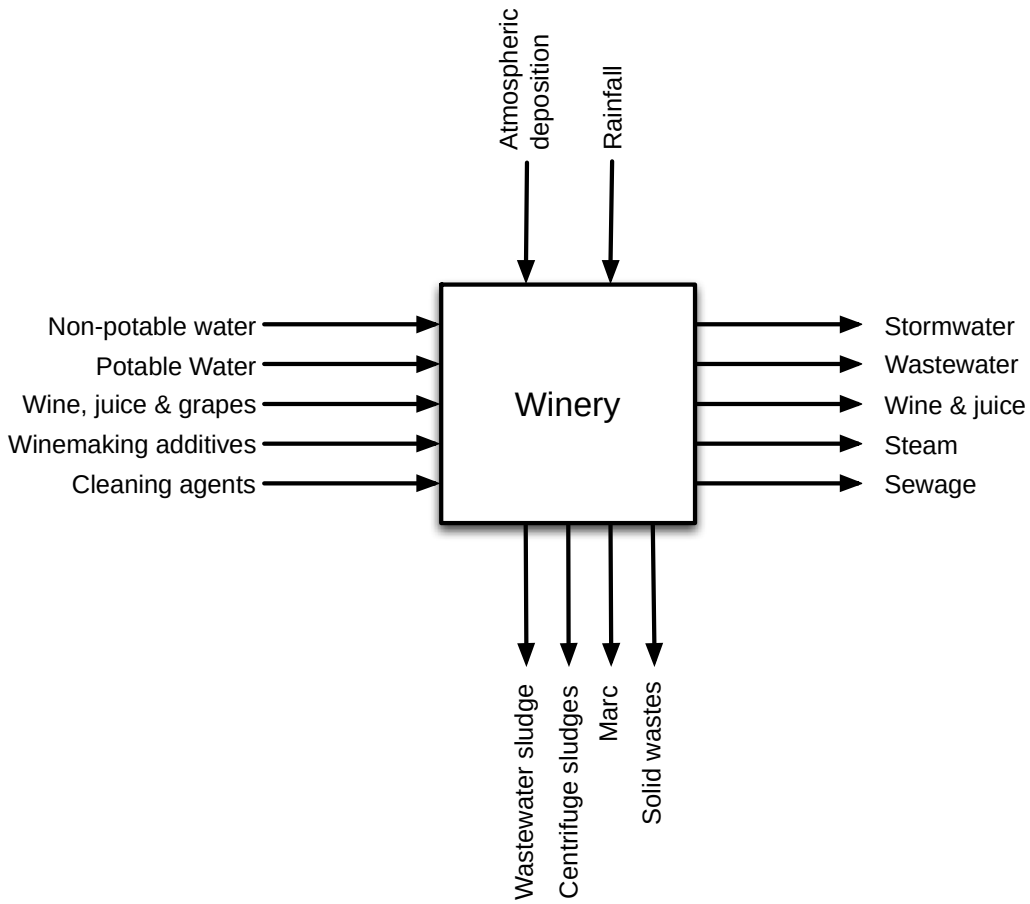


Figure 8.1 Whole of winery salt balance elements

4. Liquid Exports
    a. Wine
    b. Juice
    c. Stormwater
    d. Collected and treated wastewater
    e. Steam and evaporate from cooling systems and boilers
    f. Sewage

To simplify the salt balance for the purpose of calculating the sources of salt in Wirra Wirra wastewaters the following simplifying assumptions have been made.

1. Deliberate imports
    a. Winemaking additives are ignored as they are minor amounts and bring in minor amounts of salt
    b. Disinfectants, citric acid and oxidants such as ozone are ignored as they import only minor amounts of salt, if any
2. Accidental/unintentional imports
    a. Rainwater is treated as containing no salt
    b. Atmospheric deposition is treated as zero
3. Solid and Sludge Exports
    a. Solid Wastes are ignored as they are external to the salt cycle
4. Liquid exports
    a. No juice is exported

b. Steam is ignored as having no salt
c. Sewage is ignored as it utilises minor amounts of potable water and is discharged to a separate sewage scheme
d. Stormwater is treated as that component which is separately managed – water falling on roofs and managed separately, therefore ignored

Finally, the grape, juice and wine sources can be treated as production losses and grouped. There is a small error as some grape solids enter wastewater directly during white crushing and are lost to the marc. By grouping this way, wine and juice production and marc can also be also ignored. The simplified mass balance is shown in Figure 8.2.

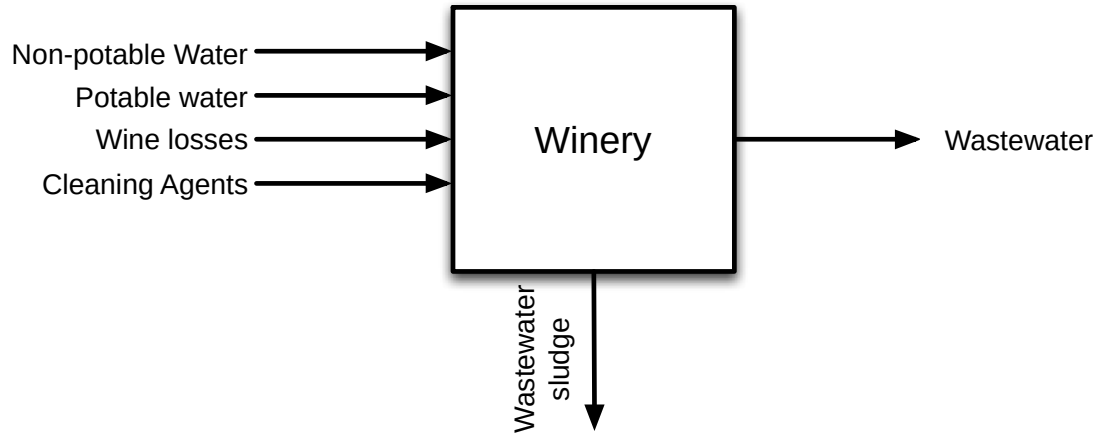


Figure 8.2 Simplified winery salt balance for Wirra Wirra

8.2 Salt imported from potable water

8.2.1 SALT COMPOSITION OF POTABLE WATER

Potable water at Wirra Wirra is sourced from SA Water's Happy Valley Reservoir and associated supply pipeline networks. Data sources for assessing the potable water at the winery were water analyses conducted during this trial by CSIRO and data supplied by SA Water from 2007 to 2011. For the SA Water data, 68 data points were available across the entire Happy Valley water supply network. Comparison of these analyses is shown in Table 8.1.

Table 8.1 Potable water quality data for Wirra Wirra

	SA WATER DATA			THIS TRIAL		
Parameter	**Average**	**Minimum**	**Maximum**	**Average**	**Minimum**	**Maximum**
Potassium (mg/L)	4.1	3.1	5.2	5.3	4.0	7.4
Sodium (mg/L)	72.9	49.3	93.0	100.7	95.7	104.0
Conductivity (µS/cm)	620.5	514.0	781.0			
TDS (from EC)	341.1	280.0	430.0			

The sodium composition of the potable water supply averaged 72.9 mg/L with a range of 49.3 mg/L to 93.0 mg/L. This is 30% lower than the estimate of sodium composition measured during the trial. The SA Water data has been used to compute the mass balance as a much richer data set is available.

8.2.2 ESTIMATING POTABLE WATERUSE FOR PRODUCTIONAT THE WINERY

Potable water supplied to the winery is used in both wine production and for site irrigation. A water balance was conducted to determine the water utilised in production, to thereby estimate the total mass of salt imported into the winery via potable water. This analysis leans heavily on work conducted for Wirra Wirra by JJC Engineering and supplied by the winery for reference.

Rainfall data was available from Wirra Wirra for 2009 and 2010 and from the nearest Bureau of Meteorology site at Pirramima as shown in Table 8.2. For the purposes of the water balance, the Wirra Wirra data was used to calculate the contribution of stormwater to wastewater.

Table 8.2 Rainfall (mm) data for the Wirra Wirra site

	RAINFALL (mm)		
Station	2009	2010	2011
Wirra Wirra	623.5	704	612.4[1]
Pirramima (BOM)	561.6	594.8	514.4

[1]Calculated from relationship with data sourced from the BOM station at Pirramima

According to JJC Engineering's calculations, the area of the winery that contributes stormwater to the total inflow to the wastewater treatment plant is 3,917 m² generating 3.917 kL of stormwater per mm of rainfall. The contribution of water lost in the cooling towers to the water mass balance is calculated as being a sixth of the water used in processing.

For the purpose of this analysis, it is estimated that five percent of the volume of wine is lost to the waste stream. Water that is lost to sludges has been ignored as the volumes are inside the error of the analysis.

These calculated values have been used to determine the volume of potable water used in processing by difference as shown in Table 8.3 based on Equation 1.

Equation 1 Calculations of potable water used for processing at Wirra Wirra

PP = WW + CWL – SW – WL and

PP = MP - AP

Table 8.3 Calculation of potable water use for winemaking at Wirra Wirra

WATER COMPONENT	SYMBOL IN Equation 1	2009	2010	2011
Wastewater (kL)	WW	6,103	4,503	4,855
Cooling tower water loss (kL)	CWL	593	278	396
Stormwater to WWTP (kL)	SW	2,442	2,758	2,399
Wine loss estimated (kL)	WL	102	80	78
Total potable water used in processing (kL)	PP	4,152	1,943	2,775
Metered potable water use (kL)	MP	7,832	5,628	4,456
Potable water for ammenities (kL)	AP	3,680	3,685	1,681
Total potable water used in processing (kL)	PP	4,152	1,943	2,775

8.3 Salt imported from purchases of cleaning reagents

The cleaning agents used in the winery are Cleanskin-K, K Clean and Pearl Caustic. Wirra Wirra provided salt purchase data for the winery from

The estimated salt compositions of these cleaning agents, based on manufacturers data is 546g of Na/kg for pearl caustic at 99.5% purity; 348g of K/kg assuming liquid KOH at 50% for K-Clean; and 509g of K/kg based on an assumed 90% potassium carbonate.

Utilising the provided cleaning records, the estimated purchases of Na and K in cleaning agents is shown in Table 8.4.

Table 8.4 Estimated imported Na and K in purchased cleaning agents

YEAR	K (kg)	Na (kg)
2007	178.4	68.3
2008	178.4	
2009	992.5	109.2
2010	1167.4	191.1
2011	407.4	232.1

8.4 Salt imported from grapes

8.4.1 POTASSIUM DROPOUT FROM MUST

A literature review plus data collected as part of the on-site work was used to identify the likely sources of potassium from grape must and juice and to estimate the likely input from this source into the winery were 100% of 100% of the solids to enter the waste stream.Error! Reference source not found. Table 8.5 shows a summary of the impacts of potassium in juice and must on the resulting mass and concentration in wastewater as a result of potassium precipitation in lees converting the dissolved potassium in the grapes and wine into solid phase potassium that enters the wastewater. Over the period of 2009 to 2011 the average estimated potential impact on winemaking was 200mg/L K in wastewater. The estimates of K are based on the data summarised in Table 8.5 from samples taken in this trial to determine the importance of grapes solids and liquids for potassium in wastewater.

Table 8.6 also shows comparative data from the literature.

Table 8.5 Implications of K dropout from juice in winemaking from potassium in Wirra Wirra wastewater

	2009	2010	2011
White wine volume (kL)	623	202	260
K from white juice/must in solids (kg)	872	283	363
Red wine volume (kL)	1,413	1,399	1,293
K from red juice/must in solids (kg)	565	559	517
Total K from Juice in Solids (kg)	1,437	843	881
Estimated potential impact on wastewater (mg/L)	235	187	181

Table 8.6 Estimated potassium input into waste from must and juice

	K IN WHITE (mg/L)	VARIETY	K IN RED (g/L)	VARIETY	REFERENCE
K in Juice	2,066 (1,583-2549)	Chardonnay Juice	2,355 (1,818-3,605)	Shiraz Juice	Walker & Blackmore (2010)
	1,000-3,000	Not specified	1,000-3,000	Not specified	Coombe & Iland (1988)
	1,237 (n=4)	Riesling grapes[1]			This work
	824 (n=4)	Riesling free run[2]			This work
	2,963 (n=4)	Riesling marc[3]			This work
			1,093	Merlot grapes[1]	This work
			1,655	Temperanillo grapes[1]	This work
			1,550	Grenache grapes[1]	This work
			2,265	Cabernet sauv grapes[1]	This work
			790	Merlot Marc[4]	This work
			1,285	Temperanillo marc[4]	This work
			733	Grenache marc[4]	This work
	Use 2,000		**Use 2,400**		
K in Wine	892 (669-1,200)		2,025 (1,249-2,768)		Walker & Blackmore (2010)
	200-400		1,500-2,000		Leon Deans *pers comm*
			1,158 (n=13)	Cabernet Sauv[5]	This work
	Use 600		**Use 2,000**		
Approx. K conversion to solids	1,400 mg/L		400 mg/L		

Notes:

1. Grapes macerated then screened through a 425 µm sieve
2. Free run tank samples
3. Marc squeezed then strained through a 425 µm sieve
4. Extracted with 50% w/w water then strained through 425 µm sieve
5. Fermented wine off centrifuge

8.4.2 POTENTIAL IMPACT OF MUST

A literature review was used to identify the likely sources of potassium from grape solids in the wastewater and to estimate the likely input from this source into the winery as summarised in Table 8.6, which shows the estimated K received at the winery for the 2009, 2010 and 2011 vintages. Data in Table 8.7 is based on the analysis shown in Table 8.5. The K in solids calculated in Table 8.8 is based on Equation 2.

Table 8.7 Estimated K in grape solids in 2009, 2010 and 2011

	2009	2010	2011
Total Grapes (tonne)	2,875	1,601	1,553
Total K (kg)	8,050	6,117	5,089
Potential wastewater impact (mg/L)	1,319	1,002	834

An input of 5% of grape solids entering the winery into the wastewater stream would result in an average of approximately 50 mg/L of K in wastewater.

Equation 2 Calculating potassium in grape solids

K in grapes attributable to grape solids = 100 x (K in marc) x (%dry solids) x (%marc)

Where,

K in marc is taken from Table 8.5 and has units of kg/tonne of grapes

% dry solids is the dry solids composition in marc from Table 8.5

% wet marc is assumed to be 30% of incoming grape solids (approximate pressing efficiency)

Table 8.8 Estimating K in grape marc, skins and seeds (grape solids)

COMPONENTS	VALUE	REFERENCE
K in Marc	2-3%	Patti et al (2009)
(w/w dry wt)	1.9-2.7%	DPI Vic
	2.25% (1.59-2.77%)	Saunders et al (1982)
	2.4% (2.3-3.1)	Laurenson & Houlbrooke (2012)[1]
	Use 2.3%	
Dry solids in marc	33.1% (21.1-56.3%)	Saunders et al (1982)
	49% (42-53)	Laurenson & Houlbrooke (2012)[1]
	Use 40%	
Approximate K in grapes attributable to solids	2.8 kg/tonne	Equation 2

Notes:

1. Laurenson & Houlbrooke supply a single for “fresh marc” which was 3 months old. Values in brackets are for composted marc. All other data is an average with a range in brackets.

8.4.3 POTENTIAL IMPACT OF WINE LOSSES

If wine losses are assumed at 5%, as used in Table 8.3, this will result in wine losses of 102, 80 and 78kL in 2009, 2010 and 2011 respectively. Assuming these losses equally in grape juice and white wine, using the values in Table 8.6, then this will represent approximately:

- 23, 31 and 27mg/L from red wine in 2009, 2010 and 2011 respectively
- 7, 3 and 3mg/L from white wine in 2009, 2010 and 2011 respectively

If losses are around 10%, which is not uncommon, these values will average 60mg/L K sourced from wine losses alone.

8.4.4 SUMMARY OF MASS BALANCE

Based on the simplified mass balance at Wirra Wirra shown in Figure 8.2,Table 8.9 and Table 8.10 below summarise the significant imports and exports of salt in the system in 2009, 2010 and 2011. Wastewater data used in this section is from analysis conducted by Veolia under contract to the winery.

Winery losses shown in the tables is an estimated contribution from grape skins and seeds, juice and wine waste, marc bay drainage and tartrate lees entering the wastewater calculated by subtraction of wastewater elements minus all other sources. Mass of salts in the waste stream is calculated by multiplying the concentration of salt in the waste stream as described in the previous sections by the appropriate water or wastewater volume in each study year. Sludge contributions are negligible and have been ignored. Percentages are based on the % of total mass in the wastewater. In these tables composition data for the wastewater data is taken from the decant of the SBR treatment plant.

Wastewater volumes provided by Wirra Wirra were 6,102, 4,503 and 4,844kL for 2009, 2010 and 2011 respectively. Wastewater sodium and potassium estimates were obtained from routine analysis conducted by Veolia. Only data from the decanter outlet was used. In 2009 average values from 2007 to 2012 were used as there is not sodium or potassium analysis in that year. These estimates are affected by the lack of monitoring data available for analysis.

Table 8.9 Summary of Sodium (Na) elements for Wirra Wirra in 2009

SOURCE	2009		2010		2011	
	mass (kg)	mg/L equiv[1]	mass (kg)	mg/L equiv[1]	mass (kg)	mg/L equiv[1]
Potable water supply	427	70	204	45	287	59
Pearl caustic	109	18	193	43	234	48
Estimated winery contributions		51		42		23
Wastewater		139		130		130

Notes:

1. Impact on wastewater – equivalent mg/L in the wastewater stream

Table 8.9 shows the sodium contributions to wastewater from potable water, use of pearl caustic and estimated other winery contributions. While there is a significant amount of risk of error in the estimation of potable water input, it appears that the most significant source of sodium in the wastewater is potable water, which is the largest estimated contributor in all three years. Other winery contributions to sodium could include minor inputs from salt in rainwater and atmospheric deposition, which are considered likely to be minor. Of the order of 10 mg/L could be from grape sources. (data collected for this trial found that

white grapes and juice contain about 3 to 4% of the potassium the grapes and juice contained. The remainder is attributed to the following error sources:

- Lack of data points to estimate winery wastewater sodium
- Estimating error in potable water input

There is an implication that water management has as much potential to reduce sodium in wastewater at this site as further reductions in cleaning sodium. There is also a risk of sodium contributions from water increasing as rainwater is diverted from the wastewater system.

Table 8.10 Summary of Potassium (K) elements for Wirra Wirra in 2009

SOURCE	2009		2010		2011	
	mass (kg)	mg/L equiv[1]	mass (kg)	mg/L equiv[1]	mass (kg)	mg/L equiv[1]
Potable water supply	26	4	12	3	17	4
Cleanskin K	0	0	8	2	407	84
K Clean	992	163	1,160	258	0	0
Estimated winery contributions		301		172		255
Wastewater		468		435		343

[1]Impact on wastewater – equivalent mg/L in the wastewater stream

The potassium contribution from incoming water is negligible.

Potassium from cleaning agents contributed between roughly 25 and 60% of the estimated potassium loads. Winery contributions account for the remaining 40 to 75%. The impact of a change in cleaning chemical and subsequent similar (within error) drop in wastewater potassium between 2010 and 2011 demonstrates the benefit in efficient cleaning.

The estimated impact from grapes and wine and juice losses is expected to make up the gap. The values shown here of 172 to 301mg/L attributable to grape is similar to that found by JJC (TEFF,8), where they attribute 200 to 400mg/L to grape sources, after lees recovery. Winery efficiency and improved management of potassium cleaning both have the potential to reduce potassium impacts on the wastewater, with cleaning of heavily tartrated tanks and management of winemaking lees likely to be effective targets.

It is critical to understand the importance of potassium for soils as the balance between sodium and potassium cleaners may need to be reviewed to reduce potassium levels, if the impact is in balance.

8.5 Salt concentration in the wastewater treatment train

In addition to the potential impact of salt sources in the winery, evaporation in the wastewater treatment during warmer months was reviewed. While the actual mass of salt will not change during wastewater treatment, there is potential for the concentration of salt and hence usability of the wastewater for irrigation to change during the wastewater treatment process.

At Wirra Wirra, the wastewater treatment train consists of the following stages:

1. Collection via drains in the winery. To the maximum extent currently possible the clean rainwater from roof surfaces is currently separated from the wastewater and either discharged to stream or

utilised for garden watering. Stormwater from winery tarmac and tank farms is co-collected with the winery wastewater through the drainage system.

2. Fully enclosed 200kL storage/balancing tank fed by gravity from the winery. Wastewater is pumped to the wastewater treatment plant from the tank. Sludge accumulates in this tank, which is periodically removed. Sludge volumes provided by the winery were40 to 50 kL in 2011 and 15kL in 2012
3. Wastewater is screened into a 20kL settling tank.
4. Wastewater is then fed into a 200kL buffer tank (open top).
5. Wastewater is treated in a 200kL SBR reactor.
6. Finally treated wastewater is sent to a 3ML dam where it is stored prior to land application.

As the wastewater system is largely open top, there is potential for concentration of wastewater throughout the system, and particularly in the storage lagoon, in hot dry months. In colder wetter months there is likely dilution of the effluent in the treatment plant and lagoon from incident rainfall.

Concentration during the warm months has the potential to compromise the quality of the water for land application, which is at the time of year of highest wastewater volume production and when suitable irrigation water is likely to be most beneficial to a range of land uses including grapes. Figure 8.3 shows wastewater production over the years 2007 to 2011. 2008 is excluded as the site had a major interruption to production in that year. It demonstrates the importance of the vintage period with peak wastewater production in summer over three times the typical non-vintage wastewater production.

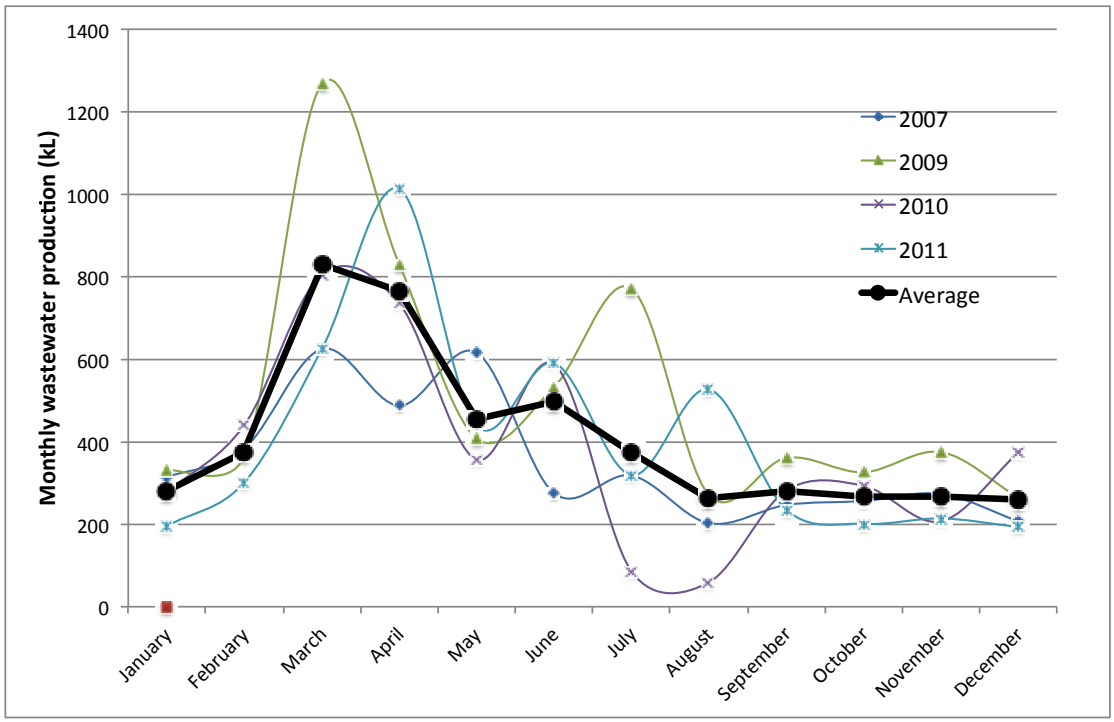


Figure 8.3 Monthly flows to the wastewater treatment plant in 2007, 2009, 2010 and 2011

Figure 8.4 to Figure 8.6 show the change in electrical conductivity (EC) of the wastewater throughout the treatment train, during vintage, in the non-vintage period, and averaged over a year respectively. For this analysis vintage is treated as January to May and non-vintage as June to December inclusive. These data are taken from analysis provided by Wirra Wirra from their internal data collection records.

The nature of the data set used is based on periodic and opportunistic monitoring for operational purposed, limiting its value for any more detailed analysis than that shown below. Table 8.12 shows the numbers of records from which the data from Figure 8.4 to Figure 8.6 were taken. Due to the low number of records because of an operational interruption, 2008 has not been considered.

Due to the low number of records because of an operational interruption, 2008 has not been considered. These figures show a decrease in salt concentration across the wastewater treatment process during the

non-vintage period and increase during the vintage period. The increase over the vintage period between the inlet to the plant and the lagoon is approximately 320 EC. Table 8.11 shows how this can be approximated to 23mg/L Na and 79 mg/L K.

Table 8.11 Calculation of the impact of the 320 EC increase in salinity across the wastewater treatment train on Na and K concentration in wastewater

	VALUE	NOTES
EC change across the treatment train	320 EC	
Conversion of EC to TDS	TDS = 0.56EC 179mg/L = 320EC	Conversion factor used for Wirra Wirra by Veolia
Total average TDS at the SBR decant	1,052 mg/L	2007 to 2012 data from Veolia (n=18)
Total average Na in the TDS at the SBR decant	139mg/L = 13%	As above
Total average K in the TDS at the SBR decant	468 mg/L = 44%	As above
Estimated impact on Na	13% of 179mg/L is 23mg/L	
Estimated impact on K	44% of 179mg/L is 79mg/L	

Table 8.12 Data points available to generate the data shown in Figures 8.4-8.6 (from Wirra Wirra in-house data)

Period	Year	Balancing tank	Treated effluent discharge	Wastewater lagoon
Vintage	2008	0	6	0
	2009	9	26	2
	2010	3	7	4
	2011	11	7	13
Non-vintage	2008	0	1	0
	2009	11	26	3
	2010	3	6	4
	2011	13	12	6
Full year	2008	0	7	0
	2009	20	52	5
	2010	6	13	8
	2011	24	19	19

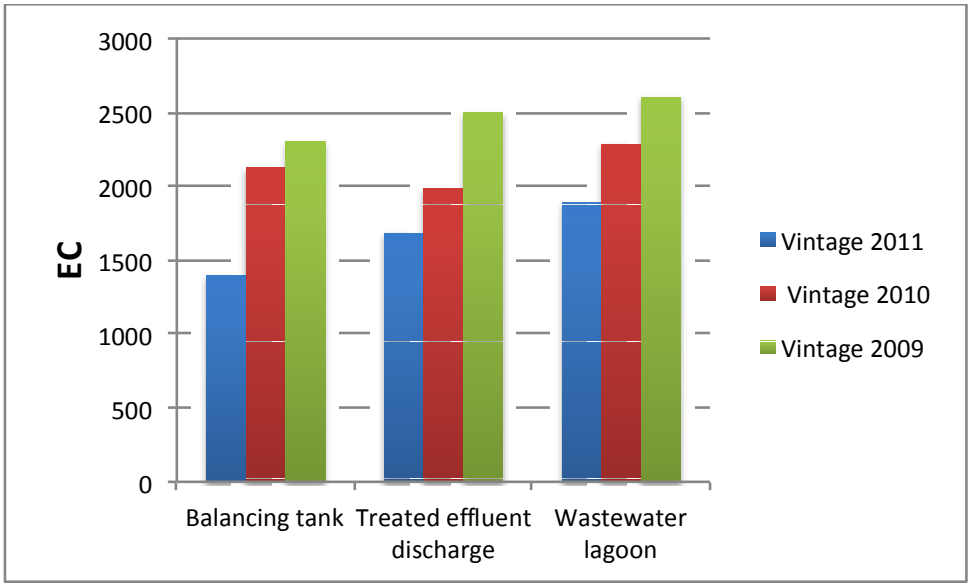


Figure 8.4 Changes in wastewater composition (EC) across the wastewater treatment process during vintage

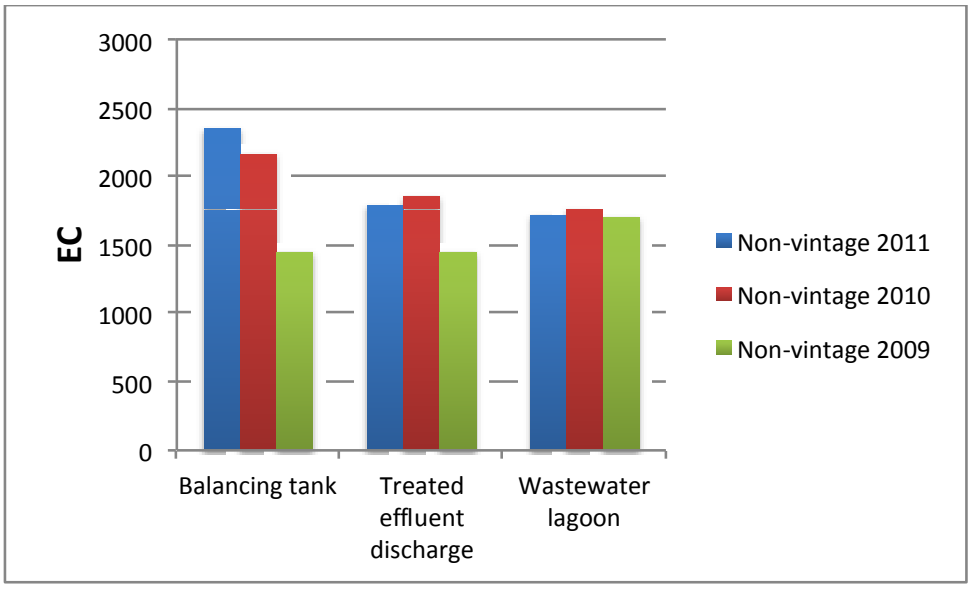


Figure 8.5 Changes in wastewater composition (EC) across the wastewater treatment process during the non-vintage period

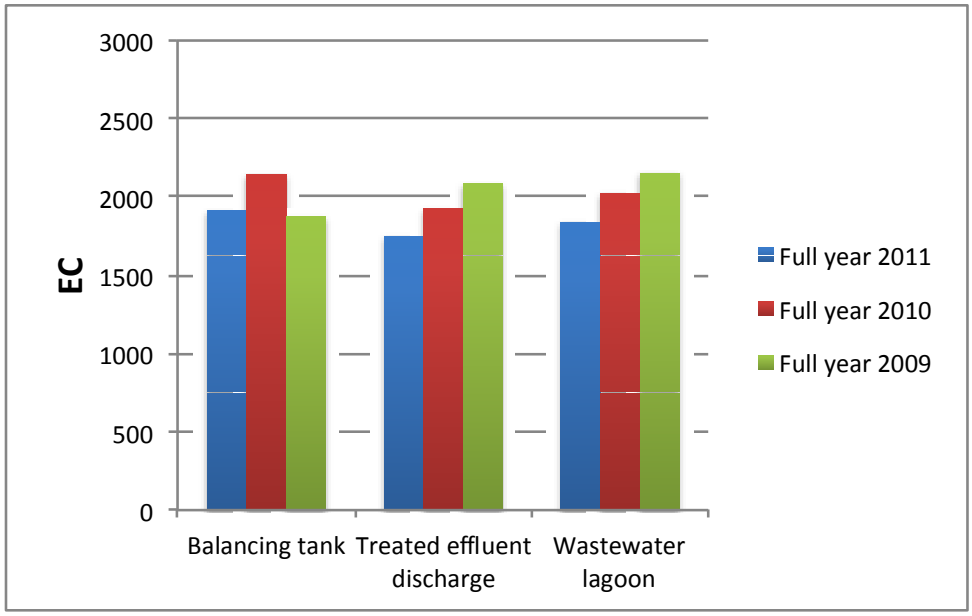


Figure 8.6 Changes in wastewater composition (EC) across the wastewater treatment process over the full calendar year

8.6 Cleaning chemical management trial

In addition to the mass balance analysis of cleaning chemical purchases, cleaning processes were assessed for their contribution to wastewater loads and potential for recycling. Moderately tartrated tanks that were cleaned with caustic were targeted for this component of the analysis. Six tank cleans were analysed, each consisting of a hot water wash followed by a hot caustic wash.

Caustic wash was specifically targeted for testing as the winery is examining caustic re-use as a means of reducing salinity of wastewaters. This trial looked at several cleans and evaluated them for potential to re-use and for potential for segregation

8.6.1 METHOD

Winery staff collected samples during washes of tartrated tanks during late vintage. All tanks sampled were moderately tartrated. Information collected was the volumes of water used and caustic solution added. All samples were analysed for cations, pH, EC, TSS and COD

8.6.2 HOT WASH SEPARATION AT SOURCE

The hot water clean was evaluated for potential to be removed from the wastewater stream via separation at source. In the six hot water washes evaluated, the average sodium in the wash water from a tank was 7g and the potassium removal was 89g. There are approximately 150 tank washes conducted on site per annum with the majority from 22 and 45kL tanks. The washes evaluated are regarded as relatively representative in terms of volume used for cleaning and mix of tank sizes for approximately 120 of these cleans. The 30 remaining cleans would be more heavily tartrated white ferments.

To recover the entire hot water tank cleaning solution utilised on site would require approximately 16kL of storage and would remove over 1kg of sodium and over 13kg of potassium from the wastewater. The effect of this would equate to an equivalent of 3mg/L of Na and K salts removed from wastewater based on the average wastewater volume of 5,154kL per annum between 2009 and 2011. This is likely an underestimate as the more heavily tartrated white tanks were not included in the testing regime. It is clear, that based on this sampling, removal of hot washes from the waste stream would not be beneficial.

8.7 Caustic wash recycling and source separation

8.7.1 POTENTIAL TO RECYCLE SPENT CAUSTIC

To recycle caustic on site would require operational change that will be difficult to implement given the nature of the site and the large proportion of small and medium sized fermentations, so a preliminary evaluation of recyclability was conducted. Figure 8.7 shows the approximate percentage of the applied caustic that was not dissolved for a given caustic addition. For the six washes analysed only two would have been recyclable based on the criteria used for caustic recycling used at the nearby Ryecroft winery where any spent caustic with a pH below 10.5 is rejected from their recycling process (GWRDC, 2011). This indicates low potential for recycle of the spent caustic, although this is a small sample. It also indicates that the caustic concentrations used in cleaning solutions are relatively conservative in the operation.

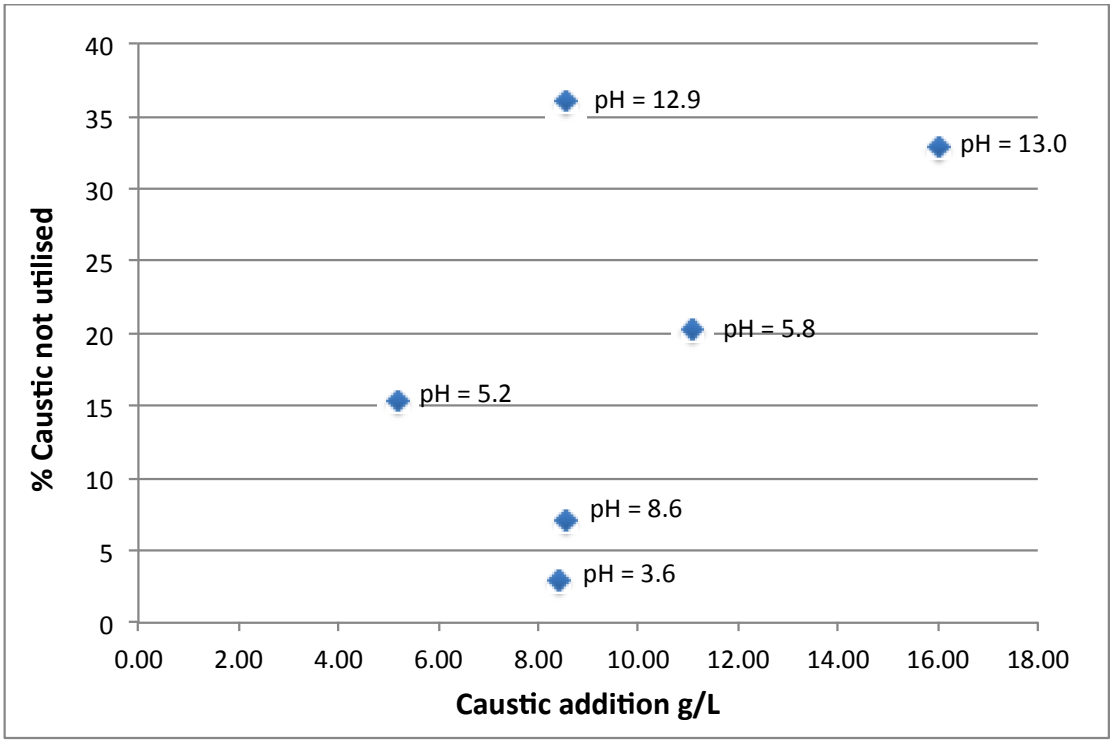


Figure 8.7 Caustic addition, utilisation and spent caustic pH for the 6 tank washed assessed

8.7.2 IMPACTS OF SEPARATION OF THE SPENT CAUSTIC SOLUTION ON WINERY SALT LOADS

The removal of caustic from the wastewater stream via separation at source was also evaluated for its benefit. In the six caustic washes evaluated, the average sodium in the wash water from a tank was 540g and the potassium removal was 642g. There are approximately 150 tanks washes conducted on site per annum with the majority from 22 and 45kL tanks, for which the evaluated washes are regarded as relatively representative in terms of volume used for cleaning and mix of tank sizes for approximately 120 of these cleans. The 30 remaining cleans would be more heavily tartrated white ferments, for which these samples are not representative.

To recover the entire caustic cleaning solution utilised on site would require approximately 21kL of storage and remove over 81kg of sodium and over 96kg of precipitated potassium from the wastewater. The effect of this would equate to an equivalent of 34mg/L of Na and K salts removed from wastewater based on the average wastewater volume of 5,154kL per annum between 2009 and 2011. This is likely a substantial underestimate as the more heavily tartrated white tanks were not included in the testing regime.

8.8 Centrifuge waste management evaluation

Eighty-five percent of all red wine produced at the site is centrifuged, equating to approximately 1,163kL per annum, based on the averages of 2009, 2010 and 2011 red wine made at the site. Waste recovery is already practised with centrifuge waste streams on the site and the purpose of this evaluation was to document the impact on winery wastewaters and winery water use and determine if any further savings are available.

A representation of the mass balance for the centrifuge is shown in Figure 8.8. This is a slight over-simplification as some of the cooling water "leaks" into process wastewater.

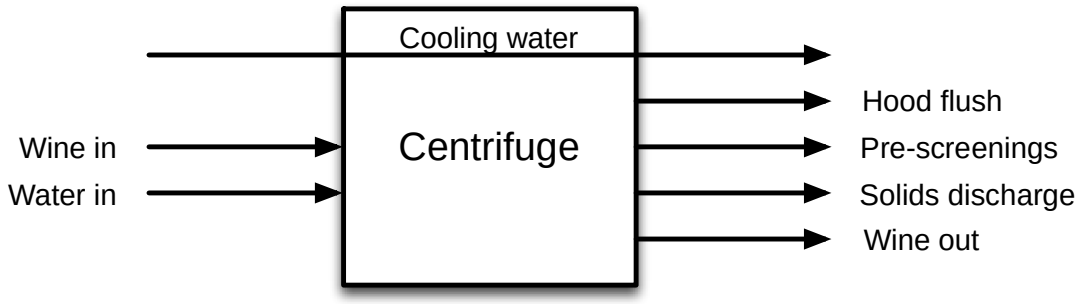


Figure 8.8 Representation of the mass balance for the centrifuge at Wirra Wirra

8.8.1 METHODS

Site evaluation was conducted for the centrifugation of two Cabernet Sauvignon ferments, one of 42.8kL and one of 38.3 kL. Flow rates for wine streams were determined from the centrifuge run time and wine volume processed. All water inputs into the centrifuge were metered and water outputs were calculated by subtraction as water is discharged in several of the waste streams. Subsamples of each of the waste streams were captured in buckets and by measuring the timing and volumes of each 'capture', the flow rate for each of the waste stream was determined. These volumes were cross-checked with SCADA data from the centrifuge. The solids discharge waste stream, which is captured in a pellecon, was also weighed on the winery weight bridge and the empty weight netted off.

Each 'capture' was also sub-sampled and these were analysed for Alcohol, COD, all cations, EC, pH, and TSS.

8.8.2 ERROR

This method is prone to sampling and estimation error and as the streams are sampled, and the volume of several of the streams was calculated by subtraction. As shown in Table 8.14 and Table 8.15, internal errors in the mass balance were below 10%. An error of 25% was found in the estimate of the volume of the solids discharge by mass compared with run time plus the direct flow rate measurements. The run-time value was used in all calculations as the weighbridge method was considered to be the less reliable. The results based on both methods are discussed.

8.8.3 MASS BALANCE

The mass balance results for Alcohol, COD, sodium and potassium are shown in Table 8.13 and Table 8.14. Mass flow rates measured and the total mass are shown in Table 8.15, Table 8.16, Table 8.17 and Table 8.18. This detail is given to so that any other sites wishing to do similar work will have mass balance tables available for comparison.

The internal error, which is the difference between the estimated mass in and the estimated mass out, has been calculated for each component of each trial and is considered to be excellent being less than 10%.

The data in these two tables are used as the basis for the calculations conducted for the remaining analysis. Table 8.13 and Table 8.14 show the analysis of the implications of the mass balance data.

8.8.4 RESULTS

Benefit to potassium and sodium in the wastewater

In this trial, the removal of potassium and sodium by way of the solids recovery at the centrifuge had no material impact on the salt loading of the wastewater treatment plant. However, the removal of COD from the treatment plant is significant.

Table 8.13 Mass balance on centrifuge Trial

	ALCOHOL		COD		Na		K	
	g/min	**g**	**mg/min**	**g**	**mg/min**	**g**	**mg/min**	**g**
Sources								
Incoming wine	6,591	4,844,135	15,564,295	11,439,757	2,758	2,027	67,618	49,699
Incoming water					731	537	30	22
TOTAL IN	**6,591**	**4,844,135**	**15,564,295**	**11,439,757**	**3,488**	**2,564**	**67,648**	**49,721**
Outputs								
Wine	5,972	4,389,489	14,521,167	10,673,058	2,625	1,930	62,260	45,761
Solids discharge	286	209,893	640,720	470,929	154	113	2,465	1,812
Pre-screenings	28	20,882	62,489	45,929	4	9	275	202
Hood flush	6	4,336	13,182	9,689	216	159	91	67
Cooling Water					516	380	21	16
Mass out	**6,292**	**4,624,601**	**15,237,558**	**11,199,605**	**3,515**	**2,590**	**65,112**	**47,857**
Error		**4.5%**		**2.1%**		**1.0%**		**3.9%**

Benefits of COD, alcohol and TSS removal in the solids discharge stream

Based on these results, by recovering or diverting the solids discharge waste stream, the wastewater COD is reduced by an equivalent of approximately 2,000mg/L at the wastewater treatment plant inlet. Accounting for measurement error, this is approximately 1,500 to 2,000mg/L COD equivalent.

The average COD at the inlet to the wastewater treatment plant from 2009 to 2011 was 8,050mg/L (from Wirra Wirra internal monitoring data). As a result of the separation of the solids discharge, COD requiring treatment at the plant is reduced by approximately 20%.

A review of the suspended solids data, not shown in tables, shows that the collection of the solids discharge waste stream reduces the load to the treatment plant by approximately 670 to 840mg/L TSS per annum at the inlet to the wastewater treatment plant.

Alcohol measurements validate the value of the stream as a recoverable resource, with the solids discharge stream having an alcohol composition of 90 mg/L, approximately 83% of the alcohol concentration of finished wine of 109g/L. This decrease is also a consequence of some input from water into this waste stream.

As a result of this trial the significant benefits of separation of solids discharge from centrifuge on treatment plant capacity has been demonstrated. This data suggests that the recovery of this waste stream has potential to significantly reduce capital and operational costs and operational difficulty at wastewater treatment plants. This is a high concentration waste stream with COD of 210g/L and TSS of 50g/L with a significant impact on wastewater. The volumes produced are low, at approximately 30-40L/kL for this trial, meaning less than 38-48kL for the whole of vintage.

Table 8.14 Mass balance on centrifuge Trial 2

	ALCOHOL		COD		Na		K	
	g/min	g	mg/min	g	mg/min	g	mg/min	g
Sources								
Incoming wine	7,261	4,582,531	16,290,03	10,280,448	2,175	1,373	72,004	45,441
Incoming water					774	488	54	34
TOTAL IN	**7,261**	**4582531**	**16,290,035**	**10,280,448**	**2,949**	**1,861**	**72,057**	**45,475**
Outputs								
Wine	6,504	4,104,893	15,268,802	9,635,960	2,054	1,296	72,233	45,586
Solids discharge	135	97,457	325,589	234,424	72	52	1,405	1,011
Pre-screenings	40	29,122	101,016	72,731	14	10	453	326
Hood flush	22	15,721	11,274	8,117	136	98	337	243
Cooling Water					634	400	44	28
Mass out	**6,702.1**	**4,247,193**	**15,706,681**	**9,951,232**	**2,910**	**1,856**	**74,471**	**47,193**
Error		**7.3%**		**3.2%**		**0.2%**		**3.8%**

Potential benefits of capturing the pre-screening stream

The pre-screenings waste stream is a much smaller stream, estimated at approximately 7L/kL of wine processed or approximately 6,400 to 8,000L for vintage, typically 200L for a single 45kL centrifuge run. However, it is a higher strength stream (both COD and alcohol) with the potential to reduce winery COD, if separated, by an equivalent of 330mg/L per annum, representing approximately a 4% decrease in COD over the year.

This stream would be more difficult to collect as it discharges around 30cm from the processing floor and difficulty in collection or retrofitting for collection would need to be considered.

Table 8.15 Average Na composition of waste streams of wine processed over the two centrifuge trials

Output	Average (g/kL)[1] of wine processed	Total mass in waste (g)[2]	Equivalent concentration in wastewater[3] (mg/L)
Solids discharge	2.0	2,366	0.46
Pre-screenings	0.2	272	0.05
Hood flush	3.2	3,685	0.72
Cooling water	9.6	11,185	2.2

Notes:

1. g/kL of wine processed
2. grams produced in average production year (average of 1,163kL centrifuged based on vintages 2009, 2010 and 2012)
3. equivalent impact on wastewater composition using the average wastewater production from 2009, 2010 and 2011 of 5,154kL

Table 8.16 Average K composition of waste streams of wine processed over the two centrifuge trials

Output	Average (g/kL)[1] of wine processed	Total mass in waste (g)[2]	Equivalent concentration in wastewater[3] (mg/L)
Solids discharge	34	40,483	7.9
Pre-screenings	6.5	7,571	1.5
Hood flush	3.8	4,445	0.86
Cooling water	0.54	631	0.12

Notes:

1. g/kL of wine processed
2. grams produced in average production year (average of 1,163kL centrifuged based on vintages 2009, 2010 and 2012)
3. equivalent impact on wastewater composition using the average wastewater production from 2009, 2010 and 2011 of 5,154kL

Table 8.17 Average COD composition of waste streams of wine processed over the two centrifuge trials

OUTPUT	Concentration in waste stream (mg/L)	Average (g/kL)[1] of wine processed	total mass in waste (kg)[2]	equivalent concentration in wastewater[3] (mg/L)
Solids discharge	209,846	8,697	10,114	1,962
Pre-screenings	255,052	1,463	1,701	330
Hood flush	7,220	220	255	50

Notes:

1. g/kL of wine processed
2. kilograms produced in average production year (average of 1,163kL centrifuged based on vintages 2009, 2010 and 2012)
3. equivalent impact on wastewater composition using the average wastewater production from 2009, 2010 and 2011 of 5,154kL

Table 8.18 Average Alcohol composition of waste streams of wine processed over the two centrifuge trials

Output	Concentration in waste stream (mg/L)	Average (g/kL)[1] of wine processed	Total mass in waste (kg)[2]	Equiv concentration in wastewater[3] (mg/L)
Solids discharge	90	3,790	4,407	855
Pre-screenings	109	617	717	139
Hood flush	8	247	288	56

Notes:

1. g/kL of wine processed
2. kilograms produced in average production year (average of 1,163kL centrifuged based on vintages 2009, 2010 and 2012)
3. equivalent impact on wastewater composition using the average wastewater production from 2009, 2010 and 2011 of 5,154kL

8.9 Conclusions

Key areas of interest from the work were:

- Potassium from cleaning agents contributed between roughly 25 and 60% of the estimated potassium loads, depending on year. Changes in cleaning agents are clearly reflected in the resulting potassium loads in the wastewater.
- The remainder, and of typically equal importance, is management of all forms of winery solid wastes entering the waste stream.
- Winery efficiency and improved management of potassium cleaning both have the potential to reduce potassium impacts on the wastewater, with cleaning of heavily tartrated tanks and management of winemaking lees likely to be effective targets.
- The potable water supply is as significant a source of sodium in the wastewater as the use of sodium cleaning agents, at this site, which has high use of potassium based cleaning agents.
- Potable water efficiency is, therefore, a significant opportunity for management of slats in wastewater. However reduction of stormwater inputs into the waste stream has potential to increase wastewater salinity.

- It is critical to understand the importance of potassium for soils as the balance between sodium and potassium cleaners may need to be reviewed to reduce potassium levels, if the impact is in balance.
- Salt concentration in the wastewater treatment train, which is predominantly open to the atmosphere, during the warm months has the potential to compromise the quality of the water for land application. This occurs at the time of year of highest wastewater volume production and when suitable irrigation water is likely to be most beneficial to a range of land uses including grapes.
- It is clear that, based on this sampling of moderately tartrated red wines, removal of waste from hot washes from the waste stream would not be demonstrably beneficial.
- To recover the entire caustic cleaning solution utilised on site would require approximately 21kL of storage and remove over 81kg of sodium and over 96kg of precipitated potassium from the wastewater. The effect of this would equate to an equivalent of 34mg/L of Na and K salts removed from wastewater.
- In this trial, the removal of potassium and sodium by way of the solids recovery at the centrifuge had no material impact on the salt loading of the wastewater treatment plant. However, the removal of COD from the treatment plant is significantly beneficial. Based on these results, by recovering or diverting the solids discharge waste stream, the wastewater COD is reduced by an equivalent of approximately 2,000mg/L at the wastewater treatment plant inlet
- The pre-screenings waste stream if separated, by an equivalent of 330mg/L per annum, representing approximately a 4% decrease in COD over the year

9 Overall conclusions and recommendations

Recent projects investigating winery wastewater have identified a number of new technologies that may help to reduce or recycle wastewater and ensure wine is produced cleanly. An industry survey was performed to gather a list of potential technologies which might lead to cleaner production methods. In total, this approach covered approximately 70% of Australian production by volume. The survey was intended to identify the potential technologies and operational strategies which the industry considered to be worth further investigation. Broadly speaking, the suggestions were related to four main categories:

- Cleaning efficiency
- Separation of solids
- Separation of waste streams
- Transfer related activities

This project tested and demonstrated these technologies and deployed case studies within the wine industry to facilitate their uptake.

Technologies were ranked using a combination of factors including ease of implementation, economic and environmental assessment. Where required, bench top and winery trials were performed to generate additional data to assist in assessments. The highest ranking opportunities were reuse of cleaning chemicals, minimisation of transfers and the solids separation techniques of lees cross flow filtration and secondary settling. Ice pigging, the re-use of crusher to press push water and an automated stormwater diversion system also ranked highly. However, the high equipment capital costs and ongoing operational costs mean that in general these techniques will not be viable for most sites. However, wineries particularly heavily constrained by wastewater treatment should consider a further evaluation of these technologies.

We identified a large number of technologies and methods that can be used to streamline, reduce, reuse and recycle winery wastewater. The re-use of caustic cleaning agents has the potential to reduce sodium levels in winery wastewater. The use of a caustic recovery system is also expected to reduce labour requirements associated with tank cleaning as it eliminates the ‘preparation step’ currently required prior to every cleaning operation. Other benefits of reuse include improved OH&S and less expenditure on chemicals. There may also be an opportunity for some wineries to reduce wine movements through working with customers to improve forecasting of product requirements, with the goal of being able to group orders from different customers into larger packaging runs. Efficiently recovering value from wine and juice lees, which typically comprise solid contents of 20-35%, is a task that provides a significant challenge to wineries of all sizes. This investigation has evaluated technologies including the Pall HS Oenoflow and the TMCI Padovan Dynamos cross-flow filters. These technologies, and potentially others such as the Bucher-Vaslin Flavy Leestar, canprovide the opportunity to improve both the economic and environmental impact of current practice lees processing, with very significant reductions in water consumption and improvements in filtration efficacy and corresponding product quality.

As a case study, a whole of winery salt balance was used to estimate the sources of salt (sodium and potassium, Na and K) in a medium sized winery and several specific issues addressed, including salt concentration in the wastewater treatment train, caustic washes of red ferments and management of waste at the centrifuge. In this trial, the removal of potassium and sodium by way of the solids recovery at the centrifuge had no material impact on the salt loading of the wastewater treatment plant. However, solids recovery significantly reduced the COD entering the treatment plant.

As the wastewater system is largely open top, there is potential for concentration of wastewater by evaporation throughout the system, and particularly in the storage lagoon in hot dry months. In colder wetter months there is likely dilution of the effluent in the treatment plant and lagoon from incident rainfall. Concentration during the warm months has the potential to compromise the quality of the water for land application, which is at the time of year of highest wastewater volume production and when suitable irrigation water is likely to be most beneficial to a range of land uses including grapes. Cleaner production requires a focus not just on reduced water use and downstream treatment, but also on

reducing organic loading and salt (Na and K) loading by addressing these contaminants at the source level. It is critical to understand the importance of potassium for soils as the balance between sodium and potassium cleaners may need to be reviewed to reduce potassium levels, if the impact is in balance.

Recommendations

The new knowledge generated by this project must now be considered in terms of:

1. A concerted effort to extend the technical knowledge and tools to industry via road shows so that adoption can occur in all wine regions.

   This would highlight the benefits of

   a. Recycling cleaning agents;
   b. Reducing the number of movements of wine; and
   c. Improving lees filtration.

2. The road show would also give an update on ice pigging.
3. Update the operating guidelines based on the new information generated through this project with a view to reducing the wine industries industrial footprint while not imposing an economic cost.

Appendix 1: Online survey – questionnaire

1. Introduction and contact details

The Grape and Wine Research and Development Corporation (GWRDC) have a funded a project by CSIRO and The Australian Wine Research Institute (AWRI) to investigate technologies that may help wineries to reduce or recycle wastewater.

This survey is an initial part of the project intended to help identify technologies worthy of trials and detailed economic investigations.

In each section of the survey, please feel free to provide additional details to supplement your responses in the "Additional comments" field on each page of the survey.

1. Winery name

2. Winery address

Address 1:
Address 2:
City/Town:
State/Province:
ZIP/Postal Code:

3. Contact person

4. Position title

5. Email address

6. Phone number

2. General winery characterisation

These questions are designed to assess the size of the winery. Questions on inter-winery juice and wine transfers are included to take into account partial processing at other sites. Please use exact values where possible, but if not available please use an estimate.

1. Red grapes crushed per annum (tonnes)

2. White grapes crushed per annum (tonnes)

3. Purchased juice volume (kL)

4. Purchased bulk wine volume (kL)

5. Wine volume packaged for consumers (bottles, bag-in-box, etc.) on site per annum (Litres)

6. Water used on site per annum (Litres)

7. What are the sources of this water (% of total):

Mains	
Bore	
Direct abstraction from river	
Farm capture (dams)	
Abstraction from irrigation network	
Recycled onsite	
Recycled from another site	
Rain	

3. Wastewater treatment

This page is designed to understand how wastewater is currently processed at your winery.

1. Volume of water from winery flowing to wastewater treatment plant per annum (Litres)

2. Please estimate the COD in mg/L of your waste water at the following time points.

During Vintage (Feb-Apr)

Post Vintage Processing (May-Aug)

Off Vintage (Sep-Jan)

3. Are wastewater streams from different parts/process in the winery segregated in any manner or are all wastewater streams treated together? Please select all streams that are segregated from the main wastewater stream prior to the wastewater treatment plant.

- [ ] Cleaning chemicals
- [ ] Stormwater
- [ ] Bathroom and kitchen waste
- [ ] Roof water
- [ ] Different processing areas
- [ ] Other

4. Which pre-treatment processes do you practice at you winery?

- [ ] No pre-treatment
- [ ] Screening
- [ ] pH adjustment
- [ ] Filtration

5. Which primary treatment processes do you practice at your winery?

- [ ] Sedimentation
- [ ] Flotation
- [ ] Other

6. which secondary treatment processes do you practice at your winery?

- [ ] Aerobic lagoon
- [ ] Anaerobic lagoon
- [ ] Facultative lagoon
- [ ] Activated sludge process
- [ ] Sequencing batch reactor
- [ ] Bioreactor
- [ ] Other

7. Which tertiary treatment processes do you practice?

- [ ] Final filtration
- [ ] Disinfection (ozone, chlorine, UV etc.)
- [ ] Artificial Wetland
- [ ] Other

8. Where does treated wastewater go?(% of total):

Sewer/tanker	
Woodlot	
Vines	
Industrial reuse	
Waterway	
Reused in processing	
Other crops/pasture	
Lawns and gardens	
Evaporation	
Other (please specify)	

9. If you use treated wastewater for irrigation of vines, what conditions do you put on water quality and what observations have you made of the influence of water quality on yields, grape/wine quality, etc?

10. What problems/issues do you have with wastewater treatment at your winery?

4. Grape receival area practices

A previous project has identified that significant quantities of water may be employed in the grape receival area, particularly associated with pushing through individual must batches. To evaluate whether this is typical in Australian wineries please fill in the following.

1. When crushing white grapes and pumping to a drainer or press when do you push through with water and when do you push through with the next lot of grapes.

	Push through with water	Push through with next lot of grapes
Between grape lots from different vineyards but going into the same drainer/press load	◯	◯
Between grape lots from the same vineyard going into a different drainer/press load	◯	◯
Between grape lots from different vineyards going into a different drainer/press load.	◯	◯

2. When crushing red grapes and pumping to a fermentor when do you push through with water and when do you push through with the next lot of grapes.

	Push through with water	Push through with next lot of grapes
Between grape lots from different vineyards but going into the same drainer/press load	◯	◯
Between grape lots from the same vineyard going into a different drainer/press load	◯	◯
Between grape lots from different vineyards going into a different drainer/press load.	◯	◯

3. Additional comments

5. Vacuum pumps

In previous work at wineries it has been observed that liquid ring vacuum pumps can be major users of water. Water is employed for gland sealing and cooling. In wineries these vacuum pumps can typically be employed by rotary drum vacuum filters and in bottling.

1. Do you use liquid ring vacuum pumps at your winery?

- ◯ Yes
- ◯ No

2. If you use liquid ring vacuum pumps at your winery where are they used?

3. If you use liquid ring vacuum pumps, which type of water system do you use (select all methods that are employed in systems at your winery).

- ☐ No water recovery (water fed to the pump is discharged directly to wastewater after 1 pass)
- ☐ Partial water recovery (much of the water - perhaps 50% - is recirculated)
- ☐ Full closed loop water recovery (vast majority of water is recirculated)

6. Cleaning chemicals

Some wineries have changed from using soidum hydroxide to using potassium hydroxide as an environmental measure. Unlike sodium, potassium is a plant macro-nutrient, and where wastewater us reused it is reportedly preferentially taken up by crops.

1. What quantity of each of the following chemicals do you employ per annum (kg) ?

Sodium hydroxide (caustic)

Potassium hydroxide

Cleanskin

2. If you changed from using sodium hydroxide to potassium hydroxide for environmental reasons and use treated wastewater on vines, and other crops, etc. What observations have you made of this change in practice?

3. Do you reuse the sodium hydroxide or potassium hydroxide cleaning solutions within your winery.

◯ Yes

◯ No

4. What is the criteria for when to dispose of the recycled solution? (e.g. colour, pH, number of uses, cleaning effectiveness, etc.)

5. Additional comments

7. Wastewater problems, opportunities and technologies of interest

This project is trying to identify high cost to benefit ratio technologies that could be used in the wine industry that may help to reduce or recycle wastewater. We are interetsted in suggestions of technologies of interest to you.

1. Please list any technologies you have considered or thought about that may assist in reducing the amount of water used within the winery.

2. Please list any technologies which you have considerd or heard of which may help treat or separate wastewater at the unit process level.

3. Are you interested in technologies that may assist with

- [ ] Greater Segregation of wasetwater streams
- [ ] Pigging to prevent water mixing with must/juice/wine during transfers
- [ ] Choosing cut-out points between water and must/juice/wine during transfers
- [ ] Reducing water use through innovative cleaning solutions
- [ ] Cleaning chemical reuse

4. Additional comments

8. Winery Waste Water - Financial Implications

This project is seeking to identify practices and technologies which will enhance cleaner production within wineries. However, to maximise benefit for the Australian Wine industry the opportunites must be financially appropiate. This section of the survey will be used to establish what constitutes as 'financially appropiate.'

1. With the appropriate due diligence studies completed and with compelling evidence to indicate an improvement, would you be able to negotiate capital expenditure to minimise water and pollutant loading?

- [ ] Yes
- [ ] No

2. What is the upper limit on the capital expenditure you would realistically seek for a project related to cleaner production?

- [ ] $1-$2k
- [ ] $2-$5k
- [ ] $5-$10k
- [ ] $10-$20k
- [ ] $20-$50k
- [ ] $50-$100k
- [ ] Above $100k

3. What pay back period do you consider to be realistic for cleaner production projects?

- ◯ Half a year
- ◯ 1 year
- ◯ 2 years
- ◯ 3 years
- ◯ 4 years
- ◯ 5 or more years

Appendix 2: Economic evaluation of crusher push water re-use technology

Financial impact and NPV Calculations						Discount rate	10.0%
Capital Expenditure	**Supplier**	**Expected lifetime (years)**	**Year**	**0**	**1**	**2**	**3**
Pipe Work		15		-$ 9,000.00			
Poly Storage tanks		15		-$20,000.00			
Rotary Screen /Trommel Style		15		-$20,000.00			
Transfer Pump		10		-$3,000.00			
Ancillary	supporting infrastructure/works	20		-$5,000.00			
Total investment				-$57,000	$0	$0	$0
Total investment/KL wine				-$1.90	$0.000	$0.000	$0.000
Operating Expenses (per KL wine)	**Rate**	**Impact/KL wine**	**Unit**	**0**	**1**	**2**	**3**
No Impact		-	$	$0	$0	$0	$0
Total Operation Expenses ($)				**$0**	**$0**	**$0**	**$0**
Total operating costs (per KL wine)				$0.00	$0.00	$0.00	$0.00
Wine Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**
Wastewater Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**
Water Savings		652.000	$	$652	$593	$490	$368
Less waste volume to process		$ 6,525.00	$	$6,525	$5,932	$4,902	$3,683
Less grape matter to treat		14,104.040	$	$14,104	$12,822	$10,597	$7,961
Environmental Benefit				**$0.709**			
Total savings by adopting the technology ($)				**$ 20,629.04**	**$ 18,753.67**	**$ 15,498.90**	**$ 11,644.56**
			Year	**0**	**1**	**2**	**3**
Savings Less Expenses				**-$36,370.96**	**$18,753.67**	**$15,498.90**	**$11,644.56**
NPV of Savings less expenses				-$36,370.96	$17,048.79	$12,809.01	$8,748.73
Cummulative NPV ($)				-$36,370.96	-$19,322.17	-$6,513.16	$2,235.57
	2.8	**Years**					
y	**A(x)^2**	**b(x)**	**c**	**x**			
-4.5426E-05	**-889.93**	**13140**	**-32359**	**3.123314204**			

Appendix 3: Economic evaluation of ice-pigging technology

Financial impact and NPV Calculations						Discount rate	10.0%							
Capital Expenditure	**Supplier**	**Expected lifetime (years)**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ice pigging equipment		15		-$60,000										
Other	supporting infrastructure/works			-$10,000										
Total investment				-$70,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total investment/KL wine				-$3.50	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Operating Expenses (per KL wine)	**Rate**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Labour	Cellar manager		hrs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Winemaker		hrs											
	Cellar hand	145.000	hrs	-$5,059	-$5,059	-$5,059	-$5,059	-$5,059	-$5,059	-$5,059	-$5,059	-$5,059	-$5,059	-$5,059
Utilities	Electricity Ice Crushing Unit	2,102.500	kWh	-$252	-$252	-$252	-$252	-$252	-$252	-$252	-$252	-$252	-$252	-$252
	Electricity Reefer		kWh	-$2,000	-$2,000	-$2,000	-$2,000	-$2,000	-$2,000	-$2,000	-$2,000	-$2,000	-$2,000	-$2,000
	Water	-	L	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Consumables	ice	36	$	-$9,720	-$9,720	-$9,720	-$9,720	-$9,720	-$9,720	-$9,720	-$9,720	-$9,720	-$9,720	-$9,720
	Ethanol additive	435	$	-$435	-$435	-$435	-$435	-$435	-$435	-$435	-$435	-$435	-$435	-$435
Reefer hire	**4 months**	124	$	-$2,232	-$2,232	-$2,232	-$2,232	-$2,232	-$2,232	-$2,232	-$2,232	-$2,232	-$2,232	-$2,232
Total Operation Expenses ($)				-$19,698	-$19,698	-$19,698	-$19,698	-$19,698	-$19,698	-$19,698	-$19,698	-$19,698	-$19,698	-$19,698
Total operating costs (per KL wine)				-$0.66	-$0.66	-$0.66	-$0.66	-$0.66	-$0.66	-$0.66	-$0.66	-$0.66	-$0.66	-$0.66
Wine Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wastewater Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wastewater volume			L											
BOD		11,600.000	kg	$ 18,218.00	$ 18,218.00	$ 18,218.00	$ 18,218.00	$ 18,218.00	$ 18,218.00	$ 18,218.00	$ 18,218.00	$ 18,218.00	$ 18,218.00	$ 18,218.00
Na			kg	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
K		58.000	kg	$ 2,706.67	$ 2,706.67	$ 2,706.67	$ 2,706.67	$ 2,706.67	$ 2,706.67	$ 2,706.67	$ 2,706.67	$ 2,706.67	$ 2,706.67	$ 2,706.67
Must Savings		58,000.000	kg	$ 14,500.00	$ 14,500.00	$ 14,500.00	$ 14,500.00	$ 14,500.00	$ 14,500.00	$ 14,500.00	$ 14,500.00	$ 14,500.00	$ 14,500.00	$ 14,500.00
Water Saving		725.000	kL	$ 1,087.50	$ 1,087.50	$ 1,087.50	$ 1,087.50	$ 1,087.50	$ 1,087.50	$ 1,087.50	$ 1,087.50	$ 1,087.50	$ 1,087.50	$ 1,087.50
Total savings by adopting the technology ($)				$ 36,512.17	$ 36,512.17	$ 36,512.17	$ 36,512.17	$ 36,512.17	$ 36,512.17	$ 36,512.17	$ 36,512.17	$ 36,512.17	$ 36,512.17	$ 36,512.17
			Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Savings Less Expenses				-$53,186.29	$16,813.71	$16,813.71	$16,813.71	$16,813.71	$16,813.71	$16,813.71	$16,813.71	$16,813.71	$16,813.71	$16,813.71
NPV of Savings less expenses				-$53,186.29	$15,285.19	$13,895.63	$12,632.39	$11,483.99	$10,439.99	$9,490.90	$8,628.09	$7,843.72	$7,130.65	$6,482.41
Cummulative NPV ($)				-$53,186.29	-$37,901.10	-$24,005.48	-$11,373.09	$110.90	$10,550.89	$20,041.78	$28,669.88	$36,513.59	$43,644.25	$50,126.66
	1.9	Years												
y	A(x)^2	b(x)	c	x										
-1.84336E-07	-483.23	15053	-52609	4.011508193										

Appendix 4: Economic evaluation of Auto-cut sensor

Financial impact and NPV Calculations						Discount rate	10.0%							
Capital Expenditure	**Supplier**	**Expected lifetime (years)**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Auto cut out sensor		15		-$30,000										
Comissioning				-$15,000										
Other	supporting infrastructure/works			-$5,000										
Total investment				-$50,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total investment/KL wine				-$10.00	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Operating Expenses (per KL wine)	**Rate**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Time taken to fit valve		75	hrs	-$4,938	-$4,938	-$4,938	-$4,938	-$4,938	-$4,938	-$4,938	-$4,938	-$4,938	-$4,938	-$4,938
Time saved by not watching transfer interface		400	hrs	$26,335	$26,335	$26,335	$26,335	$26,335	$26,335	$26,335	$26,335	$26,335	$26,335	$26,335
Total Operation Expenses ($)				$21,397	$21,397	$21,397	$21,397	$21,397	$21,397	$21,397	$21,397	$21,397	$21,397	$21,397
Total operating costs (per KL wine)				$4.28	$4.28	$4.28	$4.28	$4.28	$4.28	$4.28	$4.28	$4.28	$4.28	$4.28
Wine Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wastewater Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Savings Less Expenses				-$28,602.85	$21,397.15	$21,397.15	$21,397.15	$21,397.15	$21,397.15	$21,397.15	$21,397.15	$21,397.15	$21,397.15	$21,397.15
Environmental Savings				-$1.43	-$1.43	-$1.43	-$1.43	-$1.43	-$1.43	-$1.43	-$1.43	-$1.43	-$1.43	-$1.43
NPV of Savings less expenses				-$28,602.85	$19,451.95	$17,683.59	$16,075.99	$14,614.54	$13,285.95	$12,078.13	$10,980.12	$9,981.93	$9,074.48	$8,249.53
Cummulative NPV ($)				-$28,602.85	-$9,150.90	$8,532.69	$24,608.69	$39,223.23	$52,509.17	$64,587.31	$75,567.43	$85,549.35	$94,623.83	$102,873.36
	0.7	Years												
y	A(x)^2	b(x)	c	x										
-1.48261E-06	-614.95	20387	-47640	2.529833489										

Appendix 5: Economic evaluation of Marc bay roofing

Financial impact						Discount rate	10.0%							
Capital Expenditure	**Supplier**	**Expected**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Winery Shed		25		-$55,000										
Other	supporting infrastructure/works			-$5,000										
Total investment				-$60,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total investment/KL wine				-$2.86	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Operating Expenses (per KL wine)	**Rate**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Labour	Cellar manager	0.000	hrs		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Winemaker		hrs		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Cellar hand	0.000	hrs		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Utilities	Electricity	-	kWh		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Gas		MJ		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Water	-	L		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
IT			$		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Consumables	Lubricant		$		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance	preventative		$		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Other			$		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total operating costs (per KL wine)					$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Wine Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wine volume	no change		L		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Wine quality	no change		$		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total wine impact (per KL wine)					$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Wastewater Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wastewater volume	3 severe rainfall (50mm) events per vintage		L		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
BOD		2,700	kg	$ 4,240	$4,240	$4,240	$4,240	$4,240	$4,240	$4,240	$4,240	$4,240	$4,240	$4,240
Na		45	kg	$ 6,300	$6,300	$6,300	$6,300	$6,300	$6,300	$6,300	$6,300	$6,300	$6,300	$6,300
K		45	kg	$ 2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100	$2,100
in Waste Treatment Costs ($ per site)				$ 12,640	$ 12,640	$ 12,640	$ 12,640	$ 12,640	$ 12,640	$ 12,640	$ 12,640	$ 12,640	$ 12,640	$ 12,640
wine)				$0.60	$0.60	$0.60	$0.60	$0.60	$0.60	$0.60	$0.60	$0.60	$0.60	$0.60
			Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Income less Expense				**-$ 47,360**	**$ 12,640**	**$ 12,640**	**$ 12,640**	**$12,640**	**$ 12,640**	**$ 12,640**	**$ 12,640**	**$ 12,640**	**$ 12,640**	**$ 12,640**
NPV				-$47,359.60	$11,491.27	$10,446.61	$9,496.92	$8,633.56	$7,848.69	$7,135.17	$6,486.52	$5,896.84	$5,360.76	$4,873.42
Accumulation				-$47,359.60	-$35,868.33	-$25,421.72	-$15,924.81	-$7,291.24	$557.45	$7,692.62	$14,179.15	$20,075.98	$25,436.75	$30,310.17
Payback (discount rate ignored)	4.7	Years												
y	a(x2)	b(x)	c	x										
-5.74561E-06	-363.28	11317	-46926	4.925175541										
NPV(Zero - Payback including discount rate)	4.9	Years			Calculate									
IRR(5 years)	10.0%				Calculate									

Appendix 6: Economic evaluation of Trommel screen

Financial impact and NPV Calculations						Discount rate	10.0%							
Capital Expenditure	**Supplier**	**Expected lifetime (years)**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Concrete Bunded Platform		15		-$22,000										
Chemical Proof Poly Tanks		15		-$20,000										
Skid mounted cleaning righ		10		-$15,000										
Other	supporting infrastructure/works			-$5,000										
Total investment				-$62,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total investment/KL wine				-$3.10	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Operating Expenses (per KL wine)	**Rate**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Filling and emptying of cleaning unit		520	hrs	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143
Analysis of tank concentration	Lab Testing	156.000	hrs	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252
Total Operation Expenses ($)				-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396
Total operating costs (per KL wine)				-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57
Wine Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wastewater Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Na		500	kg	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00
Total savings by adopting the technology ($)				$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00
			Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Savings Less Expenses				-$23,395.63	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37
Environmental Savings				-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17
NPV of Savings less expenses				-$23,395.63	$35,094.88	$31,904.44	$29,004.03	$26,367.30	$23,970.28	$21,791.16	$19,810.15	$18,009.22	$16,372.02	$14,883.66
Cummulative NPV ($)				-$23,395.63	$11,699.25	$43,603.69	$72,607.72	$98,975.02	$122,945.30	$144,736.46	$164,546.61	$182,555.83	$198,927.85	$213,811.50
	0.7	Years												
y	A(x)^2	b(x)	c	x										
-2.39467E-05	-1109.5	34563	-22070	0.652198601										

Appendix 7: Economic evaluation of cleaning chemical re-use technology

Financial impact and NPV Calculations						Discount rate	10.0%							
Capital Expenditure	**Supplier**	**Expected lifetime (years)**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Concrete Bunded Platform		15		-$22,000										
Chemical Proof Poly Tanks		15		-$20,000										
Skid mounted cleaning righ		10		-$15,000										
Other	supporting infrastructure/works			-$5,000										
Total investment				-$62,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total investment/KL wine				-$3.10	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Operating Expenses (per KL wine)	**Rate**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Filling and emptying of cleaning unit		520	hrs	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143	-$18,143
Analysis of tank concentration	Lab Testing	156.000	hrs	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252	-$13,252
Total Operation Expenses ($)				-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396	-$31,396
Total operating costs (per KL wine)				-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57	-$1.57
Wine Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Wastewater Impact	**Assumptions**	**Impact/KL wine**	**Year**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Na		500	kg	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00
Total savings by adopting the technology ($)				$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00	$ 70,000.00
			Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Savings Less Expenses				-$23,395.63	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37	$38,604.37
Environmental Savings				-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17	-$1.17
NPV of Savings less expenses				-$23,395.63	$35,094.88	$31,904.44	$29,004.03	$26,367.30	$23,970.28	$21,791.16	$19,810.15	$18,009.22	$16,372.02	$14,883.66
Cummulative NPV ($)				-$23,395.63	$11,699.25	$43,603.69	$72,607.72	$98,975.02	$122,945.30	$144,736.46	$164,546.61	$182,555.83	$198,927.85	$213,811.50
	0.7	Years												
y	A(x)^2	b(x)	c	x										
-2.39467E-05	-1109.5	34563	-22070	0.652198601										

Appendix 8: Polymaster Tank Quote



STANDARDSMARK LICENCE

SAI Global hereby grants:

Polymaster Pty Ltd

ABN 66086204892

161 Karinie Street, SWAN HILL, VIC 3585, Australia

StandardsMark Licence

Manufactured to:

AS/NZS 4766:2006 - Polyethylene storage tanks for water and chemicals

"the StandardsMark Licensee" the right to use the STANDARDSMARK as shown below only in respect of the goods described and detailed in the Schedule which are produced by the Licensee or on behalf of the Licensee* and which comply with the appropriate Standard referred to above as from time to time amended. The Licence is granted subject to the rules governing the use of the STANDARDSMARK and the Terms and Conditions for certification and licence. The Licensee covenants to comply with all the Rules and Terms and Conditions.

Certificate No:SMKP21429

Issued: 11 July 2011 **Originally Certified:** 14 January 2009

Expires: 13 January 2014 **Current Certification:** 11 July 2011

Duncan Lilley
Global Head Assurance Services

Alex Ezekhovich
General Manager – Certification Services

Certified Product
Australian Standard

JAS-ANZ

* For details of manufacture, refer to the licensee

The STANDARDSMARK is a registered certification trademark of SAI Global Limited (A.C.N. 050 644 642) and is issued under licence by SAI Global Certification Services Pty Limited(ACN 108 716 669) ("SAI Global") 286 Sussex Street, Sydney NSW 2000, GPO Box 5420 SydneyNSW 2001. This certificate remains the property of SAI Global and must be returned to SAI Global upon its request. Refer to www.saiglobal.com, for the list of product marks.

SAI GLOBAL

Appendix 9: Polymaster Chemical Storage Certification

Attn: Karl Forsyth
PH: 0409 098 092
AWRI
Level 1 262-276 Lorimer St
Port Melbourne, VIC 3207

Supply Offer: Caustic Recovery System Tanks

Dear Karl,

Following our recent visit and discussion regarding your caustic recovery application, I am pleased to provide you with this Supply Offer on our Certified Polyethlyene Tanks with the required fittings modifications.

Scope of Supply

Code	Description	Qty	Cost Ea	Totals
PST7100-1.5	7100L Process Tank constructd to 1.5SG with the following equipment installed to tank: • 63PE Welded Outlet 50NB MBSPT x2 • 50NB Double Union Chemical Ball Valve x2 • 400mm ¼ turn hinged and vented hatchway x1 • 90mm PVC Overflow Socket x1 • 50NB Flexible Top Fill assembly with Ball Valve x1	1	$2789.00	$2789.00
PST9000-1.5	9000L Process Tank constructd to 1.5SG with the following equipment installed to tank: • 63PE Welded Outlet 50NB MBSPT x2 • 50NB Double Union Chemical Ball Valve x2 • 400mm ¼ turn hinged and vented hatchway x1 • 90mm PVC Overflow Socket x1 • 50NB Flexible Top Fill assembly with Ball Valve x1	0	$3325.00	
PST13600-1.5	13,600L Process Tank constructd to 1.5SG with the following equipment installed to tank: • 63PE Welded Outlet 50NB MBSPT x2 • 50NB Double Union Chemical Ball Valve x2 • 400mm ¼ turn hinged and vented hatchway x1 • 90mm PVC Overflow Socket x1 • 50NB Flexible Top Fill assembly with Ball Valve x1	0	$4475.00	
LQ01	Tank Level Indicator Kit (Chemical Resistant)	1	$92.00	$92.00
FREIGHT	Indicative Freight Cost to regional Vic & SA Locations	1	$338.00	$338.00
TOTAL COST: 7100L Option Delivered to Geelong area (exc GST)				**$3219.00**

Thank you for your enquiry, we trust we have interpreted your requirements correctly and await your further direction.

Yours sincerely,

Cameron Craig

Industrial Sales

Appendix 10: Communication

The project team has been involved in the communication of project results in a number of manners.

Findings were presented as part of a workshop at the Australian Wine Environment Conference, Adelaide Showgrounds on the 19th of October 2011. On 22nd November 2012 at Australian Society of Viticulture and Oenology (ASVO) 2012, Simon Nordestgaard gave a presentation on Wine transfers. Based on this presentation an article has been written by Simon to be included in the ASVO Seminar Proceedings.

The project team has contributed significantly in the development of the tools and resources on the winery wastewater management and recycling. The details can be found at www.gwrdc.com.au/www.

In order to case studies and all findings to the wider wine industry, we have developed a Winery wastewater Research to Practice (RTP) program and delivered this as a workshop for the first time in the Hunter Valley on the 8th of December 2011. Discussions with the regional body in McLaren Vale are also occurring regarding the delivery of a Winery wastewater RTP in that region also. Short videos and photos for the project activities can be used to further promote these case studies.

Appendix 11: Performance against planned outputs and performance targets

Planned outputs and performance targets of the project are given below (Table). We were able to achieve all listed performance targets.

Table Output and performance targets of the project

Year 1 2010-2011	Output	Performance targets	Status and Report section
1.1	**Creation of project steering group and signing off the contract.**	**1.1.1** Identification of suitable members from wineries, suppliers and service providers.	Completed Attachment-1
		1.1.2 Initial meeting of project steering group to outline project scope and responsibilities.	
1.2	**Identification of high benefit to cost processing areas within the winery.**	**1.2.1** Preliminary winery site investigations and review of past work.	Completed Section 3.1
		1.2.2 Develop an online survey template and questionnaire.	Completed Appendix 1
1.3	**Identification of potential technologies and practices for further evaluation.**	**1.3.1** Survey the Australian wine industry. Report findings.	Completed Section 3.2
		1.3.2. Collation and documentation of cleaner production strategies and recommendations in literature including recent project work by the GWRDC and CSIRO.	Completed Attachment 2
		1.3.3 Field visits and phone communication to several wine regions and other industries investigating water and wastewater technologies.	Completed Attachment 3
1.4	**Evaluation of cleaner production processes using the rigorous assessment method.**	**1.4.1** Sorting and ordering of potential technologies.	Completed Section 3.3
		1.4.2 Identification of the relevant merits of each of the new technologies or methods, using a robust assessment method, including: ▪ Preliminary concept evaluation; ▪ Economic evaluation; ▪ Environmental evaluation; ▪ Engineering design;	Completed Sections 4.1-4.9 Attachment 4

		▪ Proof of concept. ▪ Bench-top wastewater analysis	
		1.4.3 Documentation of findings.	
		1.4.4 Selection of technologies for site investigation.	Completed Section 4.10
1.5	**Preliminary Site or Bench top Case Studies**	**1.5.1** Site mapping	Completed Chapter 4
		1.5.2 Analyses of wastewater	
		1.5.3 Analysis of water associated with these processes	
1.6	**Communication of results and findings to the industry and linkage with Project 1.**	**1.61** Documentation of findings in a formal report to GWRDC.	Completed
		1.6.2 Creation of fact sheets to present the findings on each technology or method assessed based on critical criteria.	Completed Attachment 8
		1.6.3 Selected photography and video presentation for communication and linkage with Project 1.	Completed Operating guideline documents

Year 2 **2011-12**	**Output**	**Performance targets**	
2.1	**Establishment of which wineries will participate in the case studies.**	**2.1.1** Identify and select two key wineries where successfully evaluated new technologies will be implemented.	Chapters-5-8; Case studies 1-4
		2.1.2 Investigate current water and wastewater management practices within these wineries. This will include base line wastewater sampling.	
		2.1.3 In conjunction with the selected wineries purchases necessary capital equipment to facilitate the implementation of new technologies.	
	Development and implementation of	**2.2.1** Commission and implement beneficial technologies into at least two large wineries.	Chapters-5-8; Case studies 1-4

2.2	**case studies.**	**2.2.2** Commission and implement beneficial technologies into at least the two small wineries.	
		2.2.3 Train winery staff to use the technology.	

Year 3	**Output**	**Performance targets**	**Status and Report section**
3.1	**Quantification of benefits.**	**3.1.1** Quantify the reduction in waste water volume and contaminant loading. **3.1.2** Identify the Economic and Environmental benefit.	Completed Chapters 4-8 Attachment 4
3.2	**Promotion of case studies and all findings to the wider wine industry.**	**3.2.1** Document findings in a formal report to GWRDC.	Completed
		3.2.2 Disseminate results to the wider Australian wine industry via road shows and regional workshops	Completed Attachment 6
		3.2.3 Promote wide spread implementation of beneficial technologies through technical conferences and papers.	Completed Attachments 5A and 5B
		3.2.4 Development of short videos and linkage with Project 1.	Completed Attachment 7
		3.2.5 Development of fact sheets to present finding on each technology.	Completed Attachment 8

Appendix 12: References

1. Ainslie E, Quarini GL, Ash A, Deans T, Herbert M, Rhys D. 2009. Heat Exchanger Cleaning using Ice Pigging. Proc. *Int. C. Heat Exchanger Fouling and Cleaning VIII*.
2. Coombe, B. & Iland, P. (1988) *Grape Berry Development and Winegrape Quality.* In *Viticulture Volume I: Resources,* B. Coombe & P Dry Eds, chapter 11, as referenced in www.wineskills.co.uk/winemaking/winemaking-knowledge-base/chemical-composition
3. Danckwerts PV. 1952. Continuous Flow Systems. Distribution of Residence Times. *Appl. Sci. Res.* 3:279.
4. Danckwerts PV. 1953. Continuous flow systems. Distribution of residence times. *Chemical Engineering Science* 2: 1-13.
5. Deans L. 2006. Opportunities to capture more value in the winemaking process. In: Allen M, Cameron W, Francis M, Goodman K, Wall G, Waters E and Quarisa J, eds., *Proceedings of ASVO seminar: Maximising the value – maximising returns through quality and process efficiency*. Adelaide, South Australia, 12 October 2006. pp. 11-17.
6. Deans L. 2007. Opportunities to capture more value in the winemaking process. ASVO Proceedings, 2007: 11-17.
7. Department of Primary Industries Victoria (DPI Vic) *Organic Viticulture: Part 5 Soil Management* http://www.dpi.vic.gov.au/agriculture/farming-management/organic-farming/organic-viticulture/organic-viticulture-manual/soil-management (accessed 5 October 2012)
8. Grape and Wine Research and Development Corporation, GWRDC (2011) *Case Study: Caustic Recovery Treasury Wine Estates – Ryecroft Winery McLaren Vale SA.* Prepared by DO Consulting for Peter R Day Resource Strategies Winery Wastewater Management and Recycling - Communications Project
9. Grape and Wine Research and Development Corporation, GWRDC (2012) Case Study Vacuum Pumps, Accessed 10 June 2012. (http://www.gwrdc.com.au/webdata/resources/files/CS-VacuumPumps.pdf)
10. Greaney, I. Decontamination of Pipework. Patent number EP1404464B1. 10.07.2001
11. GWRDC (2011) Case Study: Caustic Recovery Treasury Wine Estates. Ryecroft Winery McLaren Vale SA
12. Kiholm R. Pipe Pig formed of Frozen Product. Patent number US 6485577. 07.01.2000
13. Kumar A & Christen E (2009) *Developing a systematic approach to winery wastewater management. CSL05/02.* CSIRO. Adelaide SA. www.gwrdc.com.au/webdata/resources/project/CSL_05-02.pdf
14. Laurenson S and Houlbrooke D. 2012 *Review of Guidelines for the Management of Winery Wastewater and Grape marc.* Marlborough District Council, AgResearch Ltd.
15. Michalewicz M, Michalewicz Z and Spitty R. 2011. Optimising the wine supply chain. In: Blair R, Lee T and Pretorius S, eds., *Proceedings of the 14th Australian Wine Industry Technical Conference*. Adelaide, South Australia, 3-8 July 2010. pp. 75-79.
16. Patti AF, Issa GJ, Smernik R and Wilkinson K. 2009. Chemical Composition of Composted Grape Marc. *Water Sci Technol* 60(5):1265-1271
17. Peter D. 2011. *Operational Guidelines: Winery Wastewater Management & Recycling, The Grape and Wine Research and Development Corporation*.
18. Peter D. 2011. Operational Guidelines: Winery Wastewater Management & Recycling, The Grape and Wine Research and Development Corporation, 2011.
19. Quarini GL 11.01.2000. Cleaning and separation in fluid flow conduits. Patent number WO0151224A1:- EP1248689B1, US 6916383, JP 2003-519571A, KOR 1020020079774A Quarini J. 2002. Ice-pigging to reduce and remove fouling and to achieve clean-in-place. *Applied Thermal Engineering* 22: 747–753.

20. Quarini GL, Ainslie E, Herbert M, Deans T, Ash D, Rhys D, Haskins N, Norton G, Andrews S and Smith M 2010. Investigation and development of an innovative pigging technique for the water-supply industry. *Proc. IMechE, Part E: J. Process Mechanical Engineering* 224(2):79-89
21. Saunders MS, Takeda F, Bates RP & Regulski F. 1982. Composition and Utilization of Florida Grape Pomace. *Proceedings of the Florida State Horticultural Society* , 95:107-109
22. Shire GSF, Quarini GL, Rhys D and Evans TS. 2008. The anomalous pressure drop behaviour of ice slurries flowing through constrictions. *International Journal of Multiphase Flow* 34:510–515
23. Sydney Water The Liquid Ring Vacuum Pump, Accessed 5 June 2012. (www.sydneywater.com.au/Water4Life/InYourBusiness/FactSheets.cfm)
24. Taylor GI. 1954. The Dispersion of Matter in Turbulent Flow through a Pipe. *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences* 223:446-468 Tichacek LJ, Barkelew CH and Baron T. 1957. Axial Mixing in Pipes. A.I. Ch. E. 3:439-442.
25. TEFF (2008) Minimising Potassium Content of Winery Wastewater (Final Report). Tarac Environment Future Fund by JJC Engineering
26. Walker RR and Blackmore DH. 2012. Potassium Concentration and pH Inter-Relationships in Grape Juice and Wine of Chardonnay and Shiraz. *Australian Journal of Grape and Wine Research* 18(2):183-193
27. Wine Australia. 2012. Wine Export Approval Report, MAT June 2012. www.wineaustralia.com. Accessed August 2012. author, city report number missing

Appendix 13: Staff

Organisation	Staff Name	Position	Role
CSIRO	Dr Anu Kumar	Principal Research Scientist	Project Leader
AWRI	Mr Karl Forsyth	Senior Engineer	Chief Investigator
Do Consulting	Dr Darren Oemcke	Senior Engineer	Chief Investigator
AWRI	Mr Simon Nordestgaard	Senior Engineer	Team member
AWRI	Mr Warren Roget	Senior Engineer	Team member
AWRI	Mr Tadro Abbott	Senior Engineer	Team member
CSIRO	Miss Debra Gonzago	Research Support officer	Team member