APPENDIX 16

Wastewater Treatment Design and Reuse : Lucid Consulting

LCA for Wastewater Treatment Design and Reuse at Barossa Hotel - Lyndoch

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Lucid Consulting Australia

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Abbreviations

Abbreviation	Unit
%	percent
a	Annum/year
ABR	Anaerobic Baffled Reactor
ADF	average daily flow
ARI	Average Recurrence Interval
BOD_5	biological oxygen demand 5 days
Ca	Calcium
cfu	colony-forming unit
cm	centimetre
d	day
DLR	design loading rate
EP	effective people
EPA	Environmental Protection Authority
ETc	crop evapotranspiration
ETo	reference evapotranspiration
FAO	Food and Agriculture Organisation of the United Nations
g	gram
H	hydrogen
ha	hectare
K	potassium
Kc	crop coefficient
kg	kilogram
L	litre
L/d	litre per day
L/p/d	litre per person per day
m	metre
m^2	metre squared
Mg	magnesium
mg	milligram
mL	millilitre
ML	megalitre
mm	millimetre
N	nitrogen
Na	sodium
NH4-N	Ammonium
P	phosphorus
p	person
PAW	plant available water
PDF	peak design flow
SA	South Australia
STE	septic tank effluent
t	tonne
TDS	total dissolved solids
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
WD	water demand
WWTP	wastewater treatment plant
v	volume
yr	year
%	percent
a	Annum/year
ABR	Anaerobic Baffled Reactor

1 Executive Summary

The property located on Lot 102 Hoffnungsthal road near Lyndoch in the Barossa Valley is a rural property of about 21ha, partly planted with vines, with a creek flowing generally in a south/north direction. The Strategic Alliance Southern Barossa Winery and Accommodation Project for the property, will see the construction of luxury accommodation as well as a winery and cellar door for tastings and light meals. Various wastes will be generated from the activities at the site, wastewater from the Hotel and function area at the cellar door, and wastewater from the wine processing premises, both of which have different characteristics and will be handled differently. Lucid Consulting engaged Fluid Environmental to provide expertise on the wastewater treatment and disposal options at the site.

After an assessment of the different options, constraints and assets of the site, the approach taken for the sustainable management of the wastewater generated from the Strategic Alliance Southern Barossa Winery and Accommodation Project is to use a balance between wastewater treatment and onsite controls to meet the requirements for beneficial reuse for the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (NRMMC, EPHC, & AHMC 2006).

Further to this the beneficial reuse of recycled water will meet the requirements of the South Australian EPA Wastewater Irrigation Management Plan (WIMP). It is proposed that the recycled water will primarily be used for irrigation of wine grape vines and lucerne planted in the interrow and that water and nutrient balances are achieved in accordance with the guideline.

To this end, a bottom-up approach to the design of the wastewater treatment system has been taken. That is to say that the end use of the recycled water has been established and health and environmental risks are managed through the treatment and end use systems.

The total wastewater generation (Peak Design Flow -PDF) for the site as follows:

- 50.2kL/d for the Hotel
- 19.6kL/d for the winery and function centre (human wastewater only)
- The wine processing wastewater contributes to about 902kL per year

In total, this would equate to approximately 26.4ML/year.

For the human generated effluent, the treatment train will include.

- Separate primary treatment for the hotel and winery/function effluent streams;
- The secondary treatment will consist in a lined ABSORBS™ bed of 1400m^2 allowing for the collection of treated water and irrigation of vines and lucerne. A balance pump chamber will receive primary treated effluent from the hotel and winery/function treatment systems.
    - This will be dosed to the ABSORBS™ Advanced Secondary Treatment system, and
    - The dosing system will be timed and sequential with and average 2days hydraulic retention time in the ABSORBS™ filter;
- Gravity sewers will have 1day emergency storage tanks at peak design flow.
- Balance irrigation storage dam where treated hotel and winery/function recycled water will be blended with treated winery process recycled water for irrigation. The role of the dam will be to store winter treated recycled water for irrigation as required.

The dispersal area for the treated wastewater is the existing vineyards on site; further plantings will be undertaken in line with the site plan (Figure 2). In total, the area available for irrigation is 10.7ha. As stated earlier, the vineyards will be planted with lucerne in the interrow, to assist with water and nutrient balance. Over the wet winter months, the excess water will be stored in the dam on site (Figure 2 and Table 13).

The nutrient balance for the vineyard/lucerne crop association presents a deficit of 1449kg (N) /a and 22kg (P) /a. This indicates that the potential nutrient demand is greater than the nutrient supply as required by the SA EPA Wastewater Irrigation Management Plan (2009).

As there is a nutrient deficit, it will be important to assess the nutrient status of each crop with tissue analysis throughout the growing season. Supplementary fertilisation may be required to maintain good crop health, critically important for the modelled water and nutrient balances as well as for economical purposes. This will be included in the vineyard management plan when required.

This report demonstrates the sustainable management of treated effluent on the site as required by the SA EPA (2009). From a nutrient and water balance perspective the on-site management of wastewater presents a significant opportunity for water recycling (beneficial reuse) and savings for the managers/owners at the site, thereby minimising the impact of the development on the environment.

2 Introduction

Fluid Environmental Pty Ltd has been engaged by Lucid Consulting Australia to provide a wastewater treatment and disposal design for a new luxury Hotel Accommodation development in the Southern Barossa. The Barossa wine region is undoubtably one of South Australia's premier tourist destinations. It has many natural and developed attractions that ensures visitors to the region have an outstanding experience.

The proposed development is located at Lot 102 Hoffnungsthal road, Williamstown SA 5351. It consists of a hotel accommodation as well as a winery and cellar door in a separate building to the Hotel, all located on a 21ha property (Table 1).

Table 1 Land Zoning, Property Boundaries and Planning Specifications

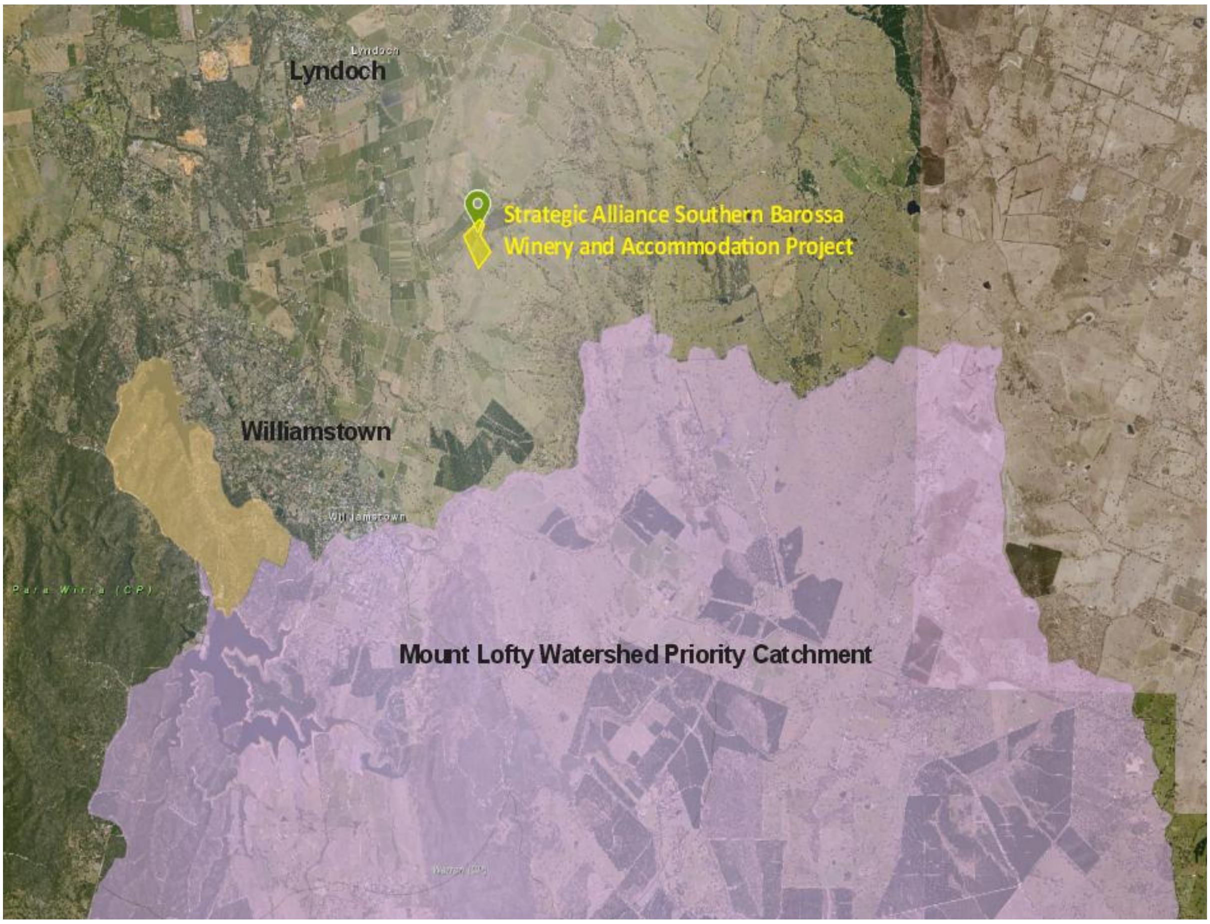
Site address	Lot 102 Hoffnungsthal road, Williamstown SA 5351
Local Government	The Barossa Council
Environment and food production area	Yes
Zoning	Rural
Lot size	21.29ha
Development proposal	Hotel (accommodation – conference room) ad Winery
Water supply	Water mains on Hoffnungsthal Road and water licences
Availability of sewer	No sewer mains
Anticipated wastewater volume	69.8kL/d
Others	
Hazards (bushfire)	High risk
Flooding	No evidence of flooding

Source: South Australian Property and Planning Atlas (SAPPA), https://sappa.plan.sa.gov.au/

The proposed development falls under the following Codes/Guidelines:

1. The wastewater application to the Department of Health is required to comply with SA Health (2013) Onsite Wastewater Systems Code and Australian Standard/New Zealand Standard (2012) 1547 On-site Domestic Wastewater Management, SA EPA Wastewater Management Plan guideline, The Australian Guidelines For Water Recycling: Managing Health and Environmental Risks (NRMMC, EPHC, & AHMC 2006), and
2. The proposed wastewater system must also meet the highest standards for environmental protection under the South Australia's Environment Protection (Water Quality) Policy 2015 and also more generally the *Environment Protection Act 1993* requirements, section 25 of the Act imposes a general environmental duty on anyone who undertakes an activity that pollutes, or has the potential to pollute, to take all reasonable and practicable measures to **prevent** or minimise environmental harm.

The new Hotel will be located outside of the Mount Lofty Ranges Water Protection Area as per the Location SA Viewer Map (accessed 17th June 2025) presented underneath.



Source: Location SA mapviewer

Figure 1 Location of the development site in relation to the Mount Lofty Ranges Water Protection Area

Lucid Consulting has provided that the Peak Design Flow (PDF) is 69.8kL/d. Our concept design is based on this PDF. This would equate to approximately 26.394ML/year.

3 Concept Proposal

In South Australia, there are approximately 40 secondary wastewater treatment systems approved by SA Health as of beginning of 2025. They provide various levels of treatment, are based on different techniques and are most suitable under different scenarios. An option assessment of all techniques and treatments available was carried out to find the most suitable and economical wastewater solution for the proposed development. This assessment is presented in Appendix A.

FE recommends that the wastewater treatment system includes a primary treatment system with the lined ABSORBS™ advanced secondary treatment system (DHW approval number: WWP-20106/2 and AS1546.3:2017 approval number: SMK41128), with disinfection and collection and reuse of treated wastewaters for irrigation of vineyards. The ABSORBS™ platform has been selected as the system does not require a system operator or significant ongoing servicing. Other significant benefits are outlined in section 4.2.

This concept ended up being chosen after extensive discussion with the Client and weighing up of options. The three main options that FE proposed, see Table 2, are described in a document prepared in February 2025 (Southern Barossa Winery and Tourist Accommodation Project, Fluid Environmental, 4 February 2025) and provided initially to Lucid Consulting. They are not discussed further in this document however, a summary of each of them is provided in Appendix B.

Table 2 Summary of wastewater design and dispersal concepts

	Wastewater treatment	Water storage	Dispersal
Concept 1	Lined ABSORBS	Yes (6-8ML)	Eucalyptus woodlot
Concept 2	Lined ABSORBS	None (soil – vadose zone- is the storage)	Eucalyptus woodlot
Concept 3	Lined ABSORBS	Yes (10.5ML)	Mostly existing vineyards, in association with lucerne.

The following focusses on Concept 3 and its feasibility, both in terms of water, nutrient balances and environmental sustainability. The various elements of the concept are illustrated in Figure 2.

4 Recycled Water Treatment System Design

The approach taken for the sustainable management of the wastewater generated from the Strategic Alliance Southern Barossa Winery and Accommodation Project is to use a balance between wastewater treatment and onsite controls to meet the requirements for beneficial reuse for the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (2006).

Further to this the beneficial reuse of recycled water will meet the requirements of the South Australian EPA Wastewater Irrigation Management Plan (SA EPA, 2009). It is proposed that the recycled water will primarily be used for irrigation of wine grape vines and lucerne and that water and nutrient balances are achieved in accordance with the guideline.

To this end, a bottom-up approach to the design of the wastewater treatment system has been taken. That is to say that the end use of the recycled water has been established and health and environmental risks are managed through the treatment and end use systems.

4.1 Wastewater Treatment System

There are three sources of wastewater for the site:

- Effluent (human) from the hotel complex, 50.2kL/d (PDF);
- Effluent (human) from the winery function centre, 19.6kL/d (PDF); and
- Treated wastewater from the wine production, 902kL/a.

The total annual Peak Design Flow is 26.4ML/a of which 25.5ML is human wastewater. The recycled water treatment system will only treat the effluent from the hotel and winery/function facility.

The winery effluent (production) is treated in a separate system and will be combined with the treated recycled water from the hotel and winery in the irrigation balance storage. Treated winery recycled water quality will achieve (source: Linney Engineering Services):

- pH 7-10
- TSS <100mg/L
- COD 200-500mg/L
- BOD_5 20-50mg/L
- EC 1.0-2.0dS/m
- Na <150mg/L
- K <150mg/L
- Total N <10mg/L
- Total P <5mg/L

For the human generated effluent, the treatment train will include.

- Separate primary treatment for the hotel and winery/function effluent streams;
    - The hotel will have 150kL of primary treatment, (approx. 3day hydraulic retention time at PDF), and
    - The winery/function system will have 60kL primary treatment capacity (approx. 3day hydraulic retention time at PDF);
- The ABSORBS™ will have a balance pump chamber that will receive primary treated effluent from the hotel and winery/function treatment systems.
    - This will be dosed to the ABSORBS™ Advanced Secondary Treatment system, and
    - The dosing system will be timed and sequential with and average 2days hydraulic retention time in the ABSORBS™ filter;
- Gravity sewers will have 1day emergency storage tanks at peak design flow.

- Balance irrigation storage dam where treated hotel and winery/function recycled water will be blended with treated winery process recycled water for irrigation. The role of the dam will be to store winter treated recycled water for irrigation as required.

Figure 2 Wastewater design concept, layout and site plan

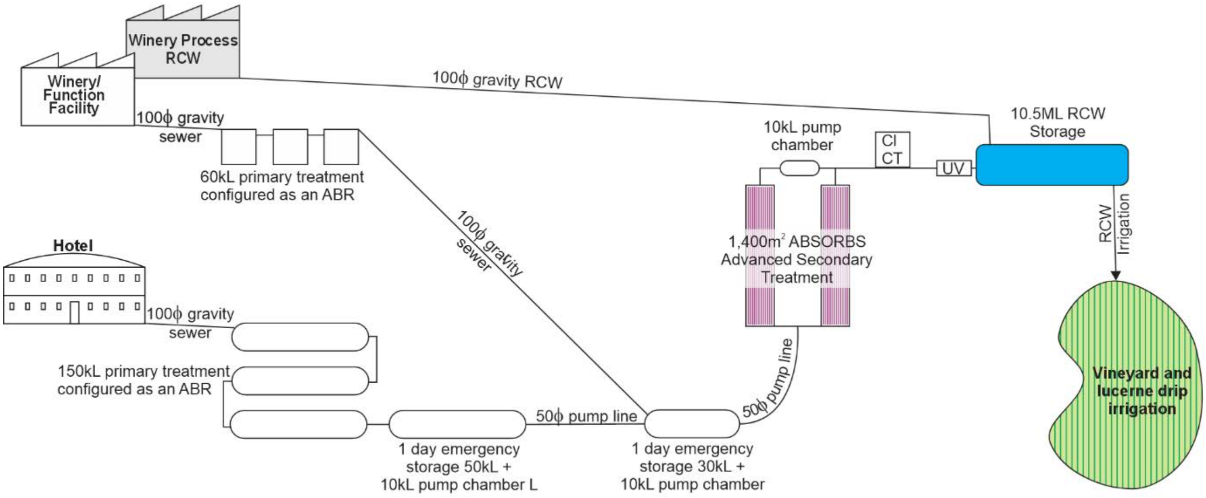


Figure 3 Wastewater Treatment Process Flow Schematic

4.2 System design benefits

Design benefits include:

- Low noise, all pumps adjacent sensitive receptors, other than irrigation pumps, are installed underground. Water transfer pumps are less than 1.1kW.
- No odour, the system is installed subterranean with mixing vents to mitigate odour risk.
- 50% lower operating greenhouse gas carbon footprint compared to conventional mechanical aerobic treatment systems (more environmentally friendly). ABSORBS™ system components are manufactured locally in South Australia (Aussie made) and can be manufactured from 100% recycled plastic, further enhancing the environmental credentials and lowering the carbon footprint of ABSORBS™ compared to other systems (circular economy benefits).
- Patented 'dual zone' effluent dispersal technology, maximising wastewater aeration, treatment and dispersal. Unique pipe trivets elevate the dosing pipelines 150 mm above the distribution bed, preventing root intrusion. Root intrusion is the number one cause of premature failure in other conventional sub-surface wastewater dispersal technologies.
- Lowest running costs of any advanced secondary approved system in the Australian market, achieved through intelligent passive design approaches and no mechanical aeration. Low energy requirement, transfer pumps 3 x 1.1kL @ 250L/min will operate 200min/d, $5.10/day, ABSORBS™ dosing pump 7.5kW @ 500L/min will operate 140min/d, $8.80/day)
- Improved amenity compared to mechanical aerobic systems, with no noise, no odours and no visual impacts (fully underground system with no surface irrigation and no visual impact).
- Tested and certified to AS 1546.3:2017 to perform at 'advanced secondary' quality effluent (≤10/10/10 mg/L BOD5/TSS/turbidity) under mild temperate climatic conditions (zone 6 region, operating ambient temperature range −4 to 41°C), so suitable for cool to cold climate zone applications.
- ABSORBS™ achieves partial nutrient reduction performance, with reductions in total nitrogen and total phosphorous during treatment at some 24% and 30% respectively (protecting sensitive environmental assets) (Appendix C).
- Low operator requirement with scheduled servicing every 30days
- Low maintenance the only mechanical components are the water transfer pumps with a combined runtime of less than 6hours per day to treat 70kL per day.
- >90% conversion of ammonia to nitrate in the filter bed. This is the first step in denitrification and a significant advantage in chlorine disinfection as ammonia reacts with

chlorine to form chloramines which reduces the concentration of free chlorine decreasing disinfection efficiency.

4.3 Recycled Water

The SA EPA WIMP requires that there is beneficial reuse of treated wastewater, as the site is an operational wine grape vineyard the treated wastewater will be reused for irrigation, a combination of grapevines and inter row lucerne.

The water quality targets for recycled water quality required for grapes under drip irrigation is provided in Table 3 (AGWR 2006), where Log reduction Targets are exceeded with the On-site Preventative Measures log reduction values. These values are provided and do not need validation.

Disinfection will be required to meet the microbial quality of the treated water, as provided in Table 3.

Table 3 Recycled Water Quality Requirements

Parameter	Log Values			Comment/treatment requirement
	Virus	Protozoa	Bacteria	
Log Reduction Targets (AGWR table 3.8)				
Crops with no ground contact and heavily processed (grapes for wine production)	**6.0**	**5.0**	**5.0**	The target log reduction for the combined wine grape and lucerne production is LRVs for grapes as it has the highest requirement.
Landscape Irrigation (lucerne)	5.0	3.5	4.0	
Treatment Pathogen Reduction (LRV)				
Chlorine Disinfection	LRV values for free chlorine disinfection are not required to meet AGWR requirements. It is included to demonstrate meeting the disinfection required for Ecoli			
Water Quality Objectives (WQO)	BOD_5 <20mg/l TSS/30mg/L *E.coli* <1,000CFU/100mL			To achieve WQO *E.coli* <1,000CFU/100mL disinfection will be required. WQO for BOD_5 and TSS will be achieved with the primary and advanced secondary treatment train prior to disinfection.
On-site Preventative Measures (LRV) (AGWR Table 3.8)				
Crops with no ground contact and heavily processes (eg grapes for wine production)	6.0	6.0	6.0	The sum of the LRVs for the on-site preventative measures meet or exceed the log reduction targets.
Public in the vicinity of Irrigation area with subsurface irrigation for landscaped (Lawned) areas	6.0	6.0	6.0	

Note: storage log reductions are allowed for in meeting the LRTs. It is recognised that the dam storage will reduce pathogens but is not required rather seen as additional control.

4.4 Chlorination

Taking raw effluent to have *E. coli* of 10^6 to 10^8CFU/100mL, and secondary treated effluent to be 10^4 to 10^6CFU/100mL then to achieve the required <1,000CFU/100mL a 3log reduction is required. Albeit, the 3log reduction value is not required to meet the log reduction target (6.0 (V), 5.0 (P), 5.0

(B) (Table 3) as these can be met with on-site control measures. However, there is a secondary requirement to have disinfection so the treated wastewater has *E.coli* <1,000CFU/100mL (Table 3).

WaterVal provides that for treatment and log reduction calculations are required for chlorine contact time (CT). For water with pH <8, turbidity <2NTU and temperature over ≥15°C, a CT of 10.0 is required for a 3Log Reduction Bacteria and Virus (WaterRA, 2017).

However, using a 50,000L unbaffled tank (top inlet and opposite bottom outlet) with a baffling factor (BF) 0.3 with a flow of 6L/s (360L/m)

- Tank volume/flow rate (L/min) = 138.9minutes
- Using a unbaffled tank BF = 0.3, T = 41.6minutes -- Calculated from US EPA (2020) Table G1

To achieve a CT of 10.0 at the outlet [Cl] of 0.25mg/L is required. A low [Cl] has been selected as concentrations of >0.2mg/L can be phytotoxic.

Free chlorine residual levels for wine grapes have not been established and is a knowledge gap (Stevens et al 2009). In Table 4, it can be seen that the chlorine threshold concentration for a range of plants is >1mg/L (Zheng,2008). Only seedlings had a lower threshold, <1. Therefore, maintaining a disinfection [Cl] of <1 is likely to be safe for grapes where the water is applied on soil.

Table 4 Plant Chlorine Threshold

Chlorine threshold ($mg{\cdot}L^{-1}$)	Plants	Reference
< 1	Vegetable seedling	Frink and Bugbee, 187
≤ 2	Vegetables	Brown, 1991
2.9	Ornamental crops	Skimina, 1992
4	Rose	Poncet et al., 2001b
4	Gerbera, rose	Poncet et al., 2001b
4	Gerbera, rose	Poncet et al., 2001b
< 5	Zinnia, chrysanthemum	Bridgen, 1986
10	Kentucky bluegrass sod, snapdragon	Brown, 1991
20-40	Tobacco	Karaivazoglou et al., 2005
> 0.1	Herbaceous crops	Brennan et al., 1996
> 0.4	Chrysanthemum and rose	Nelson, 2003
> 0.5	Weed	Brennan et al., 1996
> 1	Pine tree	Brennan et al., 1996
> 1	Tree	Coder, 2004
> 2	Begonia, geranium	Frink and Bugbee, 1987
> 5	Impatiens, marigold	Brown, 1991
> 5	Potted plants	Krone and Weinard, 1931
> 7.6	Zinnia seedling	Bridgen, 1986
> 8	Pepper, tomato	Frink and Bugbee, 1987
> 15.2	Mums	Bridgen, 1986
> 18	Kalanchoe, lettuce, tradescantia	Frink and Bugbee, 1987
> 37	Broccoli, petunia.	Frink and Bugbee, 1987
> 50	Sweet pepper	Ehret et al., 2001
> 77	English ivy, Madagascar palm, Swedish ivy	Frink and Bugbee, 1987

Source Zheng, 2008

The feasibility of a recycling water scheme depends not only on the treatment characteristics but also on the nature of the receiving environment and the water and nutrient balances to ensure that no excessive drainage or nutrient loads is encountered.

5 Site Characteristics

5.1 Climate

Climate data was retrieved at SILO (longpaddock.qld.gov.au) for the following point: -34.65° S, 138.9° E, which is located 3 km from the site (Source: SILO
Figure 6).

Figure 4 and Figure 5 show key climate characteristics for the site that influence water balance modelling and irrigation. It can be seen that Reference Evapotranspiration (ET_o) and rainfall are an inverse of each other. That is to say rainfall is high when ET_o is low and vice versa. For this reason winter water storage is required.

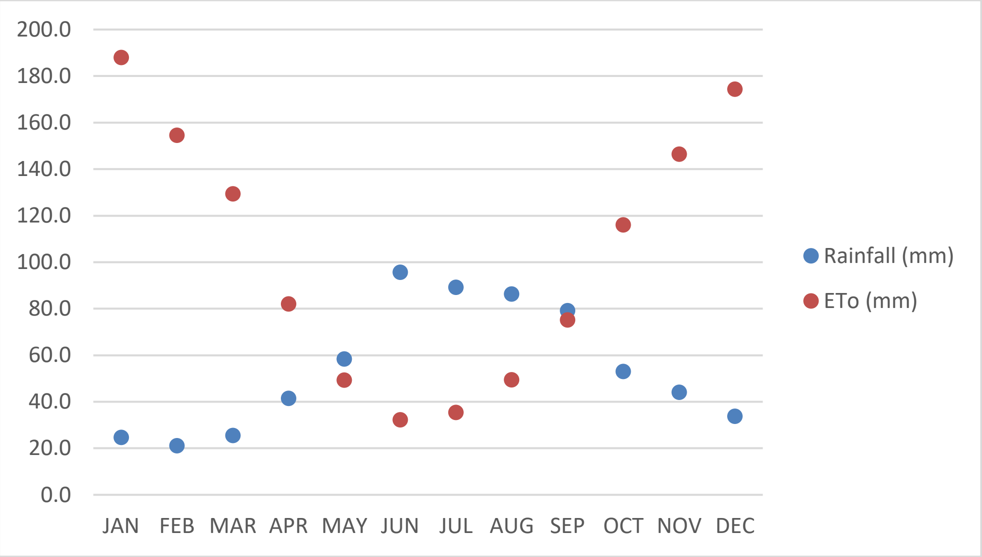


Figure 4 **Monthly statistics for rainfall and evapotranspiration (both in mm) for the Lyndoch area based on 40 years of data (1985-2024)**

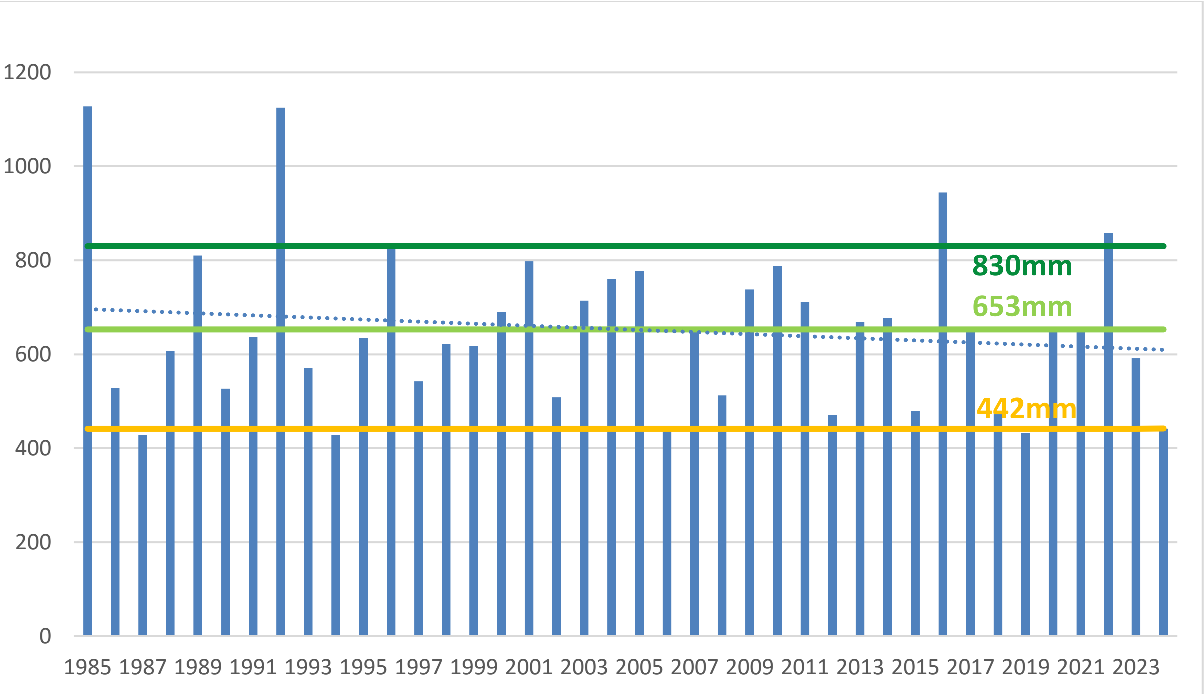
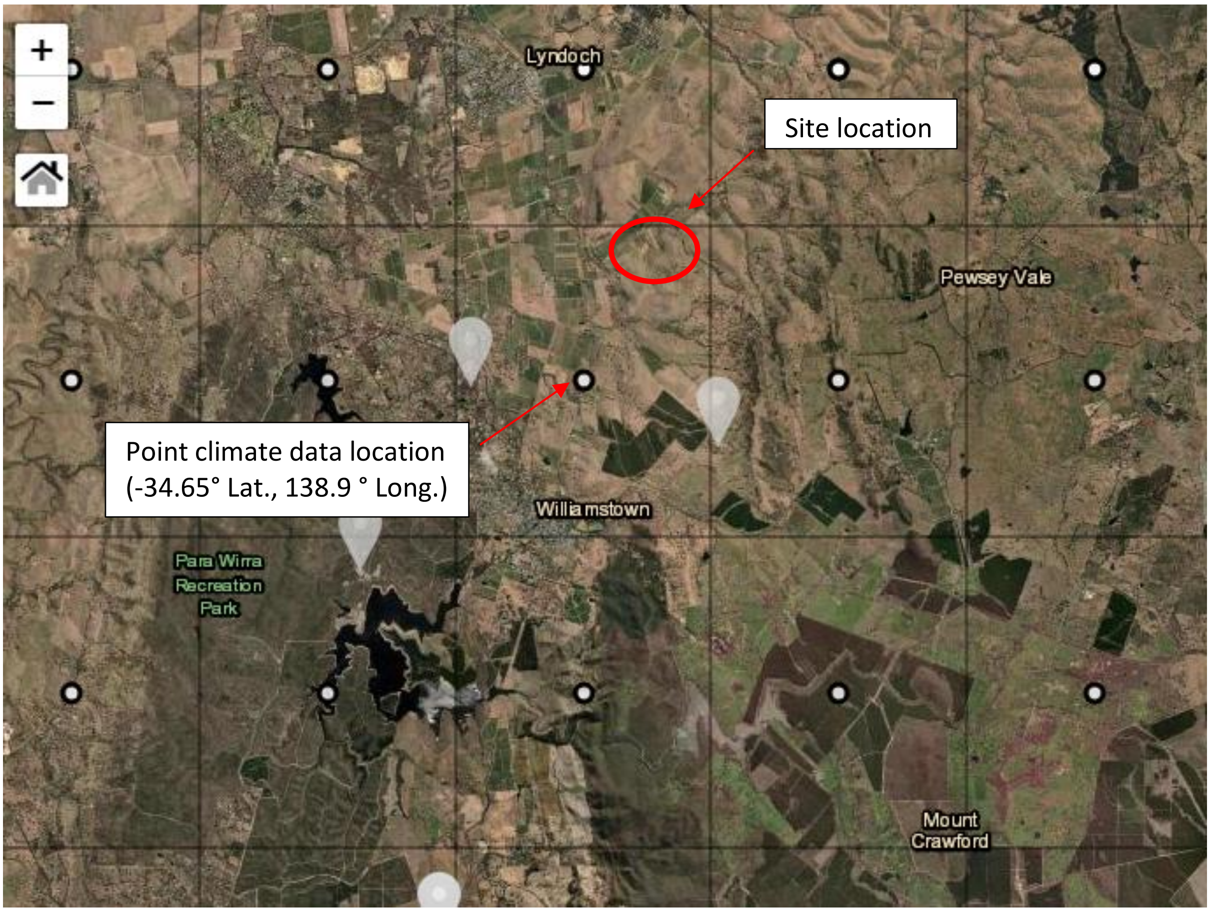


Figure 5 **Monthly statistics for rainfall (mm) and Decile 9 rainfall (dark green), average (light green) and Decile 1 (orange)**



Source: SILO

Figure 6 Location of point data for climate data

5.2 Topography of the site

The site is located on a slopy terrain with the slope running up towards the South and South-East of the block.

The elevation of the block ranges between approximately 235m-270m (estimation not based on a survey but from the contour map).

5.3 Position of surface waters

As can be seen in Figure 7, a creek flows directly in the middle of the property, in a South-North direction.

5.4 Bores

One irrigation bore is present on the property (Figure 7 – Label 662812578). Standing water levels as well as water quality data for samples collected at this bore are presented in Appendix D.

5.5 Groundwaters

Groundwater in the region is relatively shallow between 5-10m deep (BIL, 2001). The standing water levels of the bore at the site show that the levels fluctuate (seasonally) between 2-3m and more than 30m over the last 40 years. The long-term trend shows that levels have been continuously decreasing, groundwater is deeper (Appendix D).

The location of the bore is seen on Figure 7, represented by the blue circle with the label 662812578.

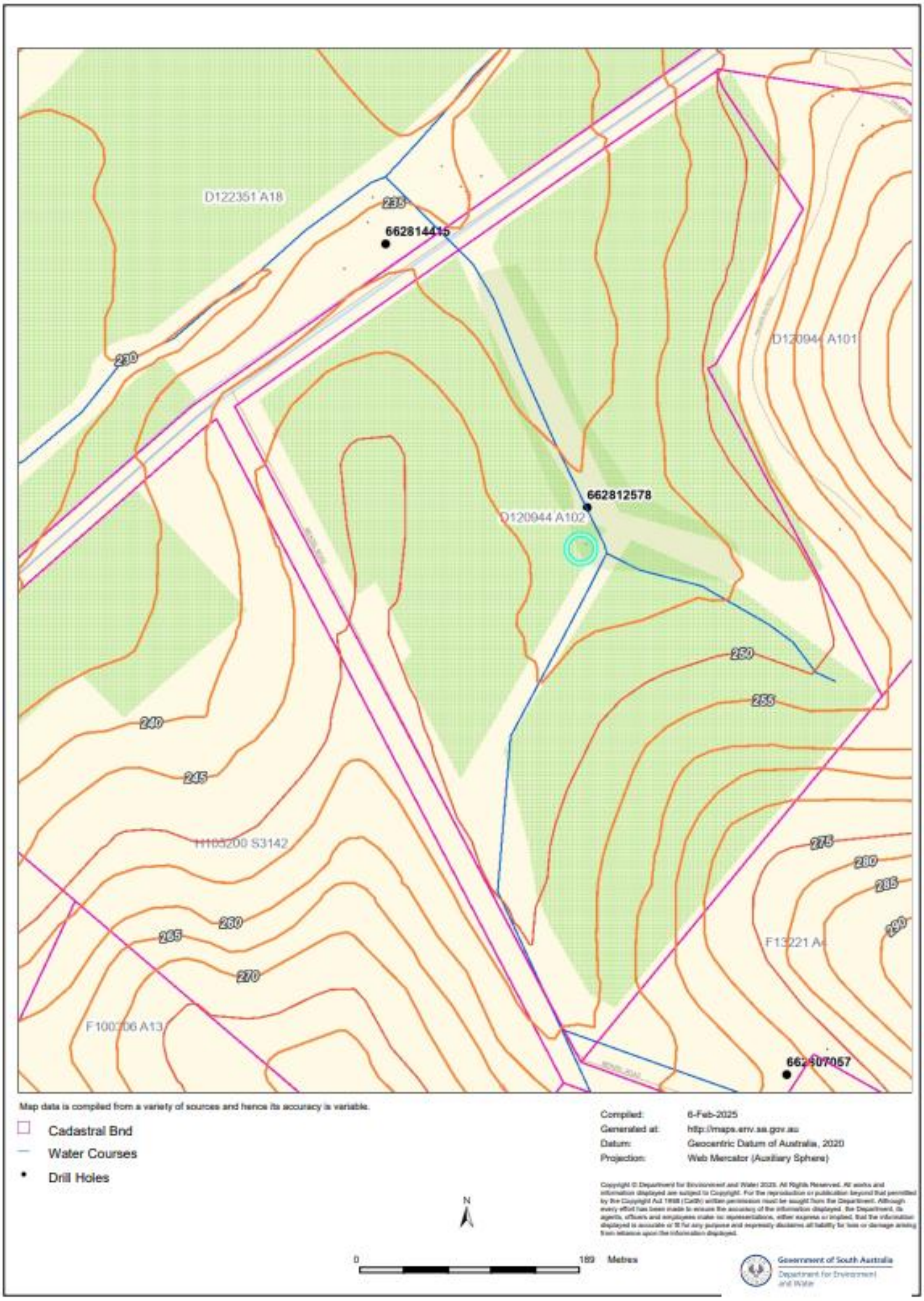


Figure 7 Topographical map of the site with 5m contours

5.6 Soils

The information contained in this paragraph are derived from a desktop study of publicly available data, sourced on the Department of Environment and Water Naturemaps portal. There are 4 main soil types over the property are described in Table 5 and shown in Figure 8. They all have a common characteristic of presenting a loam surface soil over a heavier textured lower horizon (clay type).

Table 5 Soil attributes from desktop study

Soil type (see Figure 8)	
	LYNDBC (light blue section): Loam over clay on rock LYNJUB (orange section): Loam over red clay GlGltJ (central non coloured section): Loam over brown or dark clay GLGAyC (light green sections): Acidic sandy loam over red clay on rock
Soil physical condition attributes	
Depth to hard rock	Main: >150cm - NW section: 50-100cm
Surface/subsoil limitation	Main: negligible – NW section: hard setting, sealing surface/negligible subsoil limitation
Water repellence:	Negligible to minor
Deep drainage potential	
Depth to impeding layer	>150cm
Soil erosion attributes	
Mass movement (landslip)	Negligible affected and no potential
Land affected by gully erosion	C: 5-10%
Water erosion potential	C: moderate (engineered works needed)

Source: NatureMaps

Figure 8 Soil units present at the development site

6 Water Balance for the Irrigation of Recycled Water

6.1 Wastewater volumes

Lucid Consulting has provided the Peak Design Flow (PDF) for the site as follows:

- 50.2kL/d for the Hotel
- 19.6kL/d for the winery and function centre (human wastewater only)
- The wine processing wastewater contributes to about 902kL per year (source: Linney Engineering Services).

In total, this would equate to approximately 26.4ML/year.

Note about the wine processing water: It contributes to 3.4% pf the total wastewater production. In this document, we have considered them to be part of the total wastewater production, with respect to the water and nutrient balance however we understand that this waste stream might be kept separately.

Table 6 Wastewater production across the Hotel, function centre and winery

Source of wastewater		Jan	Feb	Mar	Apr	May	Jun	Jul
Days	**kL/d**	31	28	31	30	31	30	31
Hotel*	50.2	1556.2	1405.6	1556.2	1506.0	1556.2	1506.0	1556.2
Winery/Function Centre*	19.6	608.8	549.9	608.8	589.2	608.8	589.2	608.8
Winery Production WW**		53.0	64.0	259.0	105.0	59.0	29.0	38.0
Total Monthly WW (kL/mth)		2218.0	2019.5	2424.0	2200.2	2224.0	2124.2	2203.0

Source of wastewater	Aug	Sep	Oct	Nov	Dec	Total	%	Data Source
Days	31.0	30.0	31.0	30.0	31.0	kL/a		
Hotel*	1556.2	1506.0	1556.2	1506.0	1556.2	18323.0	69%	Lucid
Winery/Function Centre*	608.8	589.2	608.8	589.2	608.8	7168.6	27%	Lucid
Winery Production WW**	57.0	53.0	65.0	70.0	50.0	902.0	3%	Linney Eng.
Total Monthly WW (kL/mth)	2222.0	2148.2	2230.0	2165.2	2215.0	26393.6	100%	

*Source: Lucid Consulting
**Source: Linney Engineering Services

6.2 Wastewater quality

As there is no data with respect to water quality, an examination of the literature on wastewater quality has been undertaken to provide a better understanding of the nutrient load of the wastewater and to be able to model its sustainable management (See Appendix E). For the purpose of modelling wastewater quality of **80mg/L of N and 15mg/L of P** has been used.

6.3 How the water balance is calculated

The dispersal area for the treated wastewater is the vineyards present on site (some area might have to be planted, Figure 2).

In total, the area available for irrigation is 10.7ha (9.9ha wine grape and lucerne + 0.8ha lawn), for water balance modelling 9.9ha has been used. We propose that the vineyards be planted with lucerne in the interrow, to assist with water and nutrient balance (Figure 9). Furthermore, the presence of vegetation in the interrow provides many benefits as detailed below.

6.3.1 Interrow management in a vineyard

Soil surface and interrow management practices in vineyards are varied, depending on a range of conditions. They include leaving the midrow (or interrow) bare, leaving also the vine row bare, mulching either/or the under row or interrow, having an annual cover crop in the interrow or a mown perennial crop, having a continuous interrow crop.

The benefits with respect to soil surface physico-chemical properties, water and nutrient management depend on the management practices adopted. It is an extensive area of research, in Australia and internationally. The general effects can be summarised as below:

Table 7 Effects of soil surface management on soil properties that affect vine performance

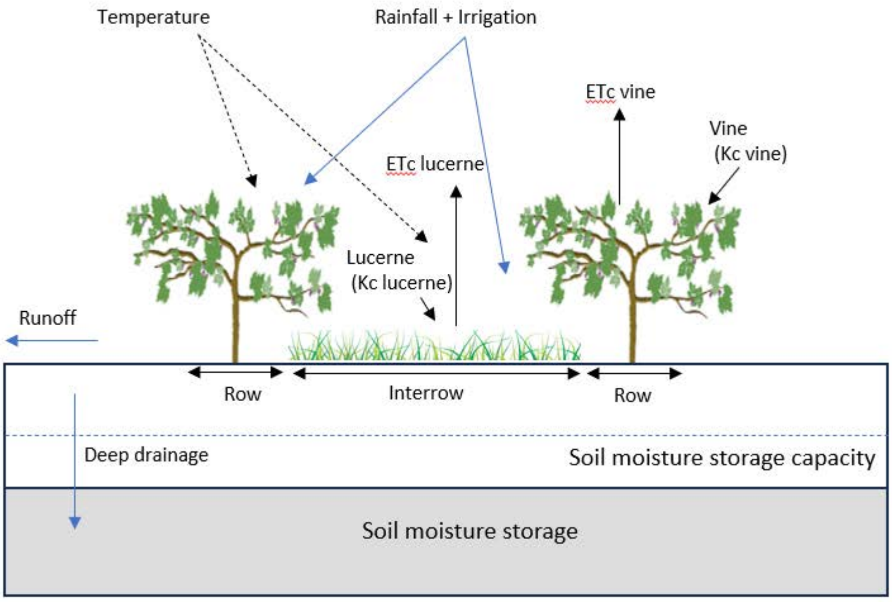
Symbols: -: negative effect, +: positive effect, |: no effect

Management practice	Water and storage availability	Improved aeration and drainage	Penetrability and porosity	Control of salinity and sodicity	Increased chemical fertility	Improved structural stability	Higher soil temperature
Bare interrow surface	--	--	--	-	--	---	+
Bare under vine row	-	-	--	-	-	-	+
Mulched vine row or interrow	++	++	+	++	+	++	-
Interrow annual cover crop	-	--	---	-	-	---	|
Interrow mown perennial crop	+	++	+	+	++	++	|
Continuous interrow crop	---	+++	++	+	++	++	|

Source: Lanyon et al., 2004

As can be seen from Table 7, the effect of interrow planting on soil surface conditions, that would ultimately positively affect vine performance, are multiple. This has been described by many other researchers (cited in Darouich et al., 2022).

Not mentioned in this Table also are the effects of interrow planting on the partition of rainfall between surface runoff and infiltration (thereby influencing soil erosion and the whole water balance).



Source : Photo supplied by B. Carrocci

Figure 9 Conceptual model (top) for the vine + lucerne system water balance and vineyard/lucerne interrow illustration in Padthaway (bottom)

6.3.2 Parameters of the water balance

Crop specific coefficient Kc

A daily water balance is modelled using the widely used evapotranspiration model based on Food and Agricultural Organisation (FAO) Drainage and Irrigation Paper 56 (FAO, 1998) where water demand (WD) is calculated using:

$$WD = K_c \times ET_o,$$

With:

K_c = the crop specific coefficient (see Figure 9), and

ET_o =- the reference evapotranspiration calculated from site specific climate data for a well-watered grass, using the Penman Monteith equation (Figure 10).

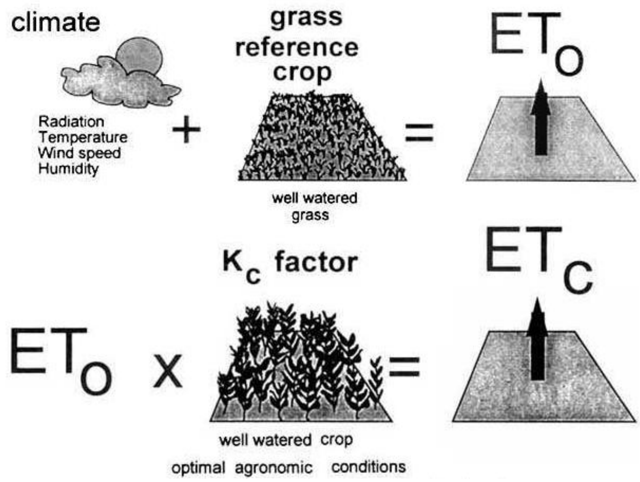


Figure 10 Schematic showing the FAO water demand model

Source: Allen et al., 1998

Crop association combined Kc

Refer to Line 1.f in Table 10

Specific to this case is the use of a crop association, lucerne in the interrow and vines in the row, each with their own specific Kc.

Therefore, a combined Kc has been derived as:

$$Kc_{\text{vine+Lucerne}} = : Kc_{\text{vine}} \times f_{\text{vine}} + Kc_{\text{Lucerne}} \times . f_{\text{Lucerne}}$$

Where:

f_{vine} = fraction of soil covered by vine

$f_{Lucerne}$ = fraction of soil covered by lucerne

Kc, particularly that of vineyards, is changing throughout the year, based on the different stages of vine development: non-growing phase, the initial stage of development, mid- and late season stages, as reflected in Table 8.

Table 8 Crop coefficient for vine and lucerne

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Vine development stage	Mid season			Late season	Non growing				initiation		Developing	
Vine												
Kc_{Vine}*	0.42	0.43	0.43	0.15	0.00	0.00	0.00	0.00	0.00	0.28	0.35	0.42
f_{Vine}*	0.30	0.30	0.23	0.23	0.05	0.05	0.05	0.05	0.20	0.20	0.30	0.30
lucerne												
$Kc_{Lucerne}$**	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
$f_{Lucerne}$*	0.65	0.65	0.77	0.77	0.85	0.85	0.85	0.85	0.75	0.75	0.65	0.65
Combined Kc	0.91	0.91	1.02	0.96	1.02	1.02	1.02	1.02	0.90	0.96	0.89	0.91

* adapted from Darouich et al., 2022 for vineyards with permanent grass cover interrow in a mediterranean climate
**Agriculture Victoria, 2017

The combined Kc is what is used for the water balance calculations.

Reference evapotranspiration (ET_0) and rainfall

Refer to Lines 1.a and 1.e in Table 10

Both these parameters have been sourced from SILO data (longpaddock.qld.gov.au) on a daily basis for the last 40 years (1985-2024). Daily values have been summed for each month, and averaged over 40 years.

From the 40 years of data, the Decile 9 rainfall year (wet year), average and Decile1 rainfall year (dry year) have been extracted.

Net effective rainfall

Refer to Line 1.b in Table 10

Not all rainfall is effective and can be assigned to meeting crop water needs. Effective rainfall is considered to be the amount of rainfall that infiltrates into the soil, contributes to soil water storage and hence is available to meet plant water requirement (PIRSA ICMS (2009), Max Thomas (1991) and Brouwer et al. Heibloem (1986)).

There are a number of factors that influence the effective rainfall including, soil structure, topography, plant characteristics, canopy, capture soil characteristics (temperature, structure, texture, …).

When assessing the effective rainfall for the Lyndoch site the PIRSA ICMS (2009), Max Thomas (1991) and Brouwer et al. (1986) give effective rainfall to be between 65-85%, calculated to be 66.6% and 10-70% respectively. The Max Thomas model has been used as it is more dynamic and reflects wet and dry season effective rainfall.

Soil water storage

Refer to Line 1.j in Table 10

Even though field investigations have not been undertaken yet, some information was retrieved from Naturemaps indicates that the site is located on the soil landscape map units where the most common soil is loam over brown or dark clay or Loam over clay on rock.

Therefore, for the purpose of water balance and soil storage, the soil is considered:

- a loam (0-15cm – Layer A)
- a medium clay (15-3m – Layer B).

Water storage properties are provided in Table 9

Table 9 Plant Available Water Content of different Textured Soils and Depths

Soil Textural Class	Soil Water Content v/v					
	Sands	Sandy loams	Loams	Clay loams	Light clays	Medium-heavy clays
Layer A						
Saturation	0.37	0.42	0.41	0.39		
Drained upper limit	0.27	0.34	0.25	0.35		
Lower limit	0.1	0.11	0.07	0.15		
Available Storage (v/v)	0.17	0.23	0.18	0.2		
PAW content in 0-2m	0.34	0.46	0.36	0.4		
Layer B						
Saturation			0.36	0.36	0.41	0.43
Drained upper limit			0.34	0.27	0.35	0.38
Lower limit			0.13	0.12	0.23	0.18

Available Storage (v/v)		0.21	0.15	0.12	0.2
PAW content	2-4m	0.42	0.3	0.24	0.4
	2-6m	0.84	0.6	0.48	0.8
	2-8m	1.26	0.9	0.72	1.2
	2-10m	1.68	1.2	0.96	1.6

Modified from: Myers *et al*, 1999
Pink cells correspond to the properties relevant to the soils at the site: loam over clay.

Note: that for the water balance model in Table 10, only the first meter (1m) of soil has been considered. This is important as the model has been designed to assess deep percolation (>1m) for assessment of leaching fraction.

Albeit the roots of grapes can and do exceed 1m the majority of roots are found in the top metre of soil (Matheson,2019).

6.3.3 Interpretation of the results of the water balance

The water balance is provided underneath for the decile 9 (wet), average and decile 1 (dry) rainfall year. It can be seen in Table 10 that there is overall a water deficit for the vine and lucerne association but an excess of water over 4 months, June through to September, with respect to crop water demand (lines 1.h, 2.h, 3.h).

This excess water could be stored in the soil (Lines 1.j, 2.j, 3.j, constant between the three models as it does not depend on rainfall or irrigation but is a characteristic of the type of soil only). **However, it will be stored in the dam on site and used in Summer.**

In an average rainfall year, the water deficit for the crop association is more important (785mm/year). According to the model, no deep percolation will occur, past the first meter of soil (line 2.l). Nevertheless, even though soil storage of excess water in winter is possible, as stated previously the water will be stored in a dam and reused over the summer months.

Table 10 Water balance model for the irrigation of vineyard and lucerne at the site per hectare

Line	1985-2024		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1.a	**Decile 9 (1996)**	RF (mm)	24.1	9	40.9	30.7	15.4	202.4	144.1	140.8	149.2	41.7	7	21.9	827
1.b		Net Eff RF (mm)	23	6.5	32	21	10	123	85	87	98	33	5	21	545
1.c		Wastewater application (mm)	22.4	20.4	24.5	22.2	22.5	21.5	22.3	22.4	21.7	22.5	21.9	22.4	267
1.d		Water for Irrigation (mm)	45.4	26.9	56.5	43.2	32.5	144.5	107.3	109.4	119.7	55.5	26.9	43.4	811
1.e		ETo (mm)	188.3	158.6	135.8	62.5	50.8	32.5	32.1	43.7	69.9	117.9	147.9	180.3	1220
1.f		Kc	0.906	0.909	1.0229	0.9585	1.02	1.02	1.02	1.02	0.9	0.956	0.885	0.906	
1.g		ET_{Crop}	170.6	144.2	138.9	59.9	51.8	33.2	32.7	44.6	62.9	112.7	130.9	163.4	1146
1.h		**Water Deficit (mm)**	**125.2**	**117.3**	**82.4**	**16.7**	**19.4**	**0.0**	**0.0**	**0.0**	**0.0**	**57.2**	**104.0**	**120.0**	**642**
1.i		*RF Percolation (mm)*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*111.3*	*74.5*	*64.9*	*56.8*	*0.0*	*0.0*	*0.0*	*307*
1.j		*Soil Storage (mm)*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	
1.k		*Water in Soil Storage (mm)*	*0*	*0*	*0*	*0*	*0*	*111*	*186*	*197*	*197*	*140*	*36*	*0*	
1.l		*Deep Percolation, >1m (mm)*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*54*	*57*	*0*	*0*	*0*	*110*
2.a	**Average (1991)**	*RF (mm)*	26.2	0	15.3	39.2	8.6	173.5	98.2	127.5	91.9	6.3	43	7.4	637
2.b		Net Eff RF (mm)	23	0	12	29	6	97	55	80	61	3	35	6	407
2.c		Wastewater application (mm)	22.4	20.4	24.5	22.2	22.5	21.5	22.3	22.4	21.7	22.5	21.9	22.4	267
2.d		Water for Irrigation (mm)	45.4	20.4	36.5	51.2	28.5	118.5	77.3	102.4	82.7	25.5	56.9	28.4	674
2.e		ETo (mm)	183.3	182.1	130.3	80.8	51.1	30.5	33.4	42.4	72.6	128.3	146.4	170.5	1252
2.f		Kc	0.99	0.99	1.085	1.0275	1.02	1.02	1.02	1.02	0.96	0.99	0.93	0.93	
2.g		ET_{Crop}	181.5	180.3	141.4	83.0	52.1	31.1	34.1	43.2	69.7	127.0	136.2	158.6	1238
2.h		**Water Deficit (mm)**	**136.1**	**159.9**	**104.9**	**31.8**	**23.7**	**0.0**	**0.0**	**0.0**	**0.0**	**101.5**	**79.3**	**130.2**	**767**
2.i		RF Percolation (mm)	0.0	0.0	0.0	0.0	0.0	87.3	43.2	59.2	13.0	0.0	0.0	0.0	203
2.j		*Soil Storage (mm)*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	
2.k		*Water in Soil Storage (mm)*	*0*	*0*	*0*	*0*	*0*	*87*	*131*	*190*	*197*	*96*	*16*	*0*	
2.l		*Deep Percolation, >1m (mm)*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*6*	*0*	*0*	*0*	*6*
3.a	**Decile 1 (2024)**	RF (mm)	39.9	0	3	6.1	13.1	94.1	82.5	58.3	43.1	61.8	29.8	9.8	442
3.b		Net Eff RF (mm)	35	0	0	4	8	58	52	39	30	49	25	9	309
3.c		Wastewater application (mm)	22.4	20.4	24.5	22.2	22.5	21.5	22.3	22.4	21.7	22.5	21.9	22.4	267
3.d		Water for Irrigation (mm)	57.4	20.4	24.5	26.2	30.5	79.5	74.3	61.4	51.7	71.5	46.9	31.4	576
3.e		ETo (mm)	184.4	164.2	145.1	74.1	58.7	33	37	61.6	78.1	126.8	148.7	190.6	1302
3.f		Kc	0.99	0.99	1.085	1.0275	1.02	1.02	1.02	1.02	0.96	0.99	0.93	0.93	
3.g		ET_{Crop}	182.6	162.6	157.4	76.1	59.9	33.7	37.7	62.8	75.0	125.5	138.3	177.3	1289
3.h		**Water Deficit (mm)**	**125.2**	**142.2**	**132.9**	**49.9**	**29.4**	**0.0**	**0.0**	**1.4**	**23.3**	**54.0**	**91.4**	**145.9**	**796**
3.i		RF Percolation (mm)	0.0	0.0	0.0	0.0	0.0	45.8	36.5	0.0	0.0	0.0	0.0	0.0	82
3.j		*Soil Storage (mm)*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	*197*	
3.k		*Water in Soil Storage (mm)*	*0*	*0*	*0*	*0*	*0*	*46*	*82*	*81*	*58*	*4*	*0*	*0*	
3.l		*Deep Percolation, >1m (mm)*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

7 Salinity and Leaching

The application of irrigation water brings with it number of contaminants that are in the water (Appendix G). Some of these contaminants can be beneficial to crop production, for example nutrients (N, P, K, etc), this is particularly true when irrigating with recycled water. Other contaminants can have a negative impact on the crop, for example salt: During the irrigation season, tons of salt may be applied to a crop. For example, irrigated potatoes on the Northern Adelaide Plains with 700mm (7mL/ha) of irrigation 7.679t of salt is applied (Table 11).

The management of salt and the maintenance of 'good soil condition' is critical to sustainable irrigation and is well understood. When discussing crop water balance, a Leaching Fraction (LF) must be included. **This is the term given to the application and deep percolation of irrigation and/or rainfall to remove salt from the crop rootzone. In other words, this is the process of applying an amount of water over and above the crop requirement**.

This practice maintains soil salinity at acceptable concentrations (DERM 2019).

Table 11 Contaminants applied in Irrigation water on the Northern Adelaide Plains

Nutrient	Irrigation Applied (mm)									
	Conc. mg/L	300	400	500	600	700	800	900	1000	
Nitrogen	8.2	25	33	41	49	57	66	74	82	Contaminant applied kg/ha
Phosphorus	1.2	3	5	6	7	8	9	10	12	
Potassium	46.8	140	187	234	281	328	374	421	468	
Calcium	39.9	120	160	200	239	279	319	359	399	
Magnesium	30.8	92	123	154	185	216	246	277	308	
Sodium	275.0	825	1100	1375	1650	1925	2200	2475	2750	
Chloride	382.0	1146	1528	1910	2292	2674	3056	3438	3820	
Boron	0.4	1.1	1.4	1.8	2.2	2.5	2.9	3.2	3.6	
Salt	1,097	3,291	4,388	5,485	6,582	7,679	8,776	9,873	10,970	

Source: Kelly et al (2001)

The planned application of irrigation water has to exceed field capacity to the extent that deep drainage can occur. This process is crucial in removing accumulated salt from the rootzone of the crop. It is important to understand that regardless of the contaminant contained in soil. Water transport is generally the only vector of transmission (movement). This is true for plant nutrient moving towards roots or for the removal of contaminants through managed leaching.

Leaching fraction does not need to be applied every year, soil salinity should be measured as a best practice and leaching fraction applied as required.

7.1 Determination of Leaching Fraction

The average root zone salinity threshold for vines is 1.8dS/m and 2.0dS/m for lucerne (ANZECC&ARMCANZ 2000). The ANZECC 2000 guidelines provide a range of threshold salinities from 1.8-3.6dS/m depending on rootstock. For the calculation the Threshold EC_{se} of 1.8dS/m will be used as a conservative threshold for both Vines and lucerne.

It is assumed that the treated recycled water will have a salinity (EC_i) of <1.6dS/m or TDS of <1,000mg/L (calculated).

There are nearly as many ways to calculate leaching fraction as there are grape varieties. Two leaching fraction calculation/tables are used as demonstration:

1) The Rhoades and Loveday calculation $Fc = EC_{e\ threshold} / EC_i$
$= 1.8 / 1.6$
$= 1.125$

Where: FC = Concentration Factor
$EC_{e\ threshold}$ = Crop average soil salinity threshold
ECi = Irrigation Water Salinity

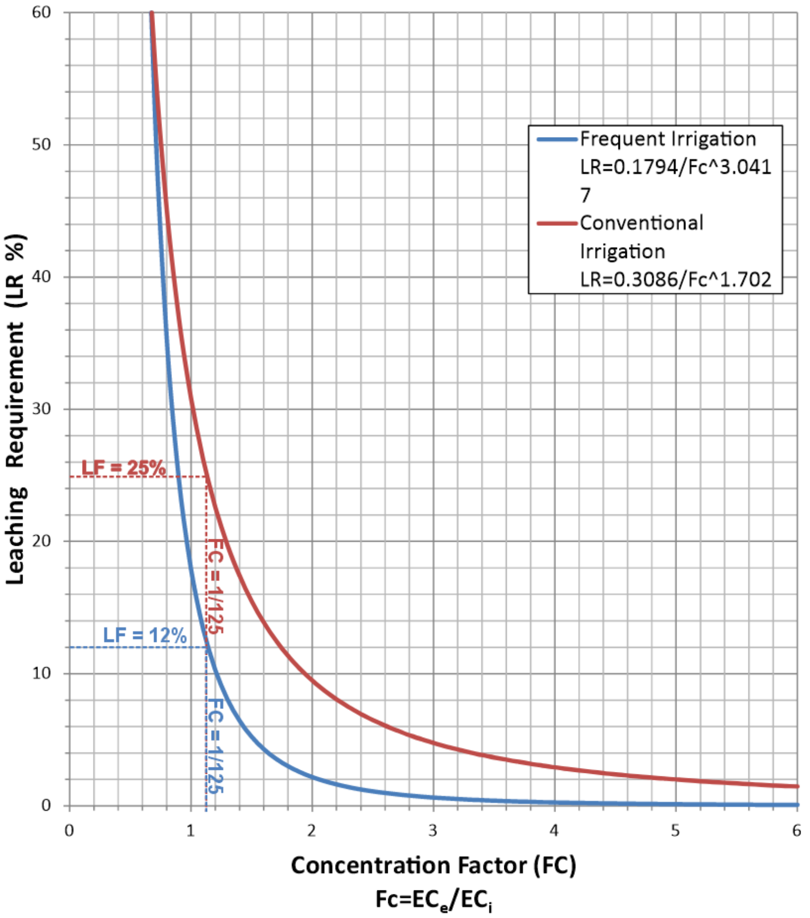
When plotted a leaching fraction of between 12% and 25% is required depending on irrigation regime (Rhoades and Loveday 1990) (Figure 11).

2) The use of tables, DERM 2019 provides a table of Leaching Factors (Table 12)

Table 12 Rough guide to how leaching fraction varies with soil properties

Soil texture	Assumed LF	Range
Sand	0.4	0.3-0.6
Loam	1.15	0.1-0.3
Light clay	0.15	0.05-0.2
Heavy clay	0.1	0.05-0.5
Clay soil with heavy clay subsoils or very poor structure with poor subsoil wetting	0.05	0.005-0.1

Source: DERM, 2019



Source: Rhoades, Loveday (1990)

Figure 11 Plot of Leaching Requirement vs Concentration Factor

For a loam soil such as the one in the Lyndoch region, there will be a requirement of for a leaching fraction between 12% and 25% (Table 12 and Figure 11). In the case of the vineyard with production of high quality grapes with reduced irrigation, the total salt load will be lower so leaching requirement will likely be at the lower end of that range.

The water balance model (Table 10) has a 15% average leaching fraction over the Decile 1 and Decile 9 rainfall years. This is inclusive of irrigation and rainfall but the leaching fraction is calculated on irrigation application alone.

Leaching fraction can be determined over time once the relationship irrigation and soil salinity is established over time. An adaptive management approach will ensure that sustainable irrigation practices will be adapted to maintain 'good soil conditions'.

8 On site Recycled Water Storage

The conventional wisdom for recycled water projects is that winter storage is required when rainfall exceeds evapotranspiration (EPA SA, 2009; Thomas, 1991) for flow balancing. The storage will enable the mixing of the different streams of treated wastewater from the Hotel, Winery/Function facility and Winery process wastewater balancing water qualities for vine irrigation.

The modelling of the storage requirements has been designed to cope with a Decile 9 rainfall year and a 1:10 ARI (annual recurrence interval) storm as required by EPA SA (2009). As the modelling treats monthly rainfall as a single event it exceeds the 1:10 ARI storm requirement.

To model the winter storage requirement a winter water storage calculator has been used (Thomas,1991). The inputs include:

- Rainfall (Decile 9) for contribution to water volume in storage;
- Pan Evaporation for evaporative losses from the dam;
- Effective rainfall (Decile 9) for irrigation requirement;
- Combined crop coefficient $KC_{vines + Lucerne}$;
- Reference Evapotranspiration ET_o for calculation of monthly irrigation requirement
- 9.9ha irrigation area;
- Dam size 35.5m x 100m, 3m deep

The storage requirement is for 10.284ML, rounded to 10.5ML in a 3,550m^2 storage 2.9 metres deep with 0.5m freeboard (Table 13).

Table 13 Calculation of recycled water storage requirement

90th percentile rainfall year (1996)	Unit		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Comments
Evaporation (Pan)	mm	A	244.4	210	182.3	79.4	62.6	42.5	42.3	55.9	96.2	147.6	180.6	228.6	1572	Silo Climate data drill for Lyndoch
Reference Evapotranspiration (ETo)	mm	A1	188.3	158.6	135.8	62.5	50.8	32.5	32.1	43.7	69.9	117.9	147.9	180.3	1220	Reference evapotranstiration used is calculated by BOM.
Rainfall (Annual 90th Percentile)	mm	B1	24.1	9	40.9	30.7	15.4	202.4	144.1	140.8	149.2	41.7	7	21.9	827	Silo Climate data drill for Lyndoch. 90th-ile rainfall year is 1996
Effective Rainfall	mm	B2	23	6.5	32	21	10	123	85	87	98	33	5	21	544.5	Table 7A (pg. 45) from EPA Victoria Publication 168.
Potential Evapotranspiration (I x A1)	mm	C1	170.6	144.2	138.9	59.9	51.8	33.2	32.7	44.6	62.9	112.7	130.9	163.4	1145.7	ETcrop = Eto * Kc
Irrigation Requirement (C1-B2)	mm	C2	147.6	137.7	106.9	38.9	41.8	0.0	0.0	0.0	0.0	79.7	125.9	142.4	820.9	Negative figures are shown as zero.
Net Evaporation from lagoons [10(0.8A-B1) x Lagoon area (ha)]	kL	D	608.5	564.5	372.5	116.5	123.1	-597.8	-391.4	-341.1	-256.5	271.1	488.1	571.5	1529.1	Total loss from lagoon. -ve cells where rainfall exceeds evaprorative losses
Volume of wastewater	kL	E	2218.04	2019.52	2424.04	2200.2	2224.04	2124.2	2203.04	2222.04	2148.2	2230.04	2165.2	2215.04	26393.6	Wastewater generation, Winery/Function + Hotel + Winery Production
Total water for irrigation (E-D)	kL	F	1609	1455	2052	2084	2101	2722	2594	2563	2405	1959	1677	1644	24865	
Area Required for Irrigation (F/10C2)	ha	G	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	Set to 9.9ha of wine grape and lucerne irrigation
Cumulative Storage [F + Balance - (10C2 x G)]	kL	H	-	-	-	-	-	2,722	5,316	7,880	10,284	4,352	-	-	10,284	Maximum Storage Requirement (kL) With 20% buffer, 35.5 (w) x 96 (l) x 3 (d)m
Crop Coefficient		I	0.906	0.909	1.0229	0.9585	1.02	1.02	1.02	1.02	0.9	0.956	0.885	0.906	-	Weighted crop coefficient for vines and lucerne
Lagoon area	m^2	J	3,550		Depth of lagoon to meet storage requirement and freeboard				3.4	m	Freeboard		0.5	m		Depth of lagoon with freeboard

Modified from: Thomas (1991)

9 Nutrient Balance

The Wastewater Irrigation Management Plan (WIMP) (SA EPA 2009) guideline requires that the nutrient additions for irrigation and the nutrient removal for crop production are balanced and that the system does not become overloaded with excess Nitrogen (N) and/or Phosphorus (P).

Simply:

$N_{removed} > N_{applied}$ and
$P_{removed} > P_{applied}$

Nitrogen removal processes will include plant uptake, atmospheric losses, fixation by soil organic matter, volatilisation in high pH soil, clay fixation and more generally soil attenuation.

Recycled water application is 239mm/yr or 2.63ML/ha. For the water and nutrient balance model combined with the client's desire to produce high quality grapes a low irrigation regime has been advocated and modelled.

There are two different system when it comes to the plant removal of nutrients within the vineyard. The grapevine and the lucerne production. As the lucerne is grown inter row 2m wide in a 3m vine trellising only 66.6% of the area will have productive lucerne. Further to this there is significant shading of the lucerne in the grape productive period.

The first step in the calculation of nutrient balance is to establish nutrient generation. There are three wastes streams that produce nutrient in put into the system:

1. Winery/Function, 7.2ML/a
2. Hotel, 18.3ML/a
3. Winery Treated, 0.9ML/a

Total wastewater generation is 26.4ML/a (Table 15)

The second step is to calculate the nutrient removal by crops.

9.1 Lucerne nutrient removal

Assumptions:

- For 5 months of the year (winter dormant months of the grape vines) there will be full production of the lucerne as there will be negligible impact from the grape vines; and
- For 7 months of the year, there will be a reduction in the production of lucerne due to shading and competition for water, estimated as 40% reduction. Therefore annually, lucerne production would be approximately 50% of full production conservatively estimated at 20t DM/ha. This is reflective of a PIRSA Trial in Barmera SA with a Mediterranean climate where the inter lucerne production was 11t/ha (55%) with 5 cuts (Humphries et al, 2009).

As a summary:

- lucerne production: 10t DM/ha/year,
- Nitrogen removal: 30kg N/t (Table 14)
- Phosphorus removal: 3kg P/t (Table 14).

Both nutrient removal rates were derived as a mid-range value from the references cited in Table 14.

Table 14 Nutrient removal per harvestable portion

Plant Part	N	P	Source
Grapes (kg/t)	1.5	0.3	Proffitt, T. Campbell-Clause, J. (2012).
Grapes (kg/t)	2.13	0.33	Holzappel, B., Holland, J., Treeby, M. (2018)
lucerne (kg/t dry matter)	30.0	3.0	ANZECC&ARMCANZ (2000)
lucerne (kg/t dry matter)	-	2.5-3.5	Agriculture Victoria (2021)
lucerne (kg/t dry matter)	35	4	Department of Environment and Conservation (NSW) (2004)

Nutrient removal from 9.9ha vineyard by Lucerne is 2,970kg (N) /a and 297 (P) /a (Table 15).

9.2 Vineyard nutrient removal

There are two plant components to consider for nutrient removal from grapevines: the removal of grapes and prunings. As a conservative approach to nutrient removal from the vineyard only grapes will be considered with 2.0kg (N)/t and 0.3kg (P)/t of grapes removed (Table 14 and Table 15). A yield of 5t/ha/a has been used in nutrient balance modelling.

Nutrient removal from 9.9ha vineyard by grapes is 99kg (N) /a and 14.9kg (P) /a (Table 15).

Total nutrient removal through the vineyard is 3,069kg (N) /a and 312 (P) /a (Table 15).

The net nutrient balance is a deficit of 1449kg (N) /a and 22kg (P) /a (Table 15). This indicates that the potential nutrient demand is greater than the nutrient supply. For this reason, it will be important to assess the nutrient status of each crop with tissue analysis throughout the growing season. Supplementary fertilisation may be required to maintain good crop health, critically important for the modelled water and nutrient balances as well as for economical purposes. This will be included in the vineyard management plan when required.

Further to this no N and P reduction has been allocated to soil attenuation(N) and adsorption (P) which would provide further protection to the sustainable irrigation with treated wastewater. There is also addition buffer in the lawn irrigation area where management will require removal of clippings to further enhance nutrient removal.

Table 15 Nutrient Balance

Nutrient Generation	Winery/Function	Hotel	Winery Treated	
Volume (ML/yr)	7.196	18.323	0.902	
[N] (mg/L)	80	80	100	
[P] (mg/L)	15	15	30	
Total N generated (kg)			2132	
Total P generated (kg)			414	
Nutrient Removal by WaterTreatment		**% red. N**	**% re. P**	
ABSORBS		-24	-30	
Net Residual Nutrient (kg)		1620	290	

Crop Nutrient Removal	Area (ha)	Yield (t/ha)	N (kg/t)	P (Kg/t)
Grape Production	9.9	5	-2	-0.3
Net Grape Harvest Nutrient Reduction			-99	-14.85
Lucerne	9.9	10	-30	-3
Net Lucerne Crop Nutrient Reduction			-2970	-297
Total Crop and water treatment nutrient removal (kg)			-3069	-312
Nutrient Balance (kg) Excess(+ve) deficit (-ve)			**-1449**	**-22**

10 Risk assessment

Risk tables interpretations (from AS 4360:1999 Risk Management) are provided in Appendix F.

Table 16 Risk assessment and mitigation measures for the wastewater treatment and irrigation at the site

Source of Risk	Consequence / Impact	DO NOTHING			Mitigation Measures	RESIDUAL RISK			Responsibility
		Likelihood (probability)	Hazard (Consequence / Impact)	Risk		Likelihood	Hazard Consequence / Impact	Risk	
Protection of terrestrial and ground water quality	Escape of fugitive treated wastewater from the dispersal area to the watershed negatively impacting water quality	3	C	3C	Use of the ABSORBS™ system for water treatment and nutrient reduction.	1	A	1A	Certified WW Engineer
		3	C	3C	Intermittent timed micro irrigation of treated recycled water. Use of Sentec soil water monitors	1	A	1A	Certified WW Engineer
		3	C	3C	Use deep rooted crops including grapevines and lucerne to beneficially reuse nutrients and water	1	A	1A	Certified WW Engineer
	Escape of surface water, overland flow, to the watershed negatively impacting water quality	3	C	3C	Use of drip irrigation with application rates <<soil infiltration rates for grape vines	1	A	1A	Certified WW Engineer
		3	C	3C	Use of sub surface drip irrigation with application rates <<soil infiltration rates for lucerne	1	A	1A	Certified WW Engineer
		3	C	3C	Use of perennial planting of lucerne to provide ground cover to mitigate risk and velocity of overland flow and increasing stormwater retention time	1	A	1A	Certified WW Engineer
		3	C	3C	Mulching of grape vine rows to provide ground cover to mitigate risk and velocity of overland flow and increasing stormwater retention time	1	A	1A	Certified WW Engineer
		3	C	3C	Maintain grassed areas between the vineyard area and ephemeral water ways to capture fugitive particulate material protecting water quality	1	A	1A	Certified WW Engineer

Source of Risk	Consequence / Impact	DO NOTHING			Mitigation Measures	RESIDUAL RISK			Responsibility
		Likelihood (probability)	Hazard (Consequence / Impact)	Risk		Likelihood	Hazard Consequence / Impact	Risk	
Protection of drinking water quality	Escape of fugitive nutrients from treated wastewater from the dispersal area to the watershed negatively impacting water quality through eutrophication	3	C	3C	Use of the ABSORBS™ treatment system for nutrient reduction ⇒ less nutrients in the system	1	A	1A	Certified WW Engineer
		3	C	3C	Crop nutrient balances have been designed to beneficially reuse nutrients from wastewater. The nutrient balance is very conservative with N and P nutrient deficits without considering soil processes of P-sorption and N attenuation.	1	A	1A	Certified WW Engineer
		3	C	3C	Use of drip and sub-surface irrigation with application rates <<than soil infiltration rates mitigating risk of overland flow and fugitive nutrient losses.	1	A	1A	Certified WW Engineer
		3	C	3C	The use of deep-rooted crops including: grape vines and lucerne to capture fugitive nutrients and water throughout the soil profile. Note: if soil water is below field capacity there is no vector of transmission for fugitive nutrients	1	A	1A	Certified WW Engineer
		3	C	3C	Use of lucerne as a inter row cover crop with high Nitrogen and Phosphorus requirements to increase nutrient sequestration by plants	2	B	2B	Vine yard manager
		3	C	3C	Biennial application of gypsum at $50g/m^2$ to maintain good soil condition and aid in the 'fixing' of P	1	A	1A	Scheduled maintenance

		DO NOTHING				RESIDUAL RISK			
Source of Risk	**Consequence / Impact**	**Likelihood (probability)**	**Hazard (Consequence / Impact)**	**Risk**	**Mitigation Measures**	**Likelihood**	**Hazard Consequence / Impact**	**Risk**	**Responsibility**
Surface ponding of wastewater	Unacceptable exposure to wastewater human and environmental health consequences	3	C	**3C**	Actively controlled ABSORBS™ beds to ensure over supply does exceed system capacity to treat and sustainably disperse wastewater. Installation design as per SA Health approval.	1	A	**1A**	Certified WW Engineer
		3	C	**3C**	The wastewater irrigation to ensure uniformity of distribution mitigates risk of localised overloading. Note: the use of deficit irrigation mitigates ponding risk in the vineyard.	1	A	**1A**	Certified WW Engineer
		3	C	**3C**	Treatment of effluent to meet the Australian Guidelines for Water Recycling mitigates human pathogen exposure.	1	A	**1A**	Certified WW Engineer
		3	C	**3C**	Drip irrigation (surface and subsurface) with application rates <<less than soil infiltration rate mitigates risk.	1	A	**1A**	Certified WW Engineer
Wastewater production in excess of system design	Water treatment and dispersal ineffective due to excessively high through flow	2	D	**2D**	The treatment and beneficial use system has been developed in accordance with SA Health On-site wastewater Management Code requirements	1	A	**1A**	Certified WW Engineer
					System is highly scalable and can be modified to meet scheme requirements.				Certified WW Engineer
		2	D	**2D**	The system has been conservatively designed on current and future wastewater production storage, treatment and dispersal capacity	1	A	**1A**	Certified WW Engineer

Source of Risk	Consequence / Impact	DO NOTHING			Mitigation Measures	RESIDUAL RISK			Responsibility
		Likelihood (probability)	Hazard (Consequence / Impact)	Risk		Likelihood	Hazard Consequence / Impact	Risk	
Wastewater salinity	Salt impacts on beneficial reuse orchard	2	C	2C	Albeit grapes are sensitive and lucerne is moderately tolerant to salinity irrigation water will be managed to be <1dS/m mitigating risk to production.	1	A	1A	Certified WW Engineer
					The Water balance model demonstrated the application of a leaching fraction in wet years to maintain good soil conditions. This leaching fraction in wet years improves salinity leaching and reduces nutrient losses due to the average water quality (Wastewater + Rainfall)	1	A	1A	Certified WW Engineer
	Salinity will increase leaching fraction leading to increased deep drainage	3	D	3D	Appropriate management of system dosing to mitigate excess salt load due to poor uniformity of distribution. Soil monitoring to be undertaken to assess negative impact of irrigation water quality.	1	A	1A	Certified WW Engineer
	Degradation of soil structure reducing infiltration	3	D	3D	Annual application of gypsum to flocculate soil, 100g/m^2. The use of Micro-Gyp in wastewater may be considered. Note : gypsum is a salt so the application should be to wet soil in late Autum.	1	A	1A	Scheduled maintenance

Source of Risk	Consequence / Impact	DO NOTHING			Mitigation Measures	RESIDUAL RISK			Responsibility
		Likelihood (probability)	Hazard (Consequence / Impact)	Risk		Likelihood	Hazard Consequence / Impact	Risk	
Leaching fraction to maintain good soil conditions impacting groundwater	Causes degradation of groundwater quality through the transport of contaminants	3	D	3D	Due to ABSORBS™ filter and plantation design leaching will occur in winter when rainfall exceeds plant demand. Leaching with a higher quality water (lower concentration) will reduce quantity of transported contaminants	3	B	3B	Certified WW Engineer
		3	D	3D	Harvesting of grasses to increase production and to minimise soil stored nutrients to reduce risk of leaching.	2	B	2B	Scheduled maintenance
		3	D	3D	Site selection with >2m depth to groundwater to provide buffer for transported salts to watertable. Deep soil attenuation of contaminates will protect groundwater system.	2	B	2B	Certified WW Engineer
		3	D	3D	Use of deep-rooted crops grape vines and lucerne to sequester fugitive nutrients and water from vineyard.	2	A	2A	Certified WW Engineer
Dispersal on sloping land, 15-20%	Uneven application of wastewater causing uneven application of nutrients and increased localised deep drainage	3	D	3D	Drip irrigation with high distribution uniformity will be used. Managed irrigation of inter -row irrigation in winter and vine row in summer to mitigate risk of excess deep percolation	1	A	1A	Certified WW Engineer
	Increased runoff due to slope causing uneven water application or offsite impacts of water and nutrients	3	D	3D	The system will be maintained with full ground cover across the vineyard to reduce runoff. Perennial lucerne in the inter row and mulching of vine rows.	1	A	1A	Certified WW Engineer

Source of Risk	Consequence / Impact	DO NOTHING			Mitigation Measures	RESIDUAL RISK			Responsibility
		Likelihood (probability)	Hazard (Consequence / Impact)	Risk		Likelihood	Hazard Consequence / Impact	Risk	
Deep drainage	Contamination of groundwater	3	D	3D	Site selection with >2m depth to groundwater to provide buffer for transported nutrients to watertable	2	B	2B	Certified WW Engineer
		3	D	3D	Strategic application of leaching fraction in wet seasons to maximise leaching water quality.	1	A	1A	Certified WW Engineer
		3	D	3D	System design on Decile 9 rainfall year	1	A	1A	Certified WW Engineer
Neglect of system	N, P or even BOD_5 and pathogens in groundwater and soil	2	E	2E	The ABSORBS™ system requires negligible operator intervention and will be serviced in accordance with the SA Health approval conditions. There will be real time monitoring of water quality with the recycled water treatment system	1	A	1A	Scheduled maintenance by service technician
Failure of pumps	Overflow of tanks, untreated effluent spill to the environment	3	E	3E	System is designed so that the majority of tanks rely on gravity overflow. Routine maintenance and servicing will ensure appropriate functionality.	2	B	2B	Scheduled maintenance by service technician

Source of Risk	Consequence / Impact	DO NOTHING			Mitigation Measures	RESIDUAL RISK			Responsibility
		Likelihood (probability)	Hazard (Consequence / Impact)	Risk		Likelihood	Hazard Consequence / Impact	Risk	
Failure of pipework	Leakage to environment	2	E	2E	As required by the Asset Management Plan to be prepared following the installation of the system	1	B	1B	Scheduled maintenance
Failure of tank and treatment system	Leakage to environment	2	E	2E	Use quality tanks and supervise installation. Tank inspection part of maintenance program	1	B	1B	Licensed installer
	System failure leading to failure to treat effluent to appropriate quality	1	C	1C	System serviced in accordance with relevant local regulation and manufacturer's requirements and asset management plan	1	A	1A	Scheduled maintenance by service technician
Dispersal area, plants perform poorly	Nutrient removal capacity reduced causing environmental harm	1	C	1C	Part of maintenance program to inspect and recommend sustainable management practices. Vines and lucerne to be managed in accordance with "bet practice management" to ensure optimal crop performance	1	B	1B	Scheduled maintenance by service technician
	Water use capacity reduced	1	C	1C	The system has been designed with a flat irrigation rate regardless of seasonal rainfall. The design takes advantage of high rainfall seasons to undertake leaching. The average leaching fraction per year is 15%.	1	B	1B	Scheduled maintenance by service technician
Construction quality	Inadequate system build subject to breakdown	3	C	3C	Use licensed plumber and installer and Fluid Environmental oversight. System commissioned by wastewater engineer.	1	A	1A	Licensed installer
System subject to malfunction	Poor and unreliable performance of the system	2	C	2C	Comprehensive commissioning plan and redundancies built into the system to ensure reliable performance.	1	A	1A	Arris supervision and certified WW engineer

Source of Risk	Consequence / Impact	DO NOTHING			Mitigation Measures	RESIDUAL RISK			Responsibility
		Likelihood (probability)	Hazard (Consequence / Impact)	Risk		Likelihood	Hazard Consequence / Impact	Risk	
Odour from wastewater management system	Odour from wastewater dispersal leading to nuisance	1	B	1B	All wastewater applied through the ABSORBS™ sub surface treatment and dispersal technique. Vents on primary treatment system can have activated carbon filters if required	1	A	1A	Certified WW Engineer
		1	B	1B	System serviced in accordance with relevant local regulation and manufacturer's requirements	1	A	1A	Certified WW Engineer
		2	B	2B	Wastewater applied through the ABSORBS™ sub surface treatment and dispersal technique to mitigate small droplets (aerosols)	1	A	1A	Certified WW Engineer
Aerosols at dispersal site	Aerosols and human exposure, pathogen transfer	2	B	2B	Site access controls and signage as required by the SA Health Code 2013	1	A	1A	Certified WW Engineer
		2	B	2B	Wastewater applied through the ABSORBS™ sub surface treatment and dispersal technique to mitigate small droplets (aerosols)	1	A	2A	Certified WW Engineer
		2	B	2B	Pumping infrastructure to be installed in tanks underground to mitigate unauthorised access and contact risk	1	A	1A	Certified WW Engineer
Noise	Pumps and main electrical components	1	A	1A	Primary treatment system is passive without pumps other than for water transfer. Low energy pumps are used to mitigate noise risk	1	A	1A	Certified WW Engineer
		3	B	3B	Pumping infrastructure to be installed in tanks underground to mitigate unauthorised access and contact risk	1	A	1A	Certified WW Engineer

Source of Risk	Consequence / Impact	DO NOTHING			Mitigation Measures	RESIDUAL RISK			Responsibility
		Likelihood (probability)	Hazard (Consequence / Impact)	Risk		Likelihood	Hazard Consequence / Impact	Risk	
Wastewater leaks from pipework	Risk of septic tank effluent leaking from infrastructure	3	C	3C	All water transfer systems (pumped) are low pressure (free end flow) mitigating risk of pipeline bursts. PN12 piping is used with a pressure rating of 1,200kPa.	1	B	1B	Certified WW Engineer
		3	C	3C	Infrastructure condition and maintenance as per quarterly service inspection.	1	B	1B	Scheduled maintenance by licensed service technician
		3	C	3C	All infrastructure to meet AS1546.1 requirement	1	B	1B	Certified WW Engineer
Bushfire	Risk to infrastructure	2	E	2E	Ensure appropriate fuel management practices and adequate fire breaks are maintained around the facility to mitigate fire damage risk	1	C	1C	Scheduled maintenance
Person accidentally accessing: drinking or washing hands from taps	Illness from ingestion/contact	3	D	3D	No taps on the system, all infrastructure is underground and signage will be installed in accordance with the SA Health Code 2013	1	D	1D	Certified WW Engineer
Cross connection with potable source of water	Illness from ingestion/contact	3	D	3D	Purple pipes will be installed to indicate recycled water. Transfer pipelines will be installed with detectable marker tape.	1	D	1D	Certified WW Engineer

11 Conclusion and Recommendations

The assessment presented in this document demonstrates that the wastewater treatment and dispersal system is suitable for the development of the Strategic Alliance Southern Barossa Winery and Accommodation Project, with a 26.4 ML/a domestic wastewater generation.

Some of the main assets of this site with respect to sustainable and beneficial wastewater management are:

- The size of the property, about 9.9ha available for irrigation
- The existing and established vineyards, that will be supplemented with lucerne in the interrow, both acting as a land application area and as sinks for water and nutrients.
- The controls implemented at the site for the wastewater treatment, meeting log reduction requirements for recycling water scheme in line with the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (2006).

The management system comprises an ABR, the ABSORBS™ filter, and the established vineyard and lucerne intercrop. They have been carefully chosen as the best fitted solution for the site as well as minimum disturbance to the location. The ABSORBS® filter will treat the effluent to an advanced secondary level, disinfected, and the water will be dispersed to the vineyards where significant amounts of water will be transpired to the atmosphere through the plant evapotranspiration. The water balance indicates a water deficit overall for the crop water demand, that may be supplemented with extra irrigation depending on vineyard management requirements. The excess of water, during the winter months will be stored in a 10.5ML dam onsite. The nutrient balances demonstrate that not only will the vines and lucerne use all the nutrients but that some supplementary fertilisation will have to be considered as there is a deficit in nutrient through irrigation only. To be more specific, there will be a deficit of 1449kg of N and 22kg P per annum.

We can therefore conclude that the wastewater treatment and dispersal system discussed in this report be is the best option for the site: The system produces advanced secondary treated water with disinfection minimising human health risks. The nutrients (N and P) and salts applied in the irrigation through the recycled water scheme do not represent a risk to the environment if a leaching fraction (for the salt) is being applied as it should for every irrigation project.

The beneficial reuse of the water should be highlighted as an effort from the developer to minimise its impact on water resources and contribute to recycling of the water resource.

Water recycling application has not been made to SA Health and will not be undertaken until project Development Approval has been granted. However, the approach laid out in this report would meet the requirements of SA Health a full water recycling application would be successful (pers. comm. Callum Brady, Manager – Wastewater Management, Health Protection and Regulation, Public Health Division, SA Health, Government of South Australia).

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Appendix A Wastewater disposal options and performance assessment

According to USEPA Onsite Wastewater Treatment Systems Manual, a list of different system techniques and their highlights and potential limitations are summarised underneath

Highlights and Limitations of a range of wastewater treatment options

System type	Highlights and potential limitations
Conventional systems	Three components: soil, subsurface wastewater infiltration system (SWIS) and septic tank. Rely on treatment of the wastewater effluent in the soil horizon(s) below the dispersal and infiltration components of the SWIS. Passive, effective, inexpensive, high removal rates for most pollutants after 1m soil infiltration depth.
Continuous-Flow, Suspended Growth Aerobic Systems (CFSGAS)	Must be managed and maintained by trained personnel. Power requirements vary from 2.5 to 10kWh/d. Need inspection at least every 2-3 months. Excess solids need pumping out. Require 12 to 28 person-hours annually. Require effluent disinfection at a minimum to meet surface discharge or any surface reuse water quality requirements. Sensitive to temperature, interruption of electric supply. Noise from blowers is irritant, significant odour during power outage.
Fixed-film processes (alternative to CFSGAS)	If managed unproperly, can result in premature failure of subsurface systems or environmental damage through the production of poor-quality effluent that may pose public health risks. Odours and filter flies may cause environmental nuisance. Mechanical complexity requires more management attention. Operation and maintenance intensive. More susceptible to extreme cold weather.
Sequencing Batch Reactor Systems	If neglected the process can result in environmental damage through production of poor-quality effluent that may pose public health risks and can result in the premature failure of subsurface systems. Odour and noise may also create some level of nuisance. Susceptible to extreme cold.
Vegetated Submerged Beds (VSB) and Other High-Specific-Surface Anaerobic Reactors	Passive in nature and require minimal O/M activity. Anaerobic up flow filters (AUFs) require periodic flushing of accumulated solids and inspection of inlet and outlet systems. AUFs should be insulated from cold weather, corrosion-resistant materials should be employed. May need odour-control system.
Evapotranspiration and Evapotranspiration/ Infiltration	Sensitive to construction techniques, poor construction can defeat their utility through poor liner installation, poor placement and choice of wicking media, compaction, and inadequate surface drainage mitigation. Minimal O/M requirement. Do not function when surface freeze.
Waste Stabilisation Ponds, FWS Constructed Wetlands, and Other Aquatic Systems	Tend to be large in area, require some form of fencing to minimise human health risk, often require supplemental treatment before discharge or reuse, and are approved in only a few states (US). Must need mechanical aeration devices. Require corrosion-resistant materials. Poorly maintained facultative lagoons and FWS systems can become sources of odour and vector problems such as mosquito infestations.

System type	Highlights and potential limitations
Intermittent Sand/Media Filters	Robust performance for intermittent flows. Need to prevent stormwater entry.
Recirculating Sand/Media Filters	Should be constructed carefully with corrosion-resistant materials. Chances of odour problems if overloaded.
Land Treatment Systems	Require large land area A water balance should be conducted to determine the need under the climate conditions, soils, and application rates and patterns of each rate. Crops grown may not be suitable for human consumption. The soil profile must also be managed to maintain infiltration rates by avoiding soil compaction and maintaining soil chemical balance. Requires disinfection and significant pre-treatment before application. Needs to be properly designed (sized) to ensure long-term soil acceptance rates can be safely maintained under design loading rate.

Performance assessment matrix for different wastewater treatment options

WWTP type	Cost (CAPEX and OPEX)	Operation and maintenance needs	Treatment performance and effluent quality (N and P)	Sludge handling requirements	Odour, noise and nuisance potential	Greenhouse gas emissions
Package plant (eg. Fuji Clean PCN20 or similar)	Low to medium (medium CAPEX and low to medium OPEX energy and maintenance	Low to medium (minimum quarterly servicing)	Medium to low (approx. 70% total N and 15% total P removal)	Low to medium (desludging every 6–12 months)	Low (odour potential if overloaded; some aeration noise)	Unknown but likely medium to high emissions (CH_4 + N_2O)
Activated sludge (sequencing batch reactor)	High (high CAPEX and OPEX from aeration energy and sludge handling)	High (needs ongoing oversight by skilled plant operator)	High (almost complete N and P removal with chemical dosing needed for P removal)	High (continuous sludge generation, dewatering and disposal requirements)	Medium (odour potential from sludge handling; aeration noise)	Medium to high (poor process control leads to high N_2O emissions)
Activated sludge (membrane bioreactor)	High (high CAPEX and OPEX from aeration energy, sludge handling and membrane cleaning)	High (needs ongoing oversight by skilled plant operator; regular chemical cleaning of membranes)	High (almost complete N and P removal with chemical dosing needed for P removal)	High (continuous sludge generation, dewatering and disposal requirements)	Medium (odour potential from sludge handling; aeration noise)	Medium to high (poor process control leads to high N_2O emissions)
Biofiltration (trickling filter or rotating biological contactor – RBC)	Medium (high CAPEX, low operating energy cost due to passive aeration)	Medium (regular desludging and process oversight)	Medium to low (generally incomplete N removal, chemical dosing needed for P removal)	Low to medium (periodic primary sludge removal; attached growth biomass limits secondary sludge)	Low to medium (overloaded trickling filters can produce odour; low noise)	Low to medium (low emissions from trickling filters, low to medium from RBCs)
Waste stabilisation ponds (facultative lagoons)	Medium (medium to high initial CAPEX from large land cost, but lower OPEX unless aerated lagoons)	Low to medium	Low (generally poor N and P removal from facultative ponds; seasonally high effluent TSS from algal growth)	Low (periodic desludging of lagoons every 5–10 years)	Medium (overloaded ponds can produce odour; potential nuisance from insects; low noise)	Low (generally low CH_4 and N_2O emissions from facultative ponds)
ABSORBS™ Advanced Secondary Treatment plus biodrain system	Low to medium (high initial CAPEX for ABSORBS™ bed but low OPEX energy)	Low to medium (higher during early years with cut and carry biodrain management but low thereafter)	Medium to high (ABSORBS™ beds deliver 20–30% N and P reduction; biodrain accounts for remainder)	Low (desludging every 12–48 months or as required by relevant code)	Low (ABSORBS™ beds fully underground; low noise and nuisance potential; biodrain amenity benefits)	Low (some CH_4 emissions from septic tanks but very low emissions from ABSORBS™)

** Something not included in the options assessment table is effluent polishing and disposal needs. All of the listed systems with the exception of the ABSORBS™ Advanced Secondary Treatment plus biodrain system still require solutions for effluent polishing/disinfection and disposal. This will require additional land area and infrastructure for surface irrigation, with additional filtration for effluent polishing.

Appendix B Summary of concepts

FE believes that Concept 3 is most in-line with the proposed development and would be the lowest cost installation. The table below gives advantages, disadvantages and high-level cost expectations of the three proposed concepts. It is important to understand that regulatory requirements can have a big impact on the project cost but cost expectations are based on past experience and the limited knowledge of SBWTAP FE has at this time.

Description	Advantages	Disadvantages
ABSORBS™ The treatment train has been considered comparing packaged treatment with the ABSORBS™	The ABSORBS™ is passive requiring little operator requirement.	Larger footprint than a packaged treatment plant
Energy Requirement	Much lower energy requirement as the only mechanical part of the process is water transfer not as part of the treatment process.	Package treatment plants require blowers that use a lot of energy
Carbon footprint	The ABSORBS™ has been assessed by University of SA as having of the order of half the carbon footprint of packaged treatment plants.	Large carbon foot print due to energy requirement and nitrogen to atmosphere
Odours	The system once commissioned is generally odourless due to underground installation	Due to large air use in treatment process odours are often given off.
Operation Cost	Very low operation cost, as the treatment process is passive, not requiring an operator, and with anaerobic treatment generating less sludge	Higher operation cost requiring higher energy inputs, operator requirements and high sludge generation form aerobic treatment (up to 10 times the sludge of anaerobic treatment). Often requires cleaning chemicals.
Variable flows associated with accommodation facilities	The ABSORBS™ treatment system has the capability to handle highly variable flows in effluent quality and quantity without any operator intervention	

Installation cost	Installation cost his highly comparable with packaged treatment plants. In the past, for projects in the Adelaide Hills, the ABSORBS™ system has been installed at a lower cost than comparable packaged treatment plants	

Concept 1 – Storage + woodlot irrigation	Advantages	Disadvantages
ABSORBS™ treatment as discussed above		
Disinfection	Disinfection of the wastewater considering pathogen log reduction in accordance with the Australian Guidelines for Water Recycling allows for easier pathway to beneficial reuse	Need to bring disinfection chemicals on to site
Woodlot	There is a lot of work being undertaken (CSIRO) with woodlot use of wastewater. This provides a clearer approval pathway for the use of woodlots.	High set up cost for irrigation and planting of the woodlot (choice of local SA eucalyptus species). Long development time when considering water and nutrient balances. The EPA WIMP requires a woodlot management plan that will involve coppicing and material removal (another job and associated costs)
Wastewater Storage	The wastewater storage will be used to balance woodlot water demand with wastewater production	Storage requires significant area. There are problems with storage of eutrophic water (algal blooms). Safety concerns for patrons especially with poly lined storages (risks can be mitigated)

Concept 2- – Woodlot irrigation + no storage	Advantages	Disadvantages
ABSORBS™ treatment as discussed above		
Disinfection	Disinfection not required	Disinfection not required
Woodlot	There is a lot of work being undertaken (CSIRO) with woodlot use of wastewater. This provides a clearer approval pathway for the use of woodlots.	High set up cost for irrigation and planting of the woodlot. Long development time when considering water and nutrient balances. The EPA WIMP requires a woodlot management plan that will involve coppicing and material removal (another job and associated costs)
Wastewater Storage	Storage not required	Significant work required to get EPA approval. However, it has been approved in the past so approval would be achievable but not guaranteed

Concept 3 - – Storage + vineyard and supplementary crop irrigation	Advantages	Disadvantages
ABSORBS™ treatment as discussed above		
Disinfection	Disinfection of the wastewater considering pathogen log reduction in accordance with the Australian Guidelines for Water Recycling allows for easier pathway to beneficial reuse	Need to bring disinfection chemicals on to site
Vineyard reuse	The use of recycled water has been widely used in vineyards. There is significant support in the literature Lower setup cost as vineyard production would be business as usual.	Requires a large area for irrigation over vineyards but this is mitigated by the existing land use and existing vineyards. Nutrient balances may be problematic as vineyards don't have significant nutrient removal It is likely that a supplementary area to be

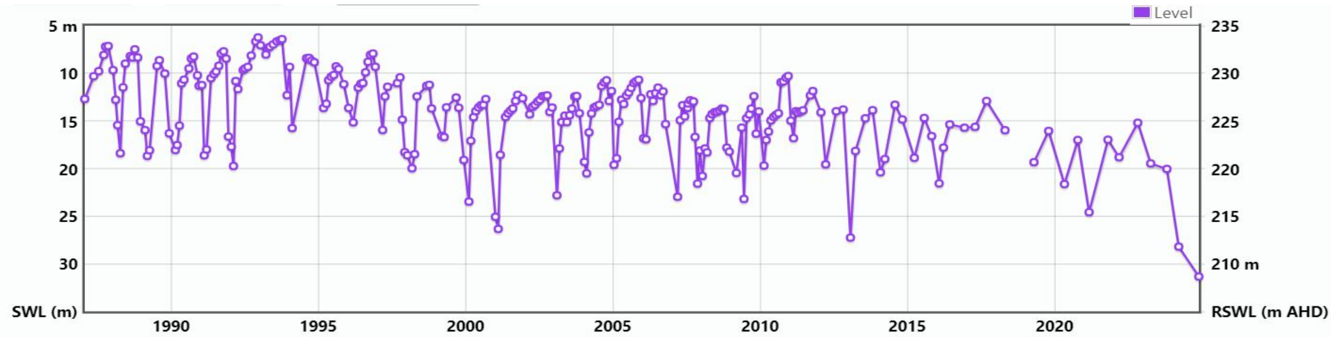
		planted with a crop (to be determined) may be required. Crop could include lucerne or vetiver grass, good at removing N and P.
Wastewater Storage	The wastewater storage will be used to balance woodlot water demand with wastewater production	Storage requires significant area. There are problems with storage of eutrophic water (algal blooms). Safety concerns for patrons especially with poly lined storages (risks can be mitigated)
Irrigation	Irrigation system is already in place (assumed) it is a simple matter of connecting into existing system	Will require significant filtration to be used from storage to drip irrigation.
Setup cost	Beneficial reuse in the vineyard is likely to have the lowest setup cost as use of existing infrastructure can be undertaken.	

Appendix C Summary of ABSORBS™ system performance

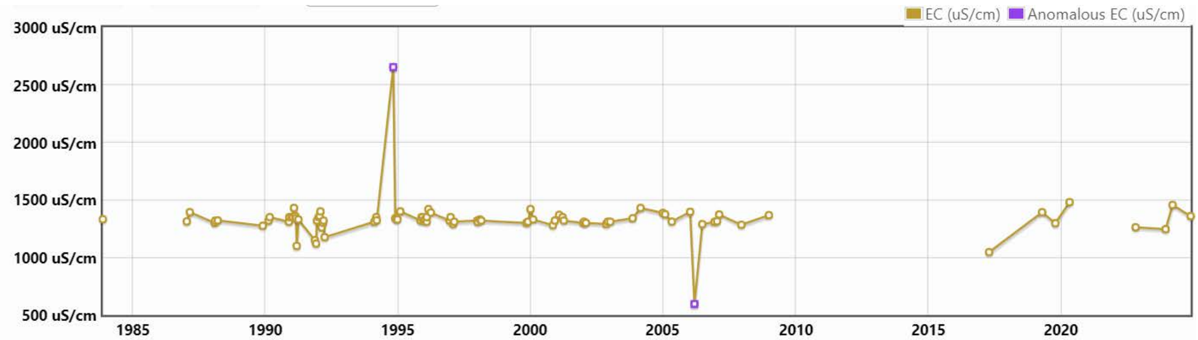
Water Scource	TSS mg/L	Turbidity NTU	NH_4-N mg/L	TKN mg/L	Org. N mg/L	TN mg/L	TP mg/L	BOD_5 mg/L	COD mg/L	FOG mg/L
West Musgrave 275kL/d										
ABR influent	560	500	68	92	24	92	14	630	1000	110
ABR Efluent	76	50	77	89	12	89	14		420	<10
(Reduction)	(-86%)	(-90%)	-13%	(-3%)	(-50%)	(-3%)	0%	(-60%)	(-58%)	-91%
ABSORBS STS	10	0.66	0.031	11	11	75	2.5	10	20	
(Reduction)	(-87%)	(-99%)	(-100%)	(-88%)	(-8%)	(-16%)	(-82%)	(-96%)	(-95%)	
Total System	10	0.41	0.051	11	11	75	2.5	5	20	
(Reduction)	(-98%)	(-100%)	(-100%)	(-88%)	(-54%)	(-18%)	(-81%)	(-99%)	-95%	
ABSORBS High Loading 60L/m2/d										
Influent	338	-	53.4	-	-	76.7	10.8	358	860	-
ABSORBS Effluent	7.2	-	13.5	-	-	76.7	10.8	5.8	53	-
(% Reduction)	98	-	74	-	-	18	27	98	93	-
ABSORBS Low loading rate 40L/m2/d										
Influent	290	-	51	-	-	65	9	345	591	-
ABSORBS Effluent	7.9	-	2.5	-	-	48	6.2	6	51	-
(Reduction)	98	-	96	-	-	24	31	98	90	-
ABSORBS P-reduction media 80L/m2/d (dosing bed)										
Influent	335	-	51	-	-	74	10	323	804	-
ABSORBS Effluent	7.8	-	0.51	-	-	65	0.14	4	50	-
(Reduction)	97	-	99	-	-	7.7	99	99	93	-
Ri ABR 1200 L/d										
Influent	326	-	51	-	-	74	10	323	786	-
ABR Effluent	40	-	53	-	-	67	9.1	121	304	-
(Reduction)	84	-	-6.5	-	-	6.1	7.1	59	57	-

Appendix D Bore 662812578 water levels and salinity data

The following information has been retrieved from the Waterconnect portal (waterconnect.sa.gov.au)



Standing water levels in the bore



Salinity of groundwater as measured in the bore (note 1000µS/cm = 1dS/m)

Appendix E Wastewater quality characteristics

A literature search was undertaken regarding wastewater quality data. To gain some insight into septic tank effluent (STE), quality data from three sources has been provided from the Tables of this Appendix. Based on the evidence contained in these tables it is fair to use STE nutrient concentrations of 80mg/L TN and 15mg/L TP (median number of the range as per AS1546.3 2017) in the discussion of sustainable beneficial reuse and nutrient balances.

Influent Wastewater Constituents (AS1546.3 2017)

Parameter	Range
BOD_5	150-750 mg/L (see Notes 1 and 2)
TSS	150-750 mg/L (see Notes 1 and 2)
Total Nitrogen (TN)	20-150 mg/L (see Note 3)
Ammonium (NH_4-N)	20-80 mg/L
Total phosphorous (TP)	6-25 mg/L (see Note 4)
pH	6.0-9.0
Fats, oils and grease	50-200 mg/L
E. coli	10^4-10^{10} cfu/100mL

Notes:

1) Adapted from the following:
    a. Environment Protection and Heritage Council, Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1), 2006.
    b. EN 12566-3, Small wastewater treatment systems for up to 50 Pt, Part 3: Packaged and/or site assembled domestic wastewater treatment plants.
    c. Metcalf and Eddy (Ed.), Wastewater Engineering, 2014.
2) Average concentration of BOD_5 and TSS in raw sewage required for onsite wastewater treatment system testing as per AS 1546.3:2017 is [3]300mg/L.
3) Average concentration of total nitrogen in raw sewage required for onsite wastewater treatment system testing as per AS 1546.3:2017 is [3]60mg/L.
4) Average concentration of total phosphorus in raw sewage required for onsite wastewater treatment system testing as per AS 1546.3:2017 is [3]8mg/L.

Wastewater Characteristics (Medcalf and Eddy, 2014)

Characteristic	Inflow Pump-Wells	Aeration Chamber
5-day Biological Oxygen Demand (BOD_5)	300mg/L	150mg/L
Total Suspended Solids (TSS)	550mg/L	185mg/L
pH	5.0 -8.5	6.0 – 8.0
Total Nitrogen	70mg/L	50mg/L
Total Phosphorous	12mg/L	8mg/L
Grease and oil	400mg/L	150mg/L
Total Dissolved Solids (TDS)	700 mg/L	650mg/L
Faecal Coliforms	10^5-10^8 cfu/100mL	10^3-10^5 cfu/100mL

Typical septic tank effluent water quality (Lowe *et al.*, 2009)

Constituent	Concentration (mg/L)	
	Median	Range
Total N	63	30–125
NO_3-N	<1	0.0–7.0
TP	10	0.5–35

Appendix F Risk Tables

Risk tables (Australian Standard 4360: 1999 Risk Management)

Probability	Rank	Description
Rare	1	May occur in exceptional circumstances > 100yrs
Unlikely	2	Could occur within 20yrs or in unusual circumstances
Possible	3	Should be expected to occur within a 5 - 10yr period
Likely	4	Will probably occur within a 1 - 5yr period
Almost Certain	5	Expected to occur or multiple occurrences in a year

Hazard	Rank	Description
Insignificant	A	Insufficient impact or not detectable
Minor	B	Probably harmful to local ecosystems, contained on site
Moderate	C	Potentially harmful to regional ecosystem, contained on site
Major	D	Potentially lethal to local ecosystems with potential off-site impacts
Catastrophic	E	Potentially lethal to regional ecosystems, widespread on and off-site impacts

Interpretation of risk

Increasing Hazard →

Increasing Occurrence ↓

Rank	Likelihood	A Insignificant	B Minor	C Moderate	D Major	E Catastrophic
1	Rare	Very Low	Very Low	Low	Moderate	High
2	Unlikely	Very Low	Very Low	Moderate	Moderate	High
3	Possible	Very Low	Low	Moderate	High	Very high
4	Likely	Very Low	Low	Moderate	High	Very high
5	Almost Certain	Low	Moderate	High	Very high	Very high

Appendix G SA Water Potable Water Quality

Your water quality - full report

A complete analysis of your drinking water

SA Water

Swan Reach water supply system

Date generated: Wednesday 2 July 2025
Period the data covers: 12 months prior to Saturday 31 May 2025

Your drinking water comes from the River Murray. It's filtered and treated using chloramine and ultraviolet light and fluoride is added for public health before coming to your taps ready to drink.

We manage South Australia's drinking water quality in line with our robust Drinking Water Quality Management System which ensures you're supplied with good quality, safe drinking water treated to meet the strict national standards set by the Australian Drinking Water Guidelines 2011 (ADWG).

Rather than an exhaustive list, the information in this report shows the characteristics of water which we regularly test for, as well as those with an ADWG health guideline. Water quality test results shown are from routine samples taken at various locations, with data reported monthly and results reflecting an average for the past 12-months.

System: Swan Reach	Unit	National health guideline	National aesthetic guideline	Result (average)	Health compliance *
Alkalinity	mg/L	No guideline	No guideline	67	Not applicable
Aluminium - acid soluble	mg/L	No guideline	≤ 0.2	0.027	Not applicable
Ammonia - free - as NH3	mg/L	No guideline	≤ 0.5	0.22	Not applicable
Antimony	mg/L	≤ 0.003	No guideline	<0.0003	100%
Arsenic	mg/L	≤ 0.01	No guideline	0.00040	100%
Barium	mg/L	≤ 2	No guideline	0.0440	100%
Beryllium	mg/L	≤ 0.06	No guideline	<0.0002	100%
Bicarbonate	mg/L	No guideline	No guideline	68	Not applicable
Boron	mg/L	≤ 4	No guideline	0.024	100%
Cadmium	mg/L	≤ 0.002	No guideline	<0.0001	100%
Calcium	mg/L	No guideline	No guideline	16.7	Not applicable
Carbonate	mg/L	No guideline	No guideline	6	Not applicable
Chloride	mg/L	No guideline	≤ 250	79	Not applicable
Chlorine (free residual)	mg/L	≤ 5	≤ 0.6	<0.1	100%
Chloramine (mono residual)	mg/L	≤ 5	No guideline	3.5	100%
Chlorine (total residual)	mg/L	≤ 5	No guideline	3.5	100%
Chlorite	mg/L	≤ 0.8	No guideline	<0.01	100%

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System: Swan Reach	Unit	National health guideline	National aesthetic guideline	Result (average)	Health compliance *
Chromium	mg/L	≤ 0.05	No guideline	<0.0001	100%
Colour	HU	No guideline	≤ 15	1	Not applicable
Copper	mg/L	≤ 2	≤ 1	0.0044	100%
Cyanide as CN	mg/L	≤ 0.08	No guideline	<0.05	100%
E. coli	cfu/100mL	0	No guideline	0	100%
Fluoride	mg/L	≤ 1.5	No guideline	0.8	100%
Hardness	mg/L	No guideline	≤ 200	84	Not applicable
Iodide	mg/L	≤ 0.5	No guideline	0.02	100%
Iron	mg/L	No guideline	≤ 0.3	0.0014	Not applicable
Lanthanum	mg/L	≤ 0.002	No guideline	<0.0001	100%
Lead	mg/L	≤ 0.01	No guideline	0.0001	100%
Magnesium	mg/L	No guideline	No guideline	10.31	Not applicable
Manganese	mg/L	≤ 0.5	≤ 0.1	0.0034	100%
Mercury	mg/L	≤ 0.001	No guideline	<0.00003	100%
Molybdenum	mg/L	≤ 0.05	No guideline	0.0004	100%
NDMA (N-Nitrosodimethylamine)	ng/L	≤ 100	No guideline	7	100%
Nickel	mg/L	≤ 0.02	No guideline	0.0004	100%
Nitrate + nitrite as NO3	mg/L	≤ 50	No guideline	0.64	100%
pH	pH units	No guideline	6.5 - 8.5	8.8	Not applicable
Potassium	mg/L	No guideline	No guideline	3.95	Not applicable
Selenium	mg/L	≤ 0.01	No guideline	<0.0001	100%
Silica - reactive	mg/L	No guideline	≤ 80	1.44	Not applicable
Silver	mg/L	≤ 0.1	No guideline	<0.00002	100%
Sodium	mg/L	No guideline	≤ 180	60.5	Not applicable
Sulphate	mg/L	No guideline	≤ 250	46.7	Not applicable
Total dissolved solids	mg/L	No guideline	≤ 600	281	Not applicable
Turbidity	NTU	No guideline	≤ 5	<0.10	Not applicable
Uranium	mg/L	≤ 0.02	No guideline	<0.0001	100%
Zinc	mg/L	No guideline	≤ 3	0.0029	Not applicable
Hardness - English Degrees	°e	No guideline	No guideline	5.88	No guideline
Hardness - French Degrees	°f	No guideline	No guideline	8.4	No guideline
Hardness - German Degrees	°dH	No guideline	No guideline	4.70	No guideline
Hardness - International	PPM or mg/L	No guideline	No guideline	84	No guideline

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See our helpful guide to explain the various elements and components listed in this report.

*** While we aim for 100 per cent health compliance all the time, the ADWG recognises exceedances in test results can happen occasionally. Most health guidelines for chemicals are based on a lifetime of exposure, therefore even if the compliance figures in this report are less than 100 per cent, it does not mean your water is not safe to drink. An exceedance of the health guideline is immediately investigated and corrective action can be taken, in conjunction with SA Health. Extensive testing by our water quality scientists is done to confirm South Australia's drinking water is clean, good quality and safe to drink.**

* Prior to calculating compliance for health related chemicals, individual water sample test results are rounded to the same number of significant figures as the ADWG value (as prescribed in the ADWG and endorsed by SA Health).

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