Review of Effluent Technologies & Practices for WA Dairy Farms

This report is written for the Regional Estuaries Initiative's Sustainable Agriculture Project Reference Group

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Various commercial effluent management systems are referenced in this report. Where this is done, these do not imply endorsement nor support for any particular technologies, technology providers, suppliers or commercial brands. Instead, the reader shall interpret the evaluation of technologies and practices in this report to be of a general nature, and shall perform their own independent evaluations, to determine solutions suitable to them with due consideration of their own personal circumstances.

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Acknowledgments

The authors would like to acknowledge that this project was supported by the Department of Water and Environmental Regulation (DWER) and funded by the State Government's Regional Estuaries Initiative (REI) through the Royalties for Regions program. The authors would like to thank the regional dairy programs and stakeholders who provided their invaluable time to organise contacts and for being part of the stakeholder engagement process of the project. A big thank you goes to the dairy farmers in each of the 6 catchments (Peel-Harvey Estuary, Leschenault Estuary, Vasse-Wonnerup Estuary, Hardy Inlet, Wilson Inlet and Oyster Harbour) for their valuable time discussing effluent systems and for kindly allowing us onto their farms to look at their various dairy effluent management systems. This information has been invaluable in formulating the approach and prioritisation of the information contained within this review report. Finally, we would like to thank Anya Lam, DWER, for her invaluable REI information, project management, support, and advice and extend our gratitude to Deborah Holtham and Malcolm Robb from DWER for their support and direction of the project.

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Executive Summary

Nutrient run-off from dairy farms in south-west Western Australia (SW WA) has been identified as a significant source of nutrients entering the six estuaries of Peel-Harvey Estuary, Leschenault Estuary, Vasse-Wonnerup Estuary, Hardy Inlet, Wilson Inlet and Oyster Harbour. Nutrients entering these estuaries have the potential to reduce water quality, which could lead to potential impacts such as ecosystem changes (flora and fauna), algal blooms, low oxygen levels and fish deaths.

Dairy effluent management has been identified as a key area of focus in the Sustainable agriculture strategy under the Regional Estuaries Initiative (REI). The REI led by the Department of Water and Environmental Regulation (DWER) funds the DairyCare program with the aim to reduce nutrient run-off from dairy farms. This program is overseen by the Sustainable Agriculture Project Reference Group (PRG). In order to assist in improving dairy effluent systems in the region, the PRG identified the need to explore innovative technologies and practices that are economically and practically viable for managing dairy effluent in SW WA.

This review funded by the REI, aims to investigate technologies and practices that ultimately minimise offsite impacts, provide farmer benefits, allow for the best return-on-investment for farmers, and reduce overall water use. The review considers the regional constraints of SW WA as well as the needs and drivers of the farmers themselves, in order to identify systems and components suitable for adoption and uptake. The review provides a description of the technologies/practices, a ranking of the technologies and practices in terms of viability for the SW WA situation, and an identification of possible system scenarios and recommendations to facilitate adoption.

The information in this review has been developed for the PRG in order to provide them with tailored dairy effluent options for SW WA. This information will ultimately benefit dairy farmers and advisors who can utilise this review to further research the identified systems/components.

The review was conducted in three stages. The first stage involved the identification of over 100 technologies and practices currently utilised by the industry, or are available in other industries such as municipal, industrial and chemical wastewater but are not yet used by dairies. The initial technologies and practices list formulated the basis for the main review following input from the stakeholder engagement process. A situational analysis was then conducted to prepare a brief overview of the current regulatory setting and catchment characteristics. The stakeholder engagement process was carried out on site with farmers and other interested stakeholders to gain a broader perspective of thoughts regarding current effluent systems, needs, barriers, perceptions, opportunities, constraints, management requirements and potential for new and improved practices and technologies. The information from the situational analysis influenced the review of technologies and practices by taking into consideration such factors as needs, drivers and constraints.

The stakeholder engagement process identified that the priorities for SW WA farmers when designing or managing an effluent system included time and labour, ease of management, costs associated with developing and running a system, value of the nutrients, environmental protection and water efficiency. All farmers rated disposal of effluent as their lowest priority.

The main regional constraints for SW WA identified included high rainfall, sandy soils, heavy clay, flat to sloping land, availability/cost of power, variability of soils, water availability/quality, low lying flood areas, lack of elevation/gravity and shallow groundwater.

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Farmers identified the need for effluent systems and components to have low complexity, require low labour inputs, be low maintenance, make money and save on fertiliser costs, be simple to manage, practical and functional, meet industry best practice, be efficient and cost effective, designed to suit site specific needs and constraints, meet consumer requirements, reduce water use, allow winter storage, maximise nutrient benefits (across wider areas of the farm) and minimise impacts on the surrounding environment.

The identified drivers to achieve a functional effluent system were ongoing support and guidance, access to good knowledge and advice, confidence in advice from information providers and suppliers, access to funding/grants, science to demonstrate benefits of effluent and systems types in order to support business case for future funding/loans and adoption, a demonstrated return on investment, system designs based on required site outcomes rather than set solutions, ability to view aspirational systems, the ability to choose options best suited to site specific drivers, constraints and objectives and a change in thinking from waste management to resource management.

The review identified several technologies that although, used in other industrial or wastewater industries, are currently not broadly suitable for dairy shed effluent management because of several factors such as scalability, complexity, suitability of effluent or unproven cost benefits for the dairy industry. These included technologies such as anaerobic digestion for biogas, dissolved air floatation and activated sludge treatment.

Several technologies and practices were identified as having potential for future application but may require validation, investigation and research. Some of these systems are currently being applied in the dairy industry but are deemed to need careful consideration if adopted. For example, mechanical separation systems may only take less than 30% solids out of the system, require energy inputs to run, and have high maintenance requirements. Potential technologies and practices that could be viable included sedimentation and evaporation pond systems, Z-filter technology (only been applied at dairies abroad) and vibrating screens.

Several viable options were identified suitable for SW WA. Many of the viable options are already being implemented in the pasture based dairy industry but may not be readily adopted in SW WA. A few potential technologies and practices were identified not commonly used in the industry or in SW WA, including recycled effluent yard wash, umbilical systems, tank and bladder storage systems, tracker equipment on travelling irrigators, rainwater diversion, sand traps and covered storage ponds.

Some of these technologies/practices such as rainfall diversion and sand traps can be low cost, may be easily implemented or retrofitted to a current system and could make a substantial difference by reducing overall effluent system size, reducing capital costs and electricity costs, and reducing labour and ongoing maintenance.

Other components such as sedimentation ponds could reduce solids handling and storage by reducing the desludging frequency from every 4 weeks to approximately once a year compared to for example trafficable solids traps.

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Table 1 lists viable and potentially viable options identified for SW WA dairies.

Table 1: Summary of Viable and Potentially Viable technologies and practices identified for SW WA Dairy Effluent

Viable or Commonly used	Potentially viable*
Collection	
• Flood wash systems-recycled effluent • High/low pressure hoses • Hydrant yard wash • Plate cooler valves that minimise water use • Pre yard wetting • Pipe and riser • Recycling of plate cooling water for flushing or in a closed loop • Rainwater diversion/covered yards, to reduce rainwater ingress into effluent system (IMPORTANT: Necessitates careful and consistent management to prevent a pollution incident) • Reduced frequency of yard washing or washing area of yard closest to sheds • Recycled effluent for yard washing	• Automated backing gate cleaning system • Dry scraping • Freestall/Barns/Feedpads. Can include dry scraping or packed bedding with minimal or no liquid effluent • Robotic dairies to minimise herd time on surfaces collecting effluent
Conveyance	
• Centrifugal pumps • Mud/stone/sand/grit traps • Piping • Rotary lobe pump • Rotary vane pump (for vacuum tankers) • Trafficable solids trap	• Effluent channels • Diaphragm pump • Macerator pump (chopper pump) • Piston/plunger pump • Progressive cavity pump (helical coil, helical screw, rotor pump) • Screw press (press auger) • Static screen (run-down screen, inclined stationary screen) • Submersible pump • Vibrating screen
Storage/Treatment	
• Effluent ponds with appropriate low permeability, including if lined with HDPE or Clay/bentonite type liners • Solids storing and management	• Bladder tanks (can be installed above or below-ground, also called pillow tanks) • Chemically assisted flocculation & sedimentation • Covering effluent ponds with an impermeable cover for rainwater exclusion. • Constructed wetland • Stirrers/Agitators • In-line strainers • Sedimentation and Evaporation Pond Systems (SEPS) • Storage tanks (above-ground or below-ground) • Z-Filter

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Viable or Commonly used	Potentially viable*
Reuse/Application	
• Composting - Active/Passive • Contract solids spreading or tankers • Centre Pivot irrigator • Dredges • Excavators • Flood Irrigation/pipe and risers • GPS Trackers/alarms for travelling irrigators • Halo system • Hydrants • Lateral Move sprinklers • Manual move low rate portable sprinklers- K Line, Uni sprinkler- effluent sprinkler, Raingun, DuCaR Sprinklers • Solids spreading • Travelling Irrigators - travelling raingun, boom irrigators • Tankers - Injection, splash plate, dribble bar, trailing shoe • Umbillical systems - rainwave, combi dribble bars, standard, swing up, duo	• Geotubes (Geobags) • Solid set sprinklers • Sludge drying bays

*Note that potentially viable relates to dairies in SW WA. Some technologies listed may be commonly used in dairies outside of SW WA.

Some of the technologies/practices identified above in table 1 as having potential, or as currently available and suitable, were subsequently included in possible whole effluent management system scenarios relevant for SW WA. The scenarios sought to illustrate how viable technologies and practices would fit together into complete functional effluent management systems including collection, conveyance, storage/treatment, and reuse. These scenarios illustrated that there is no one-size-fits-all effluent management solution.

The stakeholder engagement and site visit observations also showed that many of the farms visited already had some of the necessary effluent components in place. Accordingly, the scenarios presented cater for completely new effluent management systems as well as retrofitting or upgrading of incomplete existing systems.

Overall:

1. All farms have individual site constraints, needs and challenges, meaning there will not be a one-size-fits-all solution to dairy effluent management in SW WA. Dairy effluent system design and management needs to take this into account when developing, upgrading or retrofitting effluent systems.
2. Options identified for SW WA include low cost, easy to retrofit technologies and practices through to options that require further validation to justify benefits and performance outcomes.

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3. Effluent system design should consider anticipated future plans for expanding the milking herd.
4. Having the right supporting equipment such as the correct pipes and pumps to deliver sufficient flow and pressure is essential in any effluent management system. Incorrectly sized or not fit for purpose equipment can have a significant impact on the efficiency, running costs, labour inputs, maintenance and performance of effluent components such as conveyance/solids separation and irrigation equipment.
5. Dairy effluent system design and management need to be outcomes-focussed rather than focussed on individual specific components making up an overall effluent management system. This means that any system design should be developed from the application/reuse end back to the shed from which the effluent originates.

Identifying unsuitable technologies and practises is as important as identifying viable options, to ensure that farmers do not invest in systems that have high potential for future failure and subsequent environmental impacts. The viable options identified, if implemented correctly and taking into account the site-specific needs and constraints, should provide multiple benefits to farmers by maximising the nutrient value whilst minimising environmental losses via nutrient leaching and/or run-off.

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Abbreviations

C/N	Carbon to Nitrogen (as in composting)
DWER	Department of Water and Environmental Regulation
EP Act	Environmental Protection Act 1986
HDPE	High-density polyethylene
PRG	Sustainable Agriculture Project Reference Group
REI	Regional Estuaries Initiative
SEPS	Sedimentation and evaporation pond systems
SW WA	South Western - Western Australia
WA	Western Australia or Western Australian

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1.0 Introduction and Background

The health of six estuaries in the South West of Western Australia (WA) (Peel-Harvey Estuary, Leschenault Estuary, Vasse-Wonnerup Estuary, Hardy Inlet, Wilson Inlet and Oyster Harbour) are deemed to be under stress due to a drying climate, reduced rainfall and water flow, a growing population, historical land use, intensified agriculture and growing urbanisation.

To improve the health of these six estuaries the WA government has invested $20M in the Regional Estuaries Initiative (REI) (2016-2020). Led by the Department of Water and Environmental Regulation in WA (DWER), the REI funds a range of on-ground works, including soil and water testing, farm effluent management upgrades, fencing, revegetation and drainage, as well as new science and modelling, regional capacity, employment and training (REI, 2019).

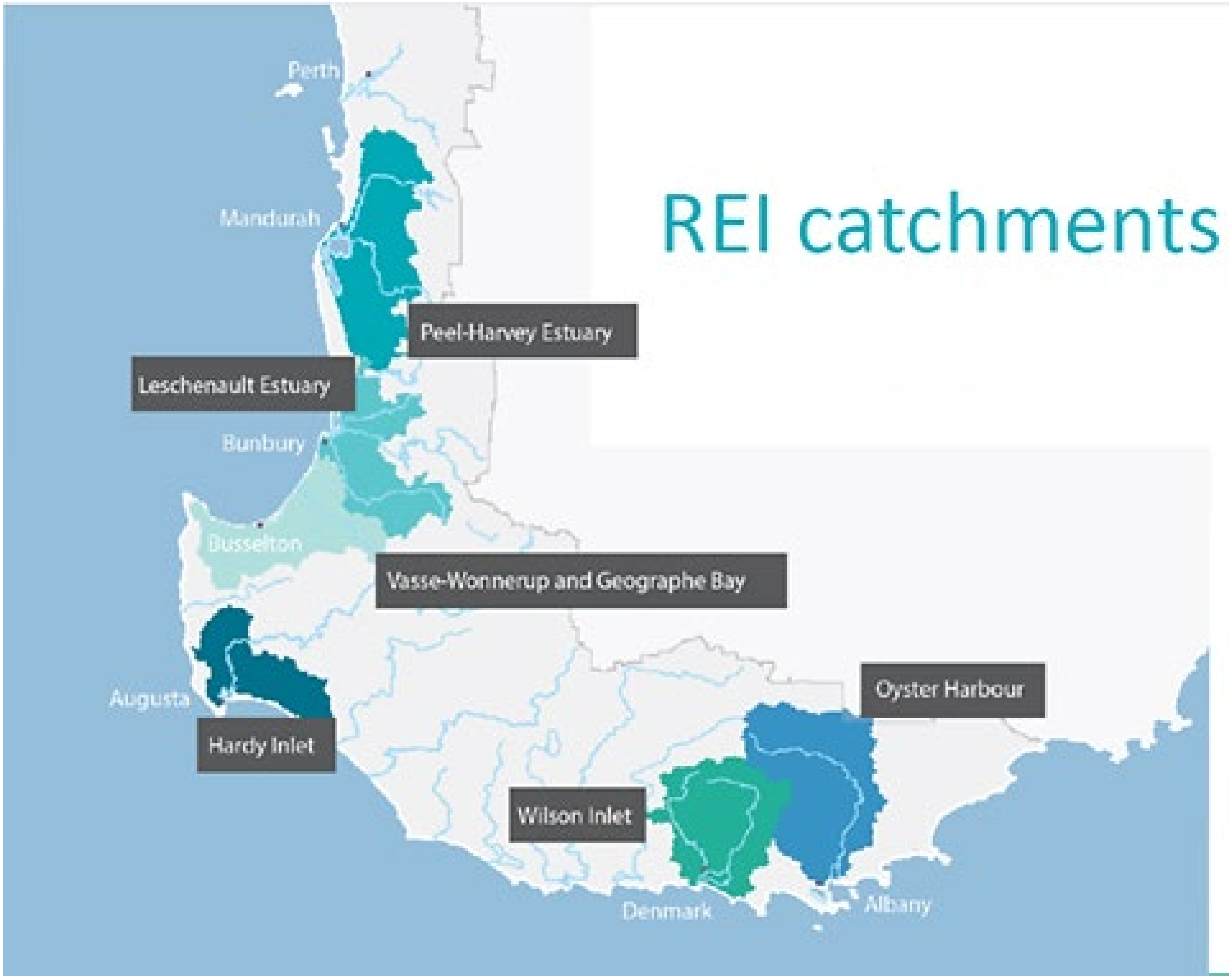

Figure 1: Regional Estuaries Initiative: Six Catchments (Source DWER, 2019)

The REI aims to drive action in catchments to improve water quality and restore the environmental balance of the estuaries. There are five strategies of the REI (Figure 2) that provide on-ground works and create the science needed for informed decision-making.

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Figure 2: Regional Estuaries Initiative five strategies (Source DWER, 2019)

One of the five strategies is the REI Sustainable Agriculture Strategy, which was developed in response to the intensification of agriculture and nutrient run-off from agricultural land being identified as significant nutrient sources of the south-west estuaries. Excess nutrients entering waterways from fertiliser and effluent can reduce water quality, which can lead to potential impacts such as ecosystem changes (flora and fauna), algal blooms, low oxygen levels and fish deaths.

The REI works with catchment and industry groups and farmers to implement the Sustainable Agriculture Strategy, with the aim to reduce nutrient run-off from farms, focussing on two key areas – fertiliser management and dairy effluent management.

To implement the Sustainable Agriculture Strategy, the REI formed the Sustainable Agriculture Project Reference Group (PRG), consisting of farmers, industry representatives, catchment councils and government staff working together to shape the direction and outcomes of the REI Sustainable Agriculture Project. The PRG provides direction to the Fertiliser Management program and the DairyCare program, to ensure strong collaboration, coordination and communication.

The DairyCare program offers farmers a 50% matching contribution up to $60,000 for upgrading dairy shed effluent systems. To assist in improving effluent systems and facilitating participation in the DairyCare program, the PRG identified a need to explore and clarify innovative yet economically and practically viable approaches for managing dairy effluent in the south west regions of WA. To do this REI has funded this review of effluent technologies and practices for WA dairy farms. However, this review is independent of and is running in parallel to existing REI programs such as DairyCare, Soil testing and uPtake (Smart Farming Partnerships) (Figure 3).

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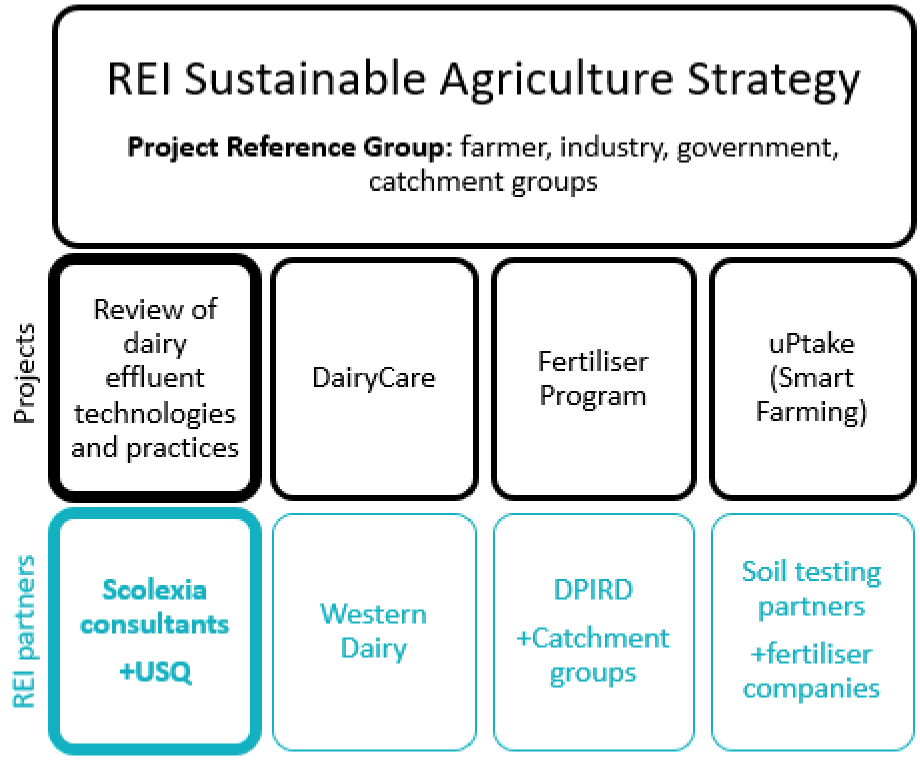

Figure 3: REI Sustainable Agriculture Projects (Source DWER, 2019)

The review aims to investigate dairy effluent technologies and practices that ultimately minimise offsite impacts, provide benefits, allow for the best return on investment, and reduce overall water use.

The review provides a description of possible effluent management technologies/practices, rankings of the technologies/practices in terms of viability for the WA situation, identification of possible system scenarios and recommendations to facilitate adoption.

To determine the needs and constraints of the SW WA dairy industry, a situation analysis was also conducted in consultation with key project stakeholders and with dairy farmers located in each SW WA catchment. This situation analysis assisted with focusing of the review and thus overall outcomes.

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2.0 Scope

The review undertakes a high-level investigation of available technologies and practices for managing dairy shed effluent with the aim of eliminating or minimising offsite impacts and maximising benefits on farm. The technologies reviewed include technologies and practices currently utilised by the industry as well as those currently not used but available in other industries such as municipal and industrial wastewater treatment.

The focus of the review is specifically on technologies and practices associated with the collection and reuse of dairy shed effluent. It does not review land management practices associated with nutrient reduction such as vegetative filter strips and buffers.

The review considers the WA dairy industry situation including constraints and needs such as ease of management, scalability, availability, integration into the current systems and overall likelihood of transference, adoption and success. Table 2 summarises in-scope and out-of-scope items.

Table 2: Summary of review project scope in terms of inclusions ("In-Scope") and exclusions ("Out-of-Scope")

In-Scope	Out-of-Scope
• technologies and practices currently utilised by the industry as well as those currently not used but available in other industries such as municipal and industrial wastewater treatment • WA dairy industry situation including constraints and needs such as ease of management, scalability, availability integration into the current systems and overall likelihood of transference, adoption and success • technologies and practices associated with the collection and reuse of dairy shed effluent on-farm • high level cost considerations • technologies and practices to be reviewed will only include those that can be implemented on site	• land management practices associated with nutrient reduction such as vegetative filter strips and buffers • detailed cost benefit analysis • systems or technologies situated or operated off site (e.g. centralised biogas system fed with manure from multiple farms. This includes technologies ancillary to centralised biogas production, such as thermal hydrolysis) • ammonia volatilisation for subsequent capture

The review included high-level cost considerations where available, but did not undertake a cost benefit analysis at this stage. The technologies and practices reviewed only included those that could be implemented on site. Systems or technologies situated off site or operated by a third-party were not included in the review due to complexities and external influencing factors such as ownership, infrastructure, finance and management that are outside the control of an individual farmer. Such systems include for example a centralised energy/biogas plant.

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3.0 Methodology

This review has been undertaken in 3 stages. The first stage involved the identification of potential technologies for review. The second stage was a stakeholder engagement process/situational analysis to identify key factors relating to dairy effluent management (e.g. drivers, needs and constraints). Stage 3 identified technologies and practices suitable for adoption in SW WA using information obtained from stage 2.

3.1 Identification of Potential Technologies and Practices

To identify the potential technologies and practices relevant across the whole dairy effluent management process, the effluent management system was broken up into the following components:

- Collection (effluent stream generation, effluent inputs, water use etc.)
- Conveyance (collection and conveyance prior to storage or application, includes solids separation)
- Storage/Treatment (storage, containment or treatment systems)
- Reuse (application systems and methods)

Over 100 technologies and practices were identified across these key areas to develop an initial technologies and practices list. This initial technologies and practices list formulated the basis for the main review following input from the stakeholder engagement process that identified additional practices/technologies to include.

3.2 Stakeholder Engagement/Situation Analysis

The authors carried out a face to face stakeholder engagement process in SW WA as part of the review of effluent technologies and practices for WA dairy farms. The engagement took place on site to gain a broader perspective of the various stakeholders' thoughts regarding current effluent systems, needs, barriers, perceptions, opportunities, constraints, management requirements and the potential for new and improved practices and technologies. All information generated from this process has been kept confidential with observations being aggregated for reporting. A situational analysis was conducted, which included observations and feedback collected during the stakeholder engagement process as well as a brief overview of the current regulatory setting and catchment characteristics. The situational analysis is given in Appendix 1. The information collected provided a good overall understanding of the considerations and paradigm shifts that need to be considered when reviewing possible effluent management practices and technologies.

Stakeholder Engagement Participants List

Stakeholders included:

- DairyCare project team members
- Western Dairy
- Relevant catchment groups (for example, Lower Blackwood Landcare District Committee)
- DWER
- Department of Primary Industries and Regional Development
- Augusta Margaret River Clean Community Energy group
- Key dairy stakeholders on the PRG

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One to two dairy farms were visited in:

- Geographe
- Lower Blackwood & Scott River
- Peel Harvey
- Leschenault

Phone interviews were also conducted with producers located in the Wilson Inlet and Oyster Harbour catchments.

To facilitate discussion and generate the information needed for the review, an engagement framework, and questions were formulated based on the ORID discussion method. This method sets out a logical process of Objective, Reflective, Interpretive and Decisional questions to facilitate deeper targeted consultation and to ensure that engagement aims are being met (see below). **Objective**- Data, Facts, Details, **Reflective**- Reactions, Feelings, Responses, **Interpretive**- Important, Meaning, Values, **Decisional** – Decisions, Actions, New Directions

Whilst the questions varied slightly to capture different stakeholder target audiences, the aims of engagement were the same for all stakeholders, as follows:

- Understanding of current effluent systems in WA dairy - what works well?, and challenges
- Understanding of what WA dairy producers/stakeholders want an effluent system to be able to do/what would an ideal system look like?
- Understanding of the drivers of effluent systems in WA dairy
- Understanding of what components of effluent systems WA dairy producers/stakeholders are most interested in
- Current/future barriers to implementation of effluent systems on WA dairy farms
- Understanding of WA dairy producer/stakeholder obligations to environmental stewardship/regulation

The results of the situational analysis can be found in Appendix 1. Information presented is an amalgamation of responses without identifiers to ensure confidentiality.

The situational analysis, including the stakeholder engagement, regulatory setting and catchment characteristics/constraints, influenced the review of the technologies and practices via consideration of needs, drivers and constraints.

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3.3 Review of Effluent Management Technologies for WA Dairy Farms

The initial list of identified technologies and practices (See Section 4) was revised in response to the stakeholder engagement process (See Appendix 1), and this revised list then formed the basis of the subsequent review. The review involved collating a brief description of each identified technology or practice, and then ranking each as “not viable”, “potentially viable” or “viable for implementation-short listed” in terms of general use across SW WA dairies, based on available information, relevant experience and stakeholder engagement/situation analysis, and considerations such as:

- drivers,
- needs,
- ease of management/complexity,
- high level costs,
- availability,
- supplier base and service availability,
- integration into current systems, and
- overall likelihood of transference, adoption and success.

Some of the technologies/practices identified as having potential or as currently available and suitable, were subsequently included in whole effluent management system scenarios relevant for SW WA. The scenarios sought to illustrate how viable technologies and practices would fit together into complete functional effluent management systems including collection, conveyance, storage/treatment, and reuse.

Note that the review was conducted with best available information and reliance upon third-party information available in the public domain at the time. Apart from professional evaluation based on significant prior relevant experience, the validity of this third-party information was not independently verified.

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4.0 Identification and Short-listing of Effluent Management Options

Table 3 provides a summary listing of identified potential effluent management technologies and practices ranked as "not viable", "potentially viable" or currently "viable for implementation" on SW WA dairy farms. "Potentially viable" includes technologies and practices currently in limited use at SW WA dairies, or with variable track record of success, or have been widely used in other industries but are yet to be proven in SW WA dairies. Further investigations, research or development would be required to confirm the long-term viability of these "potentially viable" options for SW WA dairies. Table 4 elaborates on the ranking of options by providing further information on the various technologies and practice options, including their purpose, a brief description and shortlisting reasoning.

The feasibility ranking was based on best available knowledge at the time of assessment and based on <u>general</u> applicability to the industry. The list of technologies and practices was extensive but not exhaustive. Technologies and practices may evolve or reduce in cost over time, which may change their status from what is suggested here, and farms may also have site specific needs and drivers influencing the feasibility of a specific practice or technology.

The shortlisting is colour coded as follows:

(red)	Red (not viable)	(orange)	Orange (potentially viable)
(green)	Green (viable for implementation-short listed)		

Table 3 Technology and Practice Feasibility Summary*

Viable or Commonly used	Potentially viable	Not currently viable or Not proven for dairies
Collection		
• Flood wash systems - recycled effluent • High/low pressure hoses • Hydrant yard wash • Plate cooler valves that minimise water use • Pipe and Riser • Pre yard wetting • Recycling of plate cooling water for flushing or in a closed loop • Rainwater diversion/covered yards, to reduce rainwater ingress into effluent system (IMPORTANT: Necessitates careful and consistent management to prevent a pollution incident) • Reduced frequency of yard washing or washing area of yard closest to sheds • Recycled effluent for yard washing	• Automated backing gate cleaning system • Dry scraping • Freestall/Barns/Feedpads. Can include dry scraping or packed bedding with minimal or no liquid effluent • Robotic dairies to minimise herd time on surfaces collecting effluent	

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Viable or Commonly used	Potentially viable	Not currently viable or Not proven for dairies
Conveyance		
• Centrifugal pumps • Mud/stone/sand/grit traps • Piping • Rotary lobe pump • Rotary vane pump (for vacuum tankers) • Trafficable solids trap	• Effluent channels • Diaphragm pump • Macerator pump (chopper pump) • Piston/plunger pump • Progressive cavity pump (helical coil, helical screw, rotor pump) • Screw press (press auger) • Static screen (run-down screen, inclined stationary screen) • Submersible pump • Vibrating screen	• Gear pump • Inclined screw separator (Drag flight conveyor separator, elevating stationary screen) • Peristaltic pump (squeeze hose pump, hose pump) • Rotary drum screen (trommel screen, rotating screen) • Venturi "pump"
Storage/Treatment		
• Effluent ponds with appropriate low permeability, including if lined with HDPE or Clay/bentonite type liners • Solids storing and management	• Bladder tanks (can be installed above or below-ground, also called pillow tanks) • Chemically assisted flocculation & sedimentation • Covering effluent ponds with an impermeable cover for rainwater exclusion. • Constructed wetland • Stirrers/Agitators • In-line strainers • Sedimentation and Evaporation Pond Systems (SEPS) • Storage tanks (above-ground or below-ground) • Z-Filter	• Activated sludge systems • Adsorption/Bio-oxidation process (A-stage + B-stage) • Advanced oxidation process • Anaerobic Ammonium Removal (short-cut biological nitrogen removal, commercial systems include DEMON®, Anita™ Mox, ANAMMOX®) • Anaerobic digestion • Biological contactor (Rotating biological contactor, Biorotor) • Carbon filter • Capacitive deionization (Electrodeionization) • Centrifier • Centrifuges • Dissolved air flotation (DAF, also more recent variation called microflotation unit) • Electrodialysis • Electrocoagulation • Enhanced biological phosphorus removal (EBPR) • Fermentation to produce hydrogen • Fermentation into mixed alcohol fuels • Forward osmosis (or FO) • Forsi

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Viable or Commonly used	Potentially viable	Not currently viable or Not proven for dairies
		• Hydrocyclone • Induced gas flotation • Ion exchange • Imhoff tank • Lamella clarifier (inclined plate clarifier) • Membrane distillation • Microfiltration (crossflow or submerged, Tangential Flow Separators), nanofiltration and reverse osmosis (RO) • Mechanically aerated ponds/lagoons • Microalgae • Macroalgae • Microbial bioelectrochemical systems • Photobioreactor for single cell protein recovery • Roller press • Stirring via pump recirculation • Strong acid addition to reduce nitrogen volatilisation losses • Sand filtration (can include media filtration, which mixes the sand with other media including activated carbon, and sorbers for removal of nutrients) • Trickling filter • Thermal distillation • Vermifilter/black soldier fly • Wet oxidation (Zimpro or ZIMmerman PROcess, e.g. bubble column technology)
	Reuse/Application	
• Composting - Active/Passive • Contract solids spreading or tankers • Centre Pivot irrigator • Dredges • Excavators • Flood Irrigation/pipe and risers • GPS Trackers/alarms for travelling irrigators • Halo system • Hydrants	• Geotubes (Geobags) • Solid set sprinklers • Sludge drying bays	• Adding sorbers • Belt filter (belt press filter, or belt filter press) • Granulation • Gasification • Pyrolysis • Pelletisation • Subsurface irrigation • Torrefaction

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Viable or Commonly used	Potentially viable	Not currently viable or Not proven for dairies
• Lateral Move sprinklers • Manual move low rate portable sprinklers- K Line, Uni sprinkler- effluent sprinkler, Raingun, DuCaR Sprinklers • Solids spreading • Travelling Irrigators- travelling raingun, boom irrigators • Tankers -Injection, splash plate, dribble bar, trailing shoe • Umbillical systems-rainwave, combi dribble bars, standard, swing up, duo		

* Note that technology ranking is in terms of general applicability across SW WA dairies. “Potentially viable” relates specifically to dairies in SW WA. Some technologies listed as “Potentially viable” may be commonly used in dairies outside of SW WA.

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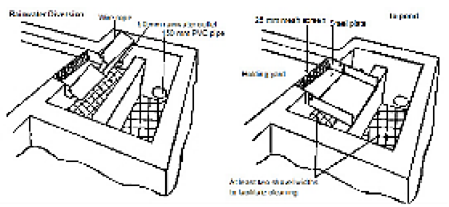
Table 4: Identification and short-listing of effluent management technologies and practices for application to south west WA dairy farms. Note: Where images and descriptions given in this section refer to technology providers or supplier names or commercial brands, these do not imply support nor endorsement of these providers, suppliers, or commercial brands. Any performance claims by service providers/manufacturers have not been verified. Specific examples are given to illustrate the technologies and practices in a general sense. Photos of "not currently viable" options have been removed from this web version of the report.

Purpose	**Technology or Practice** **(Other common names)**	**Brief description**	**Short-listing**	**Reasoning**
Collection				
Milking shed and/or yard cleaning Minimising effluent volume or minimising effluent strength	Rainwater diversion/covered yards, to reduce rainwater ingress into effluent system  Agriculture Victoria	Rainfall on a yard can generate substantial volumes of freshwater entering effluent system which will increase the overall size of collection and storage systems and will increase the volumes that need to be managed onsite. Diversion systems intercept rainwater at a point between the yard and the sump/drainage system. Can be manually or automatically operated. Particularly relevant in high rainfall areas.	Green	Can be low cost. May be difficult to retrofit to some existing yards. Easy to install if only one drainage point from the yards. Can significantly reduce collection, storage, handling, pumping and application requirements. Can reduce labour via handling and maintenance of reduced effluent volumes. Utilise gravity if possible and collect the water for reuse i.e. yard washing. Need a separate collection for the rainwater if reusing or allow it to run into an area where it will not cause environmental issues. **IMPORTANT: Necessitates careful and consistent management to prevent a pollution incident. Diversion therefore entail a level of risk that must be addressed when proposed.**

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Plate cooler valves that minimise water use Recycling of plate cooling water for flushing and/or in a closed loop  Daviesway	Getting the correct flow rate and cooling efficiency can save significant volumes of water. Plate coolers and their valves need to be sized correctly for the expected milk flow. Variable speed controllers used on the milk pump can assist in correcting the required water use. Plate cooler water is expected to maintain high water quality, despite its use at the dairy. The large volumes of freshwater used in a platecooler should be recycled back through the platecooler, diverted to freshwater storage, used for other suitable purposes inside the dairy or recycled for yard cleaning. This can reduce freshwater inputs at the dairy and excludes plate cooler water from effluent. If platecooler water enters the effluent system, it will add to effluent volumes. (Dairy Australia)	Green	Optimise and reduce water use. Can maintain water quality in a closed loop.
	High/low pressure hoses  DairyNZ	Hoses can be used on any shape and sized yard. Multiple shorter hoses located at various points in the yard can facilitate better cleaning and reduce time on yard.	Green	Commonly used. Inexpensive to install. High pressure hoses may be less efficient in terms of water use as compared to low pressure washing options. Water use is dependent on operator behaviour. Labour and time requirement to clean yard. Long hoses can be heavy to operate and have potential OH&S issues due to high pressure. Can use multiple short hoses. Cracks and grooved surfaces running across the yard can trap manure and sand and increase cleaning times. Grooves running down the length of the yard can improve cleaning and time taken. Unknown risk from aerosols may make the use of recycled effluent unsuitable with hoses.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Hydrant yard wash  Yardblaster.com, Dairy NZ	High pressure hydrants are a fixed hosing system which use flow rates of approximately 2000L/min to clean a yard. Provides good cleaning of the yards as the spray can be manually directed to dirty areas of the yards. Can position at different areas of the yard. Need to have a collection system that can cope with the large volumes of water generated at once. Ensure correct pipes and pumps to deliver optimum results.	Green	Low-Moderate cost Typically high water use. Can save time to clean the yards by targeting only the dirty areas of the yard. Slope of the yard not as important as for other systems such as flood washing and can handle multiple slopes. Produce less splash than high pressure hoses. Can be retrofitted to existing yards and accommodate yard upgrades and extensions. Suitable for single or three phase power supply. OH&S risks associated with high pressure. Unknown risks of aerosols make them unsuitable for use with recycled effluent.
	Pre yard wetting	Wetting yards prior to washdown can reduce cleaning times and reduce water use entering the effluent system.	Green	Low cost Reduce water use entering effluent system and time required to clean yard
	Reduced frequency of yard washing or washing area of yard closest to sheds	Limiting the yard wash area or reducing the frequency of yard washing can substantially reduce water inputs into the effluent system. (Dairy Australia) Can be used in conjunction with dry scrapers. Cleaning of the whole yard will need to be done periodically.	Green	Low cost. Reduced effluent volume and dilution. Reduced labour Yards may become slippery Careful stock handling Care to maintain drains and pumps May increase slips and falls, increase teat washing and mastitis.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Flood wash Systems  Dairy NZ	Tanks deliver large volumes of water at once over the surface of the yards. Flood wash usually use recycled effluent or plate cooler water or a shandy of fresh and recycled water to reduce freshwater entering the effluent system thereby reducing the size of the effluent storage required.	Green	Moderate-High Cost Can be difficult to retrofit to an existing system due to appropriate levels, shape, size of yard. Saves labour and can reduce freshwater volumes entering the effluent system if recycled water used. If freshwater used only, significant volumes of water enters the effluent system - High water use. Flood wash systems need a suitably sized sump to capture the large volumes of water released at once. Coverage is often difficult to achieve. Manure pads may need to be broken up to assist cleaning. Placement of the tank, slope, head and pipework need to be sized correctly for flow across the yard to adequately clean yard.
	Recycled effluent for yard washing  DairyNZ	Recycling effluent for yard washing can significantly reduce the volumes of freshwater entering an effluent system and reduce the overall size and cost of a system. Recycled effluent should not be used in the milking shed area. Recycled effluent should only be used in the holding yards, feed pads and barns.	Green	Significantly reduce collection, storage, handling, pumping and application requirements on site. Need solids separation via solids separation equipment or settling in a pond system to facilitate ease of handling and pumping, and to reduce blockages and wear of equipment. A typical recommendation is to use good quality effluent that has had effective solids removal, such as via a large single pond or via a two-pond system to avoid higher levels of suspended solids being deposited onto yards and potentially causing slippery surface layers.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Pipe and Riser  Dairy Australia	Risers are placed at intervals across the top of the yard and are spaced where effluent is expected to build up. Can evenly distribute water or recycled effluent across the yard. Generally requires 500l/m of yard width (Dairy Australia)	Green	High cost. Needs to be installed at time of construction. Difficult to retrofit. If using fresh clean water, it will increase the size of the effluent system. High water volumes required. Need high flow to create a wave affect across the yard, and sufficient sump capacity to catch large volume of water/effluent distributed over a short time. Provides more even water/recycled effluent distribution across yard than flood wash systems. Low labour input however may need to break up pads prior to cleaning. Using recycled effluent requires improved water quality (e.g. solids separation). Recycled effluent can cause blockages and corrosion.
	Automated backing gate cleaning system  Dairy NZ	This system uses backing gates with small high-pressure jets that wash the yard as the backing gate moves. The system can have drag chains positioned between the nozzles to break up manure before the water flushes the area	Orange	Reduces labour, reduced cleaning times. May need to clean small areas that are missed. Difficult to retrofit. If using recycled flush water, high solid separation is needed to avoid blockages and breakdowns. The expense may be offset by requiring smaller pond volumes. Moving backing gates can be a OH&S issue for workers.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Dry scraping  GEA yard scrapers  RATA yard scrapers	Dry scraping can involve both physical, mechanical and automatic systems. These systems break down manure pats prior to hosing or flood wash to reduce flush water requirements. Chains, rubber/metal blades and brushes made from metal or bristle have been used to break up manure prior to cleaning a yard. These scrapers can be hand pushed or attached to bikes, tractors and backing gates. Solid blades are best suited to smoother concrete with rough concrete requiring stiffer brushes. Dry scraping can be carried out in conjunction with less frequent washdown to reduce water use. Some farms have reported scraping yards every 1-3 weeks and giving a complete clean when rain softens the built-up manure. (Dairy Australia)	Orange	Can be effective at reducing water for cleaning and to reduce manure volumes for subsequent storage and treatment. More commonly used with feed pads, feed barns and free stalls. Tractor mounted scraping in common use. Requires labour inputs and appropriate storage of manure. Need to be large enough to prevent solids flowing over or past the scraper and heavy enough to not sit on top of the manure. Some scrapers such as metal blades may damage concrete surfaces over time. Commercial automatic systems can be at moderate-to-high cost and moderate-to-high complexity. Can be difficult to incorporate on smaller yards and can be an OH&S issue and animal health issue regarding slippery surfaces.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Freestall/ Barns/ Feedpads  Agriculture Victoria	A permanent or temporary feeding area, which can include a housed bedded area for the cows to lie down. Cows may be housed temporarily or for the majority of their time. The system is on an impermeable surface and can have a composted manure-packed bedding area for cows to rest and ruminate. Solids are generally removed periodically. Solids spreading may be infrequent. These systems use partial or full mixed ration feeding. Can include dry scraping or packed bedding to significantly reduce liquid effluent volumes.	Orange	Can reduce environmental impacts on the land, e.g. via reduced water use, reduced pugging, run-off, deposition, and risk of nutrients leaching into groundwater, especially during the wetter months. Larger proportion of nutrient capture. Can have high capital costs for full-shed systems. Higher labour for mixed ration feeding. Increasing popularity in New Zealand and Victoria.
	Robotic dairies  Pacific dairy centre	Automatic milking systems generally have a series of milking stations that the cows can access 24-7. A single box station can milk approx. 60-70 cows a day (Dairy Australia). There is no set milking times and cows are not held on the yards for extended periods-if at all. Many systems have eliminated yards all together or are built in conjunction with free stall barn type systems. The system recognises each cow via electronic identification. The robot cleans the teats and attaches and removes the cups based on milk flow. Minimises herd time on surfaces collecting effluent.	Orange	Low labour. Significantly reduced water use, elimination/reduction of yard cleaning as cows are not held for any length of time. High capital cost Challenges with incorporation into pasture based systems. Usually used on barn/freestall barn systems. Availability of technical support must be considered.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
Conveyance				
Solids separation prior to subsequent treatment	Mud/stone/sand/grit trap to remove sand from cows entering milking yard or to capture grit from effluent immediately flowing from the milking yards and shed.  mud/stone/sand trap for sand removal - Agriculture Victoria  Stone/sand trap - Agriculture Victoria	Can be placed immediately before the entry point to the yard. Cattle walk through the bath, rinsing off sand and grit, preventing these from entering the effluent stream and causing blockages and wear. A stone trap can also decrease the flow velocity of the washdown water prior to a sump or storage to allow for sand and grit to drop out prior to exiting the trap.	Green	Removal of sand from yards which is washed through the effluent system creating blockages, abrasive wear and tear on pumps and pipes. Can be low cost to set up. May be low labour, but will still need to be cleaned out. Reduces sand and grit entering the system to reduce wear and tear on pumps, pipes and other equipment.

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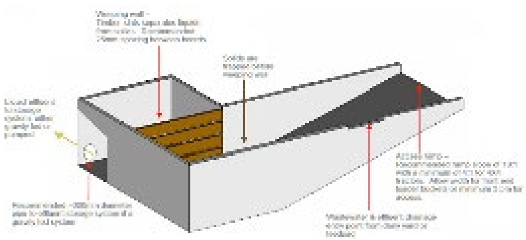
Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Trafficable solids trap  Agriculture Victoria	A trafficable solids trap is generally positioned to catch yard washdown. It holds effluent for a nominal period of time to allow suspended solids, including manure organic matter, to drop out and accumulate, with partially clarified effluent flowing across a weeping wall into a pump sump to be pumped away to subsequent effluent storage or application. A ramp allows periodic access with a front-end loader or rear scraper to clean out accumulated solids.	Green	Moderate Cost. A trafficable solids trap is commonly used in dairies with yard flood washing and can be cost effective and practical if designed and sized appropriately. Moderate to High Labour. Poor design or under sized traps can significantly increase labour and maintenance and decrease performance.
	Screw press (press auger)  FAN Separator	A screw press squeezes effluent under pressure past a screen, forcing liquid (with entrained smaller solids) through the screen to be collected, and retaining coarse solids which are dewatered at the same time.	Orange	High cost and complexity. High maintenance. Commonly removes less than 40% of manure solids. (Hjorth et al., 2010). Effluent must be pumped. Uses electricity for moving parts. Produces a well-dewatered and compact solid manure cake.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Static screen (run-down screen, inclined stationary screen)  GEA	Effluent is pumped over an inclined mesh screen through which the liquid portion and entrained fine manure solids pass. Coarse solids are captured and progress down the face of the screen until discharged off the lower end. Coarse solids can also be washed off the screen to an extent by flowing effluent or water.	Orange	Moderate cost and complexity. Lower maintenance than vibrating screen because no moving parts. Typically requires pumping. Commonly removes 30% or less of manure solids. (Birchall et al., 2008) Can clog if manure solids not progressing off the screen but instead accumulate, cake and dry onto the screen. Retrofits from the USA have used vibrating motors mounted onto the static screen to encourage movement of solids down the screen face. A post-wash with clean water may also reduce clogging and manure build-up on the screen.
	Vibrating screen  Rainer Irrigation	Like a static screen, effluent runs over an inclined mesh screen, with coarse solids captured on the screen, except that the screen is continuously vibrating to prevent accumulation of captured solids on the screen, thereby reducing clogging.	Orange	Has been recently promoted in NZ dairies. Moderate-to-high cost and complexity. Moderate maintenance with moving parts. Expected to remove 30% or less manure solids like static screens. Typically requires pumping. Uses electricity for moving parts.
	Inclined screw separator (Drag flight conveyor separator, elevating stationary screen)	A screw conveyer drags manure over a screen, with liquid and entrained fine solids passing through the screen by gravity and capturing solids which the conveyer eventually discharges. Source: Yardmaster	Red	High cost and complexity with many moving parts. High maintenance. Commonly removes 30% or less of manure solids. (Moller et al., 2000) Uses electricity for moving parts.

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	Rotary drum screen (trommel screen, rotating screen)	Effluent is passed into a rotating cylindrical drum with a cylindrical screen through which the liquid portion of the effluent (including entrained fine solids of smaller size than the screen openings) passes. The coarse manure solids are captured on the screen and is progressed along to the exit end of the drum via rotating flighting. Source: McLanahan	Red	High cost and complexity. Moderate maintenance. Moving parts. Can handle variable effluent flow and fibrous materials (e.g. bedding). Can be used in very large dairies. Typically requires pumping. Gravity separation, so expected to remove around 30% or less of manure solids. based on (Birchall et al., 2008) Uses electricity for moving parts.
Pumps	Centrifugal pumps   Storth slurry pumps	Centrifugal pumps work by creating flow by centrifugal motion of liquid entering the centre of the pump and being flung in a radial direction by vanes/blades of the pump impeller. The rotation speed of the impeller is high. The inlet and outlet of the pump is hydraulically connected, which is distinct from positive displacement style pumps, and means that the head pressure that a centrifugal pump can deliver decreases with an increase in the flow that the pump delivers (i.e. higher pressure comes at the expense of lower flow, and vice versa).	Green	Transfer effluent and slurries, albeit can be subject to significant abrasive wear. To use for slurries or sludges, the impeller should be of non-clog open type, and have large inlets and outlets to reduce blockages (Agriculture Victoria). Horizontal shaft mounted needs priming. Vertical shaft mounted commonly used to pump from ponds (pontoon-mounted) or pump wells. Can avoid priming and foot valves. Commonly used. High flow and high head capability. Can transfer effluent to storage, gravity irrigation or irrigation.

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	Rotary lobe pump  Arroyo Process Equipment	Lobe pumps trap volumes of fluid between the pump casing and rotating lobes, and these volumes of fluid are moved from the inlet to the exit end of the pump as the lobes rotate.	Green	Suited to abrasive liquids and high solids slurries. Low maintenance. May not provide adequate flow for irrigation of effluent. Can run dry for extended periods without damage. Can deliver high pressures.
	Rotary vane pump for vacuum tankers (rotating vane pump, variant sliding vane pump)  Jabsco	A rotary vane pump is commonly used by vacuum tankers to pneumatically suck effluent, sludges or slurries into the tank of the truck. (Australian Pork Limited) This type of pump traps set volumes of a fluid being pumped in a space sealed between a vane and the pump casing and progress these volumes of fluid through the pump by the movement of the vane.	Green	Useful for vacuum tankers, for direct spreading of effluent or slurries and sludge (See below). High capital layout. Primes by syphon.

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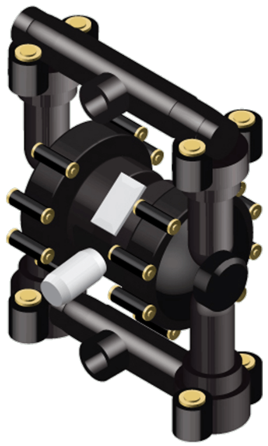
	Diaphragm pump  AODD Pumps	A diaphragm pump works by the movement of a membrane diaphragm that draws liquid being pumped into or forces liquid being pumped out of the pump chamber. This is typically achieved by the action of pressurised air supplied to the pump to force the movement of the diaphragm.	Orange	Do not produce adequate pressure or flow for irrigation. Only suitable for low flow applications. Very simple and practical operation. Self-priming with good suction lift capability. Can handle effluent and slurries with high solids content. Minimal maintenance requirements.
	Macerator pump (chopper pump)  Storth slurry pumps	A chopper pump is fitted with a cutting system on its inlet (suction side) that cuts/chops/macerates solids prior to entering the pump. This prevents clogging of the pump and piping with particulates, including with fibrous material.	Orange	Able to clear materials that would otherwise clog pumps and pipes. Chopper pumps can consume more electricity compared to an equivalently sized pump in terms of flow and pressure, because of the additional energy required for the chopper. Chopper pumps may not be required after an initial solids separation step.

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	Piston/plunger pump  Patz	A piston or plunger pump uses the reciprocating motion of a piston or plunger mounted on a crank shaft mechanism to draw fluid being pumped into a barrel and to force the liquid back out, creating flow. The pressure in the barrel opens or shuts valves to allow liquid to flow into or out of the barrel.	Orange	Good for high solids sludges or slurries. Limited use for effluent. Low flow, high pressure. Energy efficient.
	Progressive cavity (helical coil, helical screw, rotor pump)  Wangen America Inc.	A progressive cavity pump uses an internal rotor (screw) to progress fixed volumes of a fluid being pumped along the pump chamber (stator) length in sequential sealed cavities. The progress of the fluid along the length of the pump is then dictated by the rotation speed of the rotor.	Orange	Highly abrasive materials (e.g. dairy pond sludge) can destroy the pump stator. Progressive cavity pumps are not self-priming and if the pump runs dry, the rotor and stator can be damaged. Progressive cavity pumps can be used in sprinkler irrigation applications, for pumping of sludge or slurries, pumping water over long distances, pumping to elevated storage because of the high pressures that they can deliver. Commonly used.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Submersible pump  Scintex	A submersible slurry pump works submerged in the manure being pumped and therefore is designed to be resistant to abrasive slurries. Can be fitted with a chopper on the pump inlet to help prevent blockages with fibrous particulate matter.	Orange	Less common in dairies. Typically used for transfer of manure effluent to storage, but with low pressure lift capability Applications are somewhat limited to shallow pits/pump wells. Can be energy efficient. Can do a reasonable job at emptying manure sumps. Source: Agriculture Victoria
	Venturi "pump"	Past irrigation applications have applied a venturi principle to draw effluent into a main irrigation water line, thereby not requiring any direct contact between a pump and the dairy effluent. A venturi works by a negative pressure created when the pressurized main irrigation water (free of suspended solids, pumped) enters an injector inlet, where a constriction increases the flow velocity. This increase in flow velocity results in a decrease in pressure, thereby creating a vacuum that can draw in a smaller flow of effluent to be mixed in-line with the main irrigation water stream. (Skerman, 2019)	Red	Limited use to date. Requires large irrigation flows to create the venturi. May be unreliable with clogging by solids, so would likely require significant solids separation. Benefit is no direct contact between pump components and effluent.
	Gear pump	Pumps a fluid by repeatedly enclosing a fixed volume of the fluid within interlocking gaps between rotating gears and a surrounding pump casing (external gear pump), or between the gaps between an inner smaller gear and an outer larger stationary gear (internal gear pump), and transferring these fixed volumes of fluid from the suction side of the pump to the discharge side of the pump by the rotation of the gear(s). The rotation speed of the gear(s) determines the flow rate of the pumped fluid. Source: Processprinciples.com	Red	Not commonly used in dairy manure applications. The clearances in the pump inners may not accommodate manure solids, and therefore may be prone to clog up and require frequent maintenance.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Peristaltic pump (squeeze hose pump, hose pumps)	The fluid being pumped flows into a flexible tube. A roller or wiper then pinches the tube, trapping a pocket of the fluid being pumped and moving along the length of the tube to push the trapped pocket of fluid forward, thereby producing fluid flow. Source: Bredel Hose Pumps. This principal is like that used by the gastrointestinal tract.	Red	High cost. More common in clean (hygienic) or chemical dosing applications. Originally designed as a cement pump. Potentially preferred for transferring of highly abrasive sand-laden manures.
Transfer of effluent	Piping  Hynds pipe systems	Piping selected for materials compatibility and at a suitable diameter to ensure high scour velocity (e.g. >1 $m.s^{-1}$) under normal flow of effluent. (Agriculture Victoria)	Green	A typical part of effluent management systems. Available in a range of suitable materials and sizes to suite specific applications.
	Effluent channels  Concrete channel Hynds pipe systems	Can be precast concrete, or impermeable clay or plastic lined, to transfer liquid effluent without losing nutrients via leaching into surrounding soil.	Orange	Likely more costly than piping. Effluent channels can be more easily accessible for cleaning than piping. Clay or plastic channels need to be carefully cleaned to avoid damage to the impermeable base layer. Can use simple weirs (e.g. bricks) to change the direction of effluent flow to split-off branches. Not suitable for sites where an open channel would capture clean water run-off from upslope.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	 Pork CRC			
Storage and Treatment				
Storing and treatment of effluent, prior to irrigation or land-application	Effluent ponds with appropriate low permeability, including if lined with HDPE or Clay/bentonite type liners  Dairy NZ	Ponds provide biological treatment of effluent via anaerobic microbial processes that convert organic matter into carbon dioxide and methane. The same processes also mobilise nitrogen in the form of ammonia, which is then available for irrigation land application. Ponds store effluent during periods when wet weather does not permit irrigation. The gases from a pond with high organic matter loading can be odorous.	Green	A common component of liquid effluent systems. Can have multi-pond systems to accumulate solids in the first pond to allow for cleaner effluent in subsequent ponds which can be more suitable for irrigation. Plastic lined ponds are typically a more expensive option than in-situ clay or additives such as bentonite Plastic lining may require venting or drainage protection to dissipate gas that form beneath the liner by biological activity in the underlying soil or invading groundwater. This prevents the formation of floating whalebacks. (example: multi-flow synthetic liner protection by varicore technologies)

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Solids storing and management  Dairy NZ	Solids that are stored for extended periods of time on a farm should be located on an impermeable base of compacted earth or concrete to capture leaching and run-off and for ease of management. The solids storage area should permit safe access of equipment such as front-end loaders.	Green	Scalable Can be readily constructed Solids storage provides versatility and better reuse options
	Covering effluent ponds with an impermeable cover for rainwater exclusion  Pork CRC	An impermeable plastic cover placed over an effluent pond can exclude significant amounts of freshwater entering an effluent pond. This can reduce the size of the storage requirements, reduce handling and dilution of the effluent. With well-designed cover ballast pipes, it can also collect and redirect rainwater falling on the cover towards a central collection sump from where it could be pumped off the cover to beneficial reuse. In this way, no rainwater is added to the effluent stream, and the impermeable cover can reduce evaporative losses during dryer months of the year when water is in high demand.	Orange	Moderate to high cost Significantly reduce storage requirements and handling. Reduces dilution of effluent. This purpose differs from the traditional use of impermeable covers to capture gases from anaerobic ponds for destruction of odour or biogas energy use. Australian pork installations with impermeable pond covers have frequently extracted rainwater off the cover for beneficial reuse purposes. Moderate complexity because may alter the way that pond sludge is to be extracted for beneficial reuse, i.e. with impermeable covers, sludge has to be extracted in liquid-form via purpose-built sludge extraction ports. Bulk of the capital for a cover and flare project is in the covering of the anaerobic pond, so this could enable methane capture and destruction to earn carbon credits under the Emissions Reduction Fund. Covers are most cost-effective for newly built narrow and deep effluent ponds, rather than existing wide and shallow ponds.

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	Sedimentation and Evaporation Pond Systems (SEPS) (Sedimentation and Evaporation Basins, Sedimentation and Evaporation Ditches)  Australian Pork Limited  Agriculture Victoria	SEPS can be a relatively low-capital effluent management system which consist of two or three parallel long, narrow, shallow and trafficable earthen channels (typically 0.8 m deep and 7 m wide) following the contour of the land. Solids that settle out accumulate and to some extent break down by natural biological processes. Dried solids are periodically removed by excavators or front-end loaders and spread for its nutrient benefits. Each SEP is separated by a sufficient distance for movement of an excavator for clean-out. The length of the SEP is determined by the holding capacity but can be up to 600 m. Larger volumes can be achieved by building in multiples of three. The parallel operation means that one SEP is filling, one is full and drying, and one is excavated to be ready for subsequent use.	Orange	SEPS were developed in the pork industry and have been used more recently in dairies. Potentially a very low-cost solution for dairy effluent management. Requires research to validate in dairy applications. Easily desludged. Versatile. Can be less odorous than ponds. Nutrients in sludge more frequently available (6-monthly to yearly). To minimise the risk of nutrient leaching into groundwater, SEPS have to be constructed with low permeability, which can be costly if synthetic liner has to be used. The significant footprint of most SEPS may be a downside, due to the land/area that it occupies, and additional rain/runoff being collected in the SEPS.

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	Storage tanks (above-ground or below-ground)  Nevada Group NZ	A storage tank constructed of a strong, corrosion resistant material like concrete, polyethylene, suitably protected steel or stainless steel.	Orange	Installed anytime. No impact on groundwater. Generally, more expensive option than an earthen pond. An expensive storage option for large effluent volumes. Commercially available sizes may restrict scalability.
	Bladder tanks (can be installed above or below-ground, also called pillow tanks)  Nevada Group NZ	A bladder tank is a large plastic flexible container that billows like a pillow as it is being filled with liquid. The storage capacity of these can be up to 1.5ML volume for off-the-shelf bladders.	Orange	Appear to be only available up to 1.5ML, so likely only an effluent storage option for smaller dairies. Impermeable. Can be provided with gas vents to prevent rupture due to accumulation of biogas. Installation requires a large flat surface free of sharp protruding surfaces that can cause damage to the bladder. Likely more costly than equivalent-sized effluent pond and can also be more costly than some above-ground tank options.

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	Constructed wetland  LSU College of Agriculture	Constructed wetlands are man-made areas that support the growth of a variety of plants adapted to water-logged conditions. The wetland provides treatment of effluent (typically after substantial upfront pond treatment to remove organic matter and suspended solids) by removing nutrients via plant uptake and by filtration-sedimentation. Wetlands can be designed for zero-liquid discharge by relying on the evapotranspiration of water from the wetland. Source: (Birchall et al., 2008)	Orange	Low ongoing capital expenditure and maintenance once established High establishment cost Typically used in conjunction with other effluent system components, such as complementing up-front effluent ponds. Not 'stand alone' treatment systems, and require substantial pre-treatment to prevent overload The wetland has to be periodically harvested and re-established with new growth medium. Need a lot of flat land and need to be managed. Can provide habitat for desirable fauna.
	Mechanically aerated ponds/lagoons	An effluent lagoon or pond, typically receiving flow from an anaerobic or facultative pond with already reduced organic matter loading, and with mechanical surface aeration to reduce odour by minimising/preventing septic conditions and further reducing organic matter content. (Birchall et al., 2008) Ammonia nitrogen may also be converted biologically into nitrate nitrogen.	Red	High electricity cost for mechanical aeration. Less cost effective than shallow secondary treatment ponds. SW WA dairies do not appear to have considerable odour management issues.

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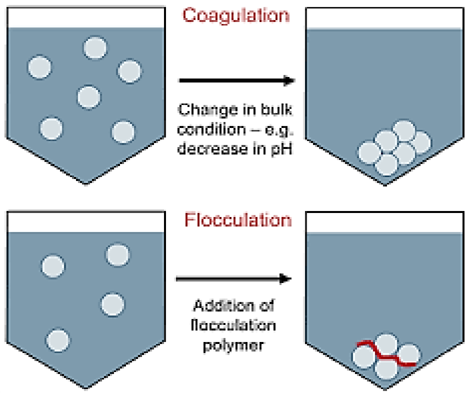
Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
Keeping effluent solids in suspension for ease of pumping and transfer	Stirrers/Agitators   GEA, Pluck's Engineering	Stirrer units with axial flow impellers are commonly used to keep particulate matter (including sand and grit) in suspension in manure pump wells, sumps, pits, above-ground or below-ground tanks or ponds. Without agitation, sediment can accumulate, reducing the holding capacity for manure effluent over time and potentially exacerbating blockages of pumps and outlet piping.	Orange	Electricity required for mixing but based on its common need and use at dairies, mixing-agitation might be considered generically applicable.
	Stirring via pump recirculation	Works by drawing a portion of effluent from and returning it back into a manure pump well, sump, pit or above-ground or below-ground tank, via a pump. This flow of effluent causes mixing. Source: BioCycle	Red	Very energy-intensive compared to a stirrer/agitator, i.e. can use up to two-orders of magnitude more electricity for the same flow as an agitator/stirrer. Pump recirculation mixing is typically only applicable in cases where little mixing is required and thus the cost of a small mixing pump is preferred over the cost of a large stirrer/agitator.
Enhanced solids separation to enable better reuse of clarified/ cleaner effluent and separated solids	Chemically assisted flocculation & sedimentation  Aquarden Technologies	Consists of adding chemicals that cause solids to aggregate, forming larger particles that settle out more effectively and could produce a denser settled sludge with higher solids content.	Orange	Chemical dosing equipment required. Moderate-high chemical cost. Can produce solid sludge rich in nutrients. Can greatly increase solids and nutrient capture. Currently being trialled in research at a WA dairy farm.

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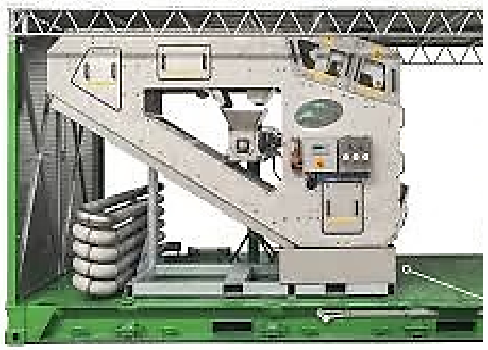
	Z-Filter  Z-Filter	Originally developed in WA, the Z-Filter uses a porous fabric filter element, into which effluent is pumped, which is then folded over and zipped up to form an enclosed sock that holds the effluent solids. The sock travels through a set of compression rollers which forces water to drain from the solids, thereby producing a stackable solids cake. The shape and operation mode of the Z-Filter is designed to be modular and light weight as compared to other belt filter dewatering technologies.	Orange	Requires chemical dosing of a coagulant and/or flocculant chemical to provide high extent of solids and nutrient capture and removal - Moderate-high chemical cost. Electricity for moving components and pumping. Complex. Service and support locally available to SW WA. Scalable by adding more units. Produces a stackable manure solids cake and a clear filtrate to facilitate easier land application. Modular, so may be transportable between farms, subject to biosecurity considerations. Currently being trialled in research at a WA dairy farm.
	Hydrocyclone	A hydrocyclone uses centrifugal force to separate solids from a liquid. This centrifugal force is created by directing the inflowing liquid tangentially near the top of a cylindroconical vessel, causing the liquid to swirl as it flows down the vessel. Source: McLanahan	Red	Simple Moderate capital cost. Requires pumping. Requires a significant density difference between the solid being separated and the liquid from which it is being separated, hence would be effective for sand and grit. Less suitable for organic matter removal. Less effective for fibre in manure.
	Centrifier	Operates with principles similar to inclined separator, except using a fine plastic clothe filter mesh to capture smaller manure particles. Source: Yardmaster	Red	Previously used in dairies. Can operate by gravity feed from an upstream solid separator, so no pumping required. Not a standalone treatment step because it separates smaller particles after an initial course solids separation step. Additional capital and operating expense. Maintenance and moving parts complex. Uncertain local supplier base.

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	Centrifuges	A centrifuge works similarly to a hydrocyclone by separating solids using centrifugal force, except that the centrifugal forces are created by the continuous rotation of the centrifuge bowl. Source: GEA	Red	High capital cost and operating costs. Highly complex. Highly energy intensive. Not readily scalable to dairy farms in Australia.
	Lamella clarifier (inclined plate clarifier)	An inclined plate clarifier separates manure solids from liquid effluent by sedimentation, except that natural settling is enhanced by a bank of inclined plates. This slows the flow of fluid near the surface of the plate, thereby enhancing the opportunity for solids to aggregate, increase in size and settle out due to gravitation. Source: PROSPEX	Red	Only suitable for fine solids removal, because can clog with coarse solids. Would likely require significant pre-treatment by a coarse solids separation step. Moderate to high capital cost and complexity. Requires pumping. Operates best with chemical addition to enhance solids aggregation and settling. Supplier base uncertain.
Treatment of effluent to remove organic matter and/or nutrients and/or salts to achieve high water quality for reuse purposes	In-line strainers  Filson Filter	A strainer is an in-line screen that captures particulate matter in a basket to be cleaned out periodically. Basket strainers are useful to prevent clogging of irrigation equipment.	Orange	Only suitable for liquid streams with minimal entrained coarse solids (i.e. of larger size than the cut-off size of the strainer basket). Contributes pressure loss and therefore requires pumping. Has to be regularly cleaned if it is treating a dirty liquid stream, which will increase maintenance. Poorly designed basket strainers do not provide quick and easy access. Low cost but high maintenance.

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	Activated sludge systems	Uses a consortium of microorganisms that live under oxygenated or anoxic conditions to convert carbonaceous compounds into a CO_2 and ammonia into nitrogen gas, and in this way removes organic matter and nitrogen from waters being treated. Activated sludge systems require aeration via: • Coarse bubble diffusers • Fine bubble diffusers • Surface aeration Importantly, microbe concentration is maintained at a sufficiently high level to effect treatment. This means a proportion of the microbial biomass that grows during treatment must be retained (via settling or attachment). Some systems operate as sequencing batch reactors, that include a cyclic air-on air-off operation, with the air-off periods allowing settling and retention of microbial biomass. **Aerobic granular sludge** is a type of activated sludge which uses microbes that grow in the shape of granules and thereby are more easily removed from the treated water by settling. **A moving bed bioreactor (MBBR)** is a type of activated sludge where microbes grow attached to a plastic packing carrier medium, which facilitates the necessary retention of microbial biomass without requiring settling. **A membrane bioreactor (MBR)** is a type of the activated sludge processes that uses a membrane to recover and retain microbial biomass, and also producing a clear filtered effluent. The membrane has to be kept clean by scouring with air and the membrane capital and operating costs are high and membrane biofouling can be an issue, especially with high organic loading such as in dairy effluent. The effluent quality can be excellent because of the filtration process. The **Super Dissolved Oxygen (Bi-Act SDO)** is an exotic commercial technology that relies on migration of air through a stacked plate tower. This is said to transfer oxygen into the water being treated much more efficiently. There is no known supplier base for this technology in Australia. Source: Water Technology; (Tchobanoglous et al., 2004)	Red	High cost. Electricity demand for aeration. Complex. Produces significant quantities of biological sludge requiring further handling. Fine and coarse bubble diffusers unlikely to be feasible for dairy effluent, because of high maintenance requirements due to expected blockages with manure solids and growing biofilm. Can remove nitrogen by volatilisation in sophisticated designs, but this may be an unwanted side effect if nitrogen is considered a valuable nutrient.

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	Adsorption/Bio-oxidation process (A-stage + B-stage)	An adsorption/bio-oxidation process is similar to an activated sludge system, except that it relies on a two-step process, wherein the first step (A-stage) includes a highly loaded (in terms of organic loading) biological process where much of the organic matter present in the effluent is sequestered as biomass via adsorption, settling, and microbial growth processes. The second B-stage is a conventional activated sludge system that treats effluent that has been pre-treated by the A-stage step. Source: Sancho et al. (2019). Science of The Total Environment, 647: 1373-1384.	Red	Complex Difficult to control and operate Impractical High cost Extensive aeration electricity required No commercial systems currently available in Australia.
	Advanced oxidation process (a common final disinfection treatment step)	Only used for final purification of waters with low organic and nutrient load. Uses UV or chemicals (e.g. Fenton's reagent) or other advanced oxidation agent to destroy contaminants in the water that are difficult to remove by other means. (Tchobanoglous et al., 2004)	Red	High cost, high maintenance and impractical. OH&S implications. Only suitable for final polishing of substantially pre-treated waters and for high cost high-quality applications (direct potable reuse). Such uses of recycled water at a dairy are likely to be met with significant regulatory scrutiny. Can produce toxic disinfection by-products with feedwaters with organic and nitrogen loading.
	Anaerobic digestion	Converts organic matter in dairy effluent into biogas, which is a renewable fuel gas. Different technology types exist for anaerobic digestion • Covered anaerobic pond (lowest cost option for liquid effluent) • Anaerobic filter • Anaerobic clarigester • Upflow anaerobic sludge blanket (UASB) reactor • Expanded granular sludge bed (EGSB) reactor • Solid-phase (semi-dry) digestion • Stirred tank heated digesters • Plug-flow digesters Anaerobic membrane bioreactor (adds a membrane to the reactor that produces a clear filtered effluent) (Batstone and Jensen, 2011)	Red	Only a small fraction of daily manure output is collected in pasture-based systems. May be more viable in dry-scraped systems or in very large dairies. Dairy shed effluent is typically dilute and costly to transport to a digester, and requires very large digestion system volumes. Biological methane potential typically lower than other organic residues used for biogas production. By covering an anaerobic pond and capturing off-gases to be burnt in a flare, odour can be reduced. Some digestion technology types not suited to the solids loads in dairy effluent. Can be very costly and may not be cost-justified.

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	Anaerobic Ammonium Removal (short-cut biological nitrogen removal, commercial variants include DEMON®, Anita™ Mox, ANAMMOX®)	A microbiological process (like activated sludge) performed by a specialist microbial community that short-cuts the nitrogen cycle, with ammonium oxidised directly into nitrogen gas via nitrite as an intermediary. Compared to conventional nitrogen removal via activated sludge, Anaerobic Ammonium Removal requires a lot less aeration and a lot less organic matter to completely remove nitrogen (Jensen et al, 2013)	Red	High cost and complexity. Specialist commercial technology. Nitrogen removal not a primary driver for SW WA. Instead beneficial use of nitrogen as a fertiliser nutrient is desired. Supplier base and service support in Australia very limited. Not applicable to effluent with a high organic loading.
	Biological contactor (Rotating biological contactor, Biorotor)	A biological contactor has a rotating drum with structured packing media that spends a proportion of its rotation time immersed in an effluent being treated and the remainder of its rotation time in ambient air. This results in aeration of effluent adhering to the packed media and aerobic microbiological processes similar to what occurs in an activated sludge system. Source: Exelio	Red	Only suitable for dilute effluent streams, so unlikely to be suitable for dairy effluent. Complex mechanical parts. High cost. High maintenance. Likely to be overloaded with suspended solids, nutrients and organic matter in dairy effluent.
	Carbon filter	Carbon filtering uses a packed bed of activated carbon to remove contaminants and impurities from a contaminated water stream by chemisorption.	Red	A typical treatment step in the preparation of high-quality water. Not suitable for dairy shed effluent without substantial prior treatment. Not a stand-alone technology or practice for treatment. Very costly to run because will likely need to replace activated carbon regularly in the case of turbid water streams. Supplier base and service capabilities to SW WA dairies unknown.

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	Capacitive deionisation (Electrodeionisation)	Capacitive deionisation uses an electrical potential difference between two electrodes to attract negatively charged and positively charged ions, which are then retained by diffusion into a porous electrode and thus the water is treated, and salts are removed. Source: EcoloxTech	Red	Complex. High capital and operating costs. Specialist application. Not suitable for use directly on dairy effluent and would likely require substantial pre-treatment. Not readily scalable. Produces a brine reject stream that needs to be disposed of, with a much higher salt concentration than in the original water prior to treatment.
	Dissolved air flotation (DAF, also more recent variation called microflotation unit)	Dissolved Air Flotation or DAF Unit is a solids separation device that contacts a portion of treated effluent from the DAF unit in a pressurised drum with compressed air. This dissolves air into the effluent, which is then recycled back to the inlet of the DAF unit. When this effluent is mixed with the inlet untreated effluent and is exposed to atmospheric conditions (1 atm pressure), the previously dissolved air emerges as very small bubbles. These bubbles attach to suspended organic matter and create a float. This float accumulates on the DAF unit surface and is scraped into a collection bin. Source: Progressive Dairy; (Tchobanoglous et al., 2004)	Red	More commonly used as a treatment step for dairy processing wastewater. Complex and likely impractical for dairy farms, albeit that DAF units have been installed at dairies abroad. High capital costs, operating and maintenance. Energy for pumping and moving parts. Not scalable for small-to-medium dairy sizes.
	Enhanced biological phosphorus removal (EBPR)	An extension of activated sludge, where an upfront anaerobic fermentation step is added. This ferments organic matter into volatile organic acids, which are taken up in the aeration part of the activated sludge process in the form of poly-phosphate, thereby greatly enhancing the removal of phosphorus as compared to conventional activated sludge processes. Source: Enhanced Biological Phosphorus Removal Metabolic Insights and Salinity Effects by Laurens Welles; (Tchobanoglous et al., 2004)	Red	High cost and complex. Requires infrastructure similar to activated sludge processes, with the addition of a separate upfront fermentation tank. Supplier and service base not available to SW WA dairies. Most common application in municipal wastewater treatment, not in agricultural-industrial effluent treatment. Produces large volumes of sludge requiring subsequent handling/ spreading at additional cost.

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	Electrodialysis	Electrodialysis is similar to capacitive deionisation, except that the electrodes are not porous and instead a membrane is used placed between the positive and negatively charged electrodes, to selectively retain or transfer certain charged salts. This offers the potential to recover concentrated streams containing certain desirable nutrients such a potassium and ammonia nitrogen. Source: Lenntech	Red	Complex. High capital and operating costs. Specialist application. Not suitable for use directly on dairy effluent and would likely require substantial pre-treatment. Not readily scalable.
	Electrocoagulation	Electrocoagulation (EC) uses electrolysis with a sacrificial metal cathode that dissolves due to electrolysis and causes coagulation of suspended solids in the water being treated, which then settle out or float (if hydrogen is produced, depending on the cell potential). It is said to remove suspended solids to sub-µm levels as well as heavy metals from contaminated waters. Source: Hatco Systems	Red	Moderately complex. Requires sacrificial anode. Specialist application. Not suitable for use directly on dairy effluent, and would likely require substantial pre-treatment to remove coarse solids. Not readily scalable. Uncertain supplier and service base to SW WA dairies.
	Fermentation to produce hydrogen	Fermentation for hydrogen production works by the microbial fermentative conversion of organic matter into biohydrogen. Dark fermentation occurs in the absence of light and in the absence of oxygen (anaerobic), where a series of microbiological reactions break down the organic matter, producing biohydrogen as by-product. (Pandey and Mohan, 2013)	Red	Requires selectively enriched mixed microbial cultures. May require a chemical suppressant of methane production, otherwise the natural breakdown processes that occurs will want to proceed to its end point, which is methane production. High cost and complexity. Impractical for dairy farms. Likely uneconomical. Hydrogen production and storage is a specialist field. No commercial systems available for dairy effluent.

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	Fermentation into mixed alcohol fuels	As for biohydrogen production, but in the presence of active yeast and at acidic to slightly alkaline pH. The alcohol has to be distilled and processed.	Red	For fuel alcohol blends only. Highly complex and specialist industrial application. Has been done with dairy manure and patented (1981), but not scalable to dairies in SW WA. Not proven.
	Forward osmosis (or FO)	FO is similar to RO, in that a membrane is used to effect water separation, but forward osmosis instead uses natural osmotic pressure to force water through the membrane instead of mechanically applied pressure. This natural osmotic pressure is induced by using a draw solution (lower water concentration) that pulls the water through the membrane, leaving behind contaminants such as pathogens, viruses and large organic substances. Source: ForwardOsmosisTech	Red	Like RO, except somewhat more energy efficient. However, typically requires RO to prepare the final water for reuse.
	Forsi	The Forsi system is a packaged effluent treatment plant, that includes a series of technologies, including chemically assisted solids separation, fine filtration (including media filtration, nanofiltration) and disinfection to prepare a high-quality water for recycling in the dairy. Source: Forsi innovations https://www.forsi.co.nz/	Red	Complex. Supplier base unknown in SW WA. High chemical and operating cost. High capital cost. Water costs in SW WA typically unlikely to justify the extent and cost of treatment provided by the FORSI system. Promoted in New Zealand dairies.
	Ion exchange	Uses a medium that sorbs salts from a contaminated water and thereby desalinates. Produces a concentrated reject stream that still requires careful disposal/post-treatment. Source: Newterra	Red	Will likely form part of a more elaborate filtration treatment system to produce high quality water for reuse (e.g. FORSI technology). High cost. Not suitable without significant pre-treatment. Chemical costs for regeneration.

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	Imhoff tank	The Imhoff tank consists of a chamber conventionally used for the reception and processing of organic sewage sludge by simple settling and sedimentation, as well as biological breakdown of organic matter by anaerobic digestion. Source: SSWM	Red	Covered anaerobic ponds more cost-effective alternative. Relatively high maintenance as compared to covered anaerobic pond. Better suited to sewage application.
	Induced gas flotation	Induced air flotation works on similar operating principles to a DAF unit, except that air is injected with the feed water forming small bubbles, causing the rising of suspended solids adhered to the small bubbles, and the formation of a float layer that is collected and thus separated from the main water line. Source: http://www.processgroupintl.com/media/downloads/D04_Gas_Flotation_rev_11-12.pdf	Red	As for DAF
	Microalgae	Planktonic growth in race-way ponds or photobioreactors. Grows on UV-Vis spectrum of light. Grows autotrophically, so requires CO_2. Can sequester remove nutrients (nitrogen and phosphorus) from secondary treated effluent. Source: Bitog et al, 2011	Red	Naturally occurring process. Can be a complex engineered process. Can be low cost if in raceway ponds. Algae can be biomass source for aquaculture feeding applications. Removes nitrogen and phosphorus. Can grow using natural light. Separation of microalgae from the suspension can be difficult. Complex harvesting process. Limited by high ammonia concentrations, so typically requires some dilution or upstream secondary treatment to reduce ammonia levels in the effluent. Vadiveloo et al, 2019
	Macroalgae	Similar to microalgae, except that macroalgae grows in large mats and can be grown on scaffolds, thereby making the recovery for beneficial use as a biomass much easier than in the case of microalgae. Similarly to microalgae, macroalgae removes nitrogen and phosphorus from effluent. Source: Vadiveloo et al, 2019	Red	Naturally occurring process. Macroalgae much easier to separate than microalgae, making recovery for beneficial biomass uses easier. Removes nitrogen and phosphorus. Can grow using natural light. Much more sensitive to inhibition by high ammonia levels. Tends to be outgrown by microalgae in effluent. Vadiveloo et al, 2019

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	Microbial bioelectrochemical systems	Uses microbially assisted electrolysis to produce a range of exotic products from the carbon and nutrients in a contaminated water. Source: Meteorr	Red	High cost. Complex. Requires specialist operator. No commercial systems available. No WA supplier base.
	Membrane distillation	Uses a membrane to effect the selective separation from a contaminated stream, wherein the membrane only permits molecular water vapour to pass, which is collected by condensation once it has passed through the membrane. Source: Memsys	Red	High capital and operating cost. High complexity. Unlikely to be scalable to dairy farm sizes in SW WA. Water costs in SW WA typically do not justify the extent and cost of treatment provided by this technology.
	Microfiltration (crossflow or submerged, Tangential Flow Separators), nanofiltration and reverse osmosis (RO)	A differential pressure is applied across a filter membrane, which forces water through the membrane, whilst retaining contaminants based on their size and chemical charge. The particle size cut-off for the membrane is in order of largest to smallest; microfiltration (cut-off >0.1µm, rejects suspended solids); nano-filtration (1-5nm, rejects some ions and pharmaceuticals and organic molecules); and reverse osmosis (RO <1nm cut-off, rejects most inorganic salts and everything with larger size). Microfiltration is often applied in series with nanofiltration or RO, so that the microfiltration step prepares a feed water free of suspended solids for operation of the RO. Because of lower required pressure differentials, microfiltration is more energy efficient than nanofiltration and nanofiltration more energy efficient than RO, but only RO completely desalinates a water stream. Sometimes nanofiltration and microfiltration are operated as submerged membrane units, with the pressure differential across the membrane being a vacuum drawn on the clean (filtrate) side of the membrane. Source: Aquashakti Water Solution; (Tchobanoglous et al., 2004)	Red	Membrane filtration processes would likely form part of more elaborate filtration advanced treatment systems for production of high-quality water for reuse purpose (e.g. FORSI technology) Chemical and operating energy costs can be significant. Typically requires back-wash and periodically chemical cleaning. The concentrate (retentate) stream of any membrane filtration process contains the contaminants that were present in the original water stream prior to treatment, except at about 10 times the concentration. This concentrate reject stream still requires careful disposal. Requires pumping at pressure, so substantial energy costs.

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	Photobioreactor for single cell protein recovery	Uses closed illuminated bioreactors to grow autotrophic biomass (microalgae) or chemo-hetero-phototrophic microbial biomass, which can then be used to recover high value feed ingredients or be used as a protein source for aquaculture feed directly. Source: Randrianarison and Ashraf (2017). Geology, Ecology, and Landscapes, 1:2, 104-120.	Red	Complex. High cost. Not readily scalable for dairy effluent treatment. No commercial systems currently available.
	Roller press	Wet manure solids are fed into the top of the press, and the rotational movement of the roller pulls solid material through the press where it is dewatered pressing up against a screen, with the dewatered solid manure fibres passing through the roller. Source: McLanahan	Red	High cost. Complex. High maintenance. Uncertain supplier/service base. Typically requires pumping. Typically used to further dewater manure solids obtained from a trommel screen, inclined screen or other gravity-based separation method. Not a stand-alone step.
	Sand filtration (can include media filtration, which mixes the sand with other media including activated carbon, and sorbers for removal of nutrients)	Sand filtration removes fine suspended solids by flowing the liquid being filtered vertically through a fine bed of sand and/or gravel (filtration media). This captures the fine solids by sorption and physical separation. When solids have accumulated to a significant extent, the filter is backwashed by flowing water in the opposite direction to suspend and carry out the solids into a reject stream that is sent to disposal. Sand filtration can also be via slow gravity, allowing microbial communities to develop in the upper layer of the sand filter. This is called slow sand filtration and can add the function of biological contaminant removal. Source: HydroFlo Tech LLC; SSWM	Red	Only suitable for filtration of effluent that has been significantly pre-treated to remove the majority of suspended matter. This will likely limit its use on dairy effluent. Requires back-washing. Requires pumping in the case of rapid sand filtration. Slow sand filtration has a limited operational life, before the sand has to be replaced or chemically washed to remove the accumulated microbial biomass. Suitable for removal of fine suspended solids.
	Strong acid addition to reduce nitrogen volatilisation losses	Add sulfuric acid, which lowers the pH of the effluent and this discourages the volatilisation losses of ammonia nitrogen, thereby increasing the beneficial use of nitrogen on crops.	Red	Nitrogen is a lower priority concern in SW WA, compared to phosphorus. Acidic effluent may impact on soil health. Chemical cost is significant, so unlikely to be cost-feasible. Technology being researched in Victorian dairies via Agriculture Victoria.

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	Trickling filter	A trickling filter consists of a vessel filled with random or structured plastic or metal packing. Effluent is sprayed over the top of the packing and trickles down through the packing, thereby creating contact between the effluent and air flowing naturally up the packing in the opposite direction. This aerates the effluent being treated, thereby supporting the same aerobic microbiological processes that occur in activated sludge systems (see above). Source: Brentwood Industries, Sustainable Sanitation and Water Management Toolbox; (Tchobanoglous et al., 2004)	Red	Only suitable for dilute-moderate strength effluent streams, so may not be suitable for dairy effluent. Complex mechanical parts. Moderate to High cost and maintenance. Likely to be overloaded with suspended solids, so requires suspended solids removal prior to the trickling filter.
	Thermal distillation	Thermal distillation heats the feed water stream up to form water vapour, which is then condensed as a high-quality water product stream. Also, can pasteurise. Source: HRS Heat exchangers Zero liquid discharge is an extreme form of thermal distillation, whereby the original contaminated water is evaporated to dryness, typically forming impure salts.	Red	Only suited for very large-scale water recovery. Very high capital and operating expense because of exotic materials of construction to withstand high salinity and temperature.
	Vermifilter/black soldier fly larvae	Black soldier fly larvae can compost fresh manure and produce animal feed, because the pupae and pre-pupae can be fed to fish, poultry and pigs. In addition to the protein production, the excrement of the fly larvae, called frass, can be used as organic fertiliser. Source: Fish farming expert	Red	Scalability is uncertain. Uncertainty about ability to feed larvae produced from dairy manure to pigs and poultry. Research is ongoing in Australia, including experimental research currently being conducted in WA. Complex. Can be logistically complex. Suitable for solid manures. Unlikely to be suitable for liquid effluent without prior efficient solid separation step.
	Wet oxidation (Zimpro or ZIMmerman PROcess, e.g. bubble column technology)	Wet oxidation involves treatment of contaminated waters at high temperature by the contact of the water with oxygen as an oxidising agent. It is referred to as "Wet Air Oxidation" (WAO) when air is used as the oxygen source. The oxidation reactions that play a role in wet oxidation occur at a temperature above 100°C and below 374 °C, and the system is maintained under pressure to prevent too much water evaporating.	Red	High cost, high maintenance and complexity. OH&S implications of high temperature. Impractical and not expected to be readily scalable to SW WA dairies. However, a recent type, the “bubble column” has been developed up to pilot scale for use with agricultural effluents and may become an interesting pasteurisation option for dairy effluent in the future. Source: Australian Pork Limited

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Reuse/ Application				
Desludging and dewatering of effluent ponds	Vacuum tankers/Muck spreaders  Nevada	A vacuum tanker can extract sludge from an effluent pond for direct application. The sludge from an effluent pond is typically rich in phosphorus. Often some recirculating pumping or agitation is provided to resuspend the sludge to an extent to ease pumping, because sludge that has settled over extended periods (many years) can be very dense and difficult to pump. Also used for application (See further down below).	Green	Capital costs may be significant but could be feasible by third party contractor or possibly by farmer cooperative joint purchase arrangement. Mobile equipment (a tractor) can be used for other functions on the farm, thereby increasing benefit from the capital investment. Also used for application (See further down below).
	By Excavator (standard or long-reach) or dragline  Australian Pork Limited	Sludge left to dry in an effluent pond can be desludged effectively with an excavator. Long narrower effluent ponds are typically easier to desludge by an excavator.	Green	Feasible by third party contractor. Excavation costs can be reduced by pumping as much of the water in the effluent pond out and leaving the settled sludge to dry out. However, this may not be possible because for this the pond may need to be taken off-line. A destructive top layer can be installed at increased cost to protect underlying pond liners (e.g. tyres), during use of excavators.
	Dredges  Australian Pork Limited	Floating dredges resuspend and pump sludge out of an effluent pond. The floating dredge is supported on a pontoon. The cutter head of the dredge can be modified to use a wheel system in the case where the cutter head is to be kept a suitable distance away from a lined pond floor to prevent damage. Commercial companies that offer dredging services in Australia include, Epsom Environmental, Apex Envirocare, Dredging Solutions, UAT SludgeRat and Dredging Systems.	Green	Feasible by third party contractor. Suitable for desludging of effluent ponds, including ponds filled with effluent. Can be retrofitted to prevent damage to lined ponds.

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	Geotubes (Geobags)  Tencate	Geotubes consist of engineered textile permeable to water, and therefore when sludge is pumped into the bag, the water permeates through the bag walls and can be collected. The sludge that results from this natural gravity draining of effluent, has a high moisture content.	Orange	Simple Moderately costly Easy to use and mobile Supplier and support likely available to SW WA Accessing sludge inside the tube/bag for beneficial reuse is uncertain and may damage the tube/bag.
	Sludge drying bays  Australian Pork Limited	Sludge can be removed via a sealed truck into a dedicated dewatering bay where any liquid that leaches from the sludge is collected and drained back into the effluent pond. The solids in the sludge bay dries and is then hauled and land-applied with solids-spreading equipment. The base of a sludge drying bay must have a low permeability. Bunding options that have been used in the past have included large straw bales, geotextile or shade cloth fences or earthen embankments (Dairy Australia).	Orange	Can be reasonably simple. Can allow on-going operation of effluent ponds, whilst sludge instead dries in the sludge drying bays. Solar drying. Enables better solids management in terms of nutrient loading to agricultural land. Wet sludge applied directly onto paddocks can substantially increase the risk of nutrients leaching into surface waters or groundwaters. Must be conducted on an impermeable earthen or concrete base. Can work well in dryer climates. Function in SW WA unknown. Requires a water balance.

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	Belt filter (belt press filter, or belt filter press)	A continuous solid-liquid separation device, that uses a pair of filtering cloths and belts that is passed through a set of rollers. Sludge or slurry is fed into between the cloths and is thus dewatered as the cloths pass through the rollers, producing a stackable solids cake. Source: Phoenix Process Equipment; (Tchobanoglous et al., 2004)	Red	High capital and operating cost. Complex. Not readily scalable and not modular. Requires chemicals (e.g. flocculants) to remove significant amounts of nutrients from dairy effluent.
Manure solids processing	Composting - Active/Passive  Dairy SA, 2014	Composting is a process in which microbes decompose organic materials in the presence of oxygen (aerobic). Composting can be used to convert organic matter produced on the farm into a compost product. Inputs can include effluent from solids traps, sludge, spoilt feed and dead carcases. Active composting involves the turning of the piles to facilitate oxygen into the process and is much faster than passive which allows the organic material to decompose naturally and slower.	Green	Easier to spread over the land. High temperatures during the process can reduce the risk of weed seeds and pathogens. Can improve organic matter, soil fertility and soil structure. Produces a relatively stable soil amendment with slow release nutrients. Increased labour requirement especially if actively turning piles. Reduced nutrients content up to 50%N losses and 70% organic matter losses reducing the fertiliser value compared with fresh material (Dairy Australia). May need additional carbon or nitrogen sources to create a suitable Carbon-to-Nitrogen (C/N) mix for composting. Need a compost pad and drainage system. In high-rainfall areas, may need roofing structure to prevent excess moisture and run-off in the compost pile.

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	Adding sorbers	Addition of a variety of sorbing agents such as bentonite, zeolite and vermiculite to reduce greenhouse gas losses (nitrous oxide and ammonia) and retain N in the manure which can reduce conventional fertiliser costs. Have been shown in other livestock manures to reduce GHG by up to 60% and potentially improve plant growth by 20% and increase soil carbon by 50% (Hill et al, 2015).	Red	New research High cost of sorber additives Increased handing of manures.
	Gasification	A gasifier transforms manure into syngas, heat, power, fertiliser and biochar by partial oxidation at high temperatures. Depending on the operating conditions, the biochar that is formed and the energy recovery can differ. Source: United states Department of Agriculture	Red	Best suited to dryer manure products such as poultry litter. High capital cost. Complex. Not readily scalable. Whole modular units of minimum size have to be added. Loss of nitrogen. Can have unknown product mix, which may contain recalcitrant compounds.
	Granulation	An advanced processing technique for effluent pond sludge or for separated manure solids. Granulation is a treatment technology that forms grains or granules from a finer powdery solid material. The granules have better properties than the fines from which they were made, in terms of better flowability and ease of land applying. These properties can facilitate precise land application, could make transportation more affordable and could improve the acceptability of separated dairy manure solids as an organic fertiliser to provide additional sales revenue to farmers. Source: Feeco	Red	Costly. Will require manure separation before being granulated. Complex. Uncertainty about whether the value of granular product offered by available markets would cover the costs of processing via granulation. Increased handing of manures. Supplier base and service base unknown to SW WA. May require drying of the granulated manure product.
	Pyrolysis (Torrefaction is a lower temperature version)	Pyrolysis is a treatment step that decomposes organic matter thermally at high temperatures in an atmosphere devoid of oxygen. This forms volatile products, biooil and biochar. The operating conditions determine the products that form. Source: ManureManager	Red	High capital cost. Complex. Can have unknown product mix, which may contain recalcitrant compounds. Significant loss of nitrogen.

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	Pelletisation	Pellets are formed in a pellet mill where pre-dried and milled manure is extruded by compacting and forcing it through die openings by a mechanical process. The larger pellets are easier to handle and can therefore be more readily transported and/or land-applied compared to unpelleted manure. Source: Biopellet Machine & Wood Pellet Plants	Red	Costly. Requires manure separation before being pelletised and the product may require drying. Complex. Uncertainty about whether the value of pellets can offer better market potential and recover processing costs, as compared to conventional composting. Increased handing of manures. Supplier base and service base unknown to SW WA.
Effluent application methods to utilise nutrients	**Manual move** **Low Rate** **Portable sprinkler irrigator** **(Pot sprinklers, K-Line sprinklers, effluent guns)** See sprinklers below for examples  Dairy NZ	These sprinkler types are manually moved via a tractor, bike or by hand. They apply low application rates and are suitable for all soil types, terrains and varying shaped paddocks Need less than 5% solids to avoid clogging. For raw effluent, large orifices must be used. Some sprinkles have flexible nozzles that allow more solids to pass through. (Dairy for Tomorrow) Multi line systems can deliver large volumes over a relatively short time. Suitable for spreading dairy effluent and/or water irrigation on land where the contour is unsuitable for travelling irrigators. A number of examples of manual move sprinklers are provided below.	Green	Low capital costs. Low operating costs. Suitable on most soils and crops. Suit high rainfall or high-risk soils as they can apply low application rates. Generally can be used on more days of the year due to low rates and ability to distribute large volumes of effluent at once at low application rates/depth. Generally less moving parts than other irrigation methods -easier to maintain. Can be used on flat or sloping topography. Involves labour to manually move. Can be difficult to get even distribution. Need to be shifted regularly to distribute the effluent. Can block if solids separation not adequate or nozzles undersized. Need regular maintenance of sprinkler heads. Need appropriately sized pumps and pipes to ensure optimum pressures and volumes.

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	Manual Move Uni sprinkler- Low rate  Hightechenviro		Green	Simple, low cost option to spread dairy effluent nutrients. Low application rate minimises the risk of runoff, ponding and leaching. Simple to set up and move, making paddock coverage easier to achieve. Can be operated either singularly or in series. Ideally these should only be used with green water (solids separated out already). Able to be used on land unsuitable for irrigators. Application rates from 4mm-5mm/hour. 9-14mm nozzle size minimizes the chance of blockages. Jet length of 15m-24m enables wide coverage. www.hitechenviro.co.nz
	Manual Move K Line- low rate  Philmac		Green	Transportable and able to cover a large area Can shift using a quad bike or ATV. Lower maintenance costs - only moving parts are the sprinklers, pipe, pumps and valves. Suitable for all of soils types, terrain and paddock shapes. The K-Line sprinkler pods are moved when the system is operating - shifting is generally once a day with an ATV (usually no more than 3 minutes per line). Ease of installation, use, and shifting. Recommended for paddocks up to 360 metres in length (suits properties from 1-1,000 hectares). Low pressure requirements. High pressure is not needed. 45-55psi best pressure. Pressure compensating sprinklers can result in good uniformity.

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				Lower power requirements than other irrigation systems. Modular and adaptable, Wide selection of nozzle sizes. Application rates of 25mm to 80mm of water per week. Moveable out of paddocks for cropping or winter storage. www.philmac.com.au
	Manual move effluent sprinkler  Dairy Pumping Systems		Green	Single or multiple sprinklers Ideal for all soil types including high risk soils where contour is sloping greater than 7˚, there is impeded drainage, or where soil moisture content is relatively high. Sprinklers allow gentle application for enhanced soil and plant absorption. A typical system utilises 3-4 sprinkler units to give a total flow rate similar to a travelling irrigator. Low intensity application rate 4-8 mm/hr. Operating pressure range 2.4-5.3 bar (35-75 psi). Wetted diameter 30-60m. www.dairypumpingsystems.com.au
	Manual move- Raingun  hightechenviro		Green	Can pump large volumes in a short time. Low application depths and rates can reduce the risk of ponding and run-off making them suitable for poor draining soils and sloping land. Can do partial arcs. Pressure range 1.5-6.9 bar (22-100 psi). Wetted diameter 60 to 130m. Hightech enviro and dairy pumping systems.

Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	 Dairy Pumping Systems			
	DuCaR Sprinklers   Irrigation box		Green	Low maintenance. Low capital. Specifically designed for effluent and waste water irrigation. Models include effluent, sandy and clean irrigation water. Ability to move a large amount of water in a short time. Specially designed flex rubber nozzle and barrel are claimed to less likely clog and require minimal filtration requirements. Gear driven sprinklers designed to provide continuous irrigation and slow rotation even on high pressure applications. Working pressures range 37-100psi, waterflows 161-526L/min with shooting radius 22-38m www.irrigationbox.com.au

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	Travelling Irrigators (movable) See irrigators below for examples.	Moveable sprinklers Travelling irrigators are generally travelling rainguns or boom sprays. These sprinklers are self-propelled, fed by a flexible hose and guided in a straight line by a guide cable.	Green	Low capital. Not well suited to steep terrain. Can distribute large volumes of effluent at one time over a wide area. Don't require as high a level of solids removal as a sprinkler system. Not a complex system-relatively easy to service and maintain. Can have trackers or alarms attached to assist management i.e. alert to stoppages/blockages Can be low or high application depths. However, high application rates are not suited to high risk soils. Not ideal for small paddock areas. Can break down, get caught on guides/hoses and tip over if not set up correctly. If not maintained can deliver uneven and high rates leading to nutrient overloading. Application rates can range from 1-13mm and can generally travel 300-400m. www.hitechenviro.co.nz; www.williamsirrigation.com; vaughanirrigators.com.au

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	Cobra travelling raingun  hitechenviro.co.nz		Green	Can achieve low application depths and rates and spread over large distances. No long boom arms makes it easier to move around and set up. Application depths as low as 1mm and application rates down to 4.2mm per hour, minimising ponding. Can spread over large areas with full or partial circles and a setting that allows spreading to one side. Must have correct flow and pressure at all times to maximise performance. The selection of the correct nozzle size at the gun, a pump that can deliver enough flow and pressure, and well laid out drag hose are key to maximising performance Even spread and depth ensures even application and minimises risk of ponding. Ability to be used in a stationary position if required. Fitted with shut off valve shuts irrigator down at the end of a run. Min application depth and rate: 1mm and 4.2mm per hour Wetted width: 46m to 75m Travel distance: up to 400m Travel speeds: 0 to 3.5m per minute Min 50PSI. Maximum PSI: 120 www.hitechenviro.co.nz

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	Travelling Raingun irrigator  Williams Irrigation		Green	GB Magnum travelling Raingun/irrigator combines a static raingun with a travelling irrigator. Claims a wetted width more than twice as wide as a traditional travelling irrigator, with application rates and depths competitive with sprinkler systems. Can be fitted with an auto shut-off valve and/or a GPS system, to prevent over-application of effluent. Claims it can irrigate effluent in a single nutrient-rich state without the need for solids separation. Utilises nozzles with diameters greater than 13mm. Range of application depths and rates to suit different soils through travel and nozzle adjustments. Application depths of 3mm - 25mm and rates below 10mm per hour. Wetted widths from 45m 90m. 5 travel speeds. An inline filter may be important if irrigating straight from a sump. Operates at pressures and flows provided by traditional effluent pumps. www.williamsirrigation.com http://www.dairypumpingsystems.com.au

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Travelling boom irrigators  Quad x 4 Irrigator vaughanirrigators.com.au		Green	Quad x 4 is a recent low-pressure travelling irrigator. With four rotating arms the irrigator is able to throw twice as much water, and with four speeds can travel at over 2 – 4 times quicker than other irrigators cutting down on running costs. 75,00L/hr, auto shut off, 8 speed, 300m run, low centre of gravity. Other 2 boom irrigators for example have 10m or 14m booms with 300m cable, throwing 40-50m. 10 – 90 psi. 3785 – 49000L per hour. vaughanirrigators.com.au
	Spider travelling irrigator-2 boom  Image: www.williamsirrigation.com		Green	Application depth 5mm through 13mm nozzles @360 litres per minute @ 40 psi, 5 travel speeds. Differently angled arms allow for a more even spread pattern of between 30 to 50 metres depending on pump pressure. Maximum Volume 90 cubic metres per hour. Suitable for electric and PTO pumps. Drags 90 alkathene. Travel Distance up to 400 metres. http://www.dairypumpingsystems.com.au/products/williams-irrigators/greenback-spider-irrigator

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	 Image: www.williamsirrigation.com			
	Tankers - Injection, splash plate, dribble bar A number of examples of tankers and their application methods are provided below.  www.nevadagroup.co.nz  www.giltrapag.com.au	Effluent tankers suck/vacuum up the effluent directly from a pond or sump and distribute it over the land via a number of methods. Application rates can be varied based on the flow rate and speed of the tanker.	Green	Can adjust the application depth and rate based on flow and speed. Can generate low application rates. Access any part of the farm or off farm and distribute over wide areas. Especially good to distribute the nutrients away from the nutrient-rich paddock areas around the dairy. Can move large volumes quickly. No need for solids removal. Ponds can be stirred to mix up settled solids. Reduces the need for pumping. Not suitable to drive during wet weather due to potential for bogging and pugging up pastures. May not be suitable for very steep land.

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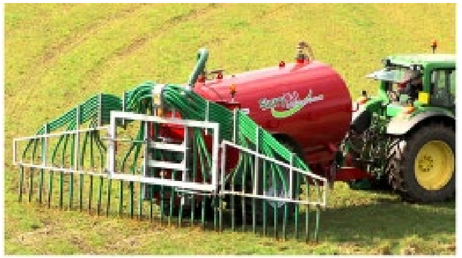
	Tanker-Splash Plate  South East Dairy Effluent Guidelines SA, No 11, 2005	Effluent is drained out of the back of the tank in which it hits a plate and sprays in an arc out over the pasture/crop.	Green	
	Tanker-Dribble bar (e.g. Standard or Duo)  www.slurrykat.com	The dribble bar distributes the effluent at ground level out of various outlets. This method of spreading reduces the surface area of slurry exposed to the air and can achieve a more uniform spread pattern and less coverage of the pasture foliage by the slurry.	Green	Reduces N losses compared to splash plates.
	Tank- trailing shoes  www.slurrykat.com	Allows the effluent to be applied at the soil surface with minimum contact with the plant foliage.	Green	

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	 www.pichonindustries.com  www.pichonindustries.com			
	 www.major-equipment.com	Slurry Tank Injector. Slurry is inserted into slits created by steel-cutting discs below the subsurface where generally slurry is injected to around 2-6cm.	Green	Reduce N loss. Delivers effluent to the root zone. Minimise run-off from effluent sitting on the surface.

Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Nevada Rainwave Slurry Spreader  www.nevadagroup.co.nz	Utilises a tractor and feeder hose with a Rainwave attachment to distribute effluent over a wide area. Using a high capacity pump, effluent is pumped through a layflat hose to a low pressure RainWave™ slurry spreader. The RainWave™ spreader is attached to a tractor's 3-point linkage, dragging the hose behind it. www.nevadagroup.co.nz	Green	Designed for damp soils. Large droplet size, so minimal wind drift. Gentle low-pressure rain pattern. Low application depth (1-10mm). Safe tractor speeds (less than 7km/h). High volume (100m^3/h - 200m^3/h). Very even spread pattern. Low maintenance. Handles thick slurry. The selection of lay flat hose for these systems is critical. Not only must the hose be abrasion resistant, it also needs a high tensile pulling strength and high working pressure. www.nevadagroup.co.nz
	Umbillical systems  www.slurrykat.com A number of examples are provided below.	Tractor Hose reeling systems can either be mounted or trailed to suit required applications. Hose capacities range from 100 metres to 3,000 metres in one complete unit.	Green	Distribute over a wide area. Low rate application.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Combi Dribble bars-Umbillical system  www.slurrykat.com/combi-dribble-bars	A compact, lightweight and efficient means of umbilical slurry/manure spreading. This system combines up to 600m of lay flat hose with a dribble bar and can be used by one operator.	Green	Available in 400m or 600m capacity and in single or double jet spreader. Used by farmers who may prefer to handle their own slurry as opposed to a contractor approach. www.slurrykat.com/combi-dribble-bars
	Standard, Swing up and Duo dribble bars Standard  www.slurrykat.com	Tractor mounted dribble bars that utilise the umbilical system to supply the effluent to the bars. The swing up incorporates an anti-drip swing up system that makes the dribble bar compact for transport and eliminates problems with dripping of slurry/manure from the delivery hoses. The duo can be mounted on the rear of any slurry tanker and then removed and used as the spreading device in the SlurryKat umbilical system. www.slurrykat.com	Green	

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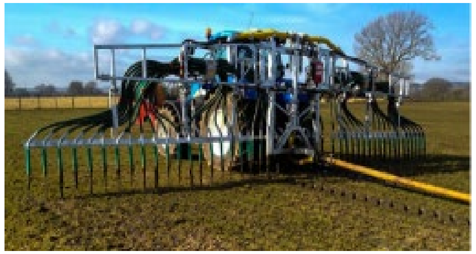
Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Swing Up  www.slurrykat.com Duo  www.slurrykat.com			
	Solids Spreading  www.nevadagroup.co.nz	Can spread a range of manure types from semi liquid to hard solids. Can be used to spread solids from desludged ponds, trafficable solids traps, sumps, laneways and feedpads.	Green	Can distribute over wide areas of the farm and away from nutrient hotspots around the dairy.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Contract solids spreading or tankers	Utilises contractors to come onto the farm and spread stockpiled solids or extract slurry straight out of the ponds.	Green	Low capital. Less control over when manure/effluent is spread. Less benefits from the nutrients due to longer storage or spread when contractor available. Reliant on availability of contractor.
	Centre Pivot irrigator  www.waterforce.co.nz/effluent	A centre pivot is a method of irrigation in which a boom is self-propelled around a central fixed point. A pipe is supported by a series of towers approximately 2-4m above the ground level. Sprinklers are mounted on or hang below (underslung) the pipeline and are graduated from small close to the centre to larger on the outside of the boom to ensure even application of the irrigated water.	Green	Can deliver very low application rates. High initial capital costs. Energy costs associated with operating the boom. Can be irrigated over many days of the year due to low rates. Delivers large volumes quickly and thus can reduce storage requirements. Depending on size of storage may only need to run for a couple of days a month. Usually effluent is incorporated into existing irrigation crop centre pivots. Need to have good solids removal or nozzles will clog. Can inject the effluent in with freshwater to shandy down the concentration. May not be able to be used over winter months when paddocks become waterlogged. Effluent can corrode the equipment and lines should be flushed out with freshwater after use.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Flood Irrigation  extensionaus.com.au/irrigatingag/agriculture-victoria-irrigation-resources/	Effluent is applied to land generally via gravity across laser graded or sloping land. Effluent can be applied straight from the ponds or shandied down with irrigation water. Pipe and riser systems (picture left) can be used to irrigate the water.	Green	Suitable for those who have an irrigation system in place. Low energy, low cost and labour. Not suited to sloping terrain. Not suited to sandy soils or high-risk soils. Can generate large volumes of run off if not managed or captured in a reuse dam. Can also increase effluent storage requirements, because of requiring a larger soil-moisture deficit.
	Lateral Move sprinklers	Similar irrigation set up as a centre pivot except rather than move around a central point the boom travels laterally in a straight path across the paddocks. Water is generally supplied from a hose along the edge of the paddock.	Green	As above.
	Solid set sprinklers  Irrigation essentials for North Coast farmers, NSW DPI	Sprinkler structures - Permanently fixed Is a stationary sprinkler system that is supplied usually by pipe network that is buried below the ground.	Orange	Low maintenance. No shifting. More suited to smaller dairies with low volumes of manure. High risk of nutrient overload as sprinklers cannot be moved. Would need across multiple paddocks/areas to distribute the nutrients evenly and rest paddocks.

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	Hydrants irrigation system  www.hitechenviro.co.nz	Hydrant systems are fed from a mainline that is supplied with irrigation water or dairy effluent. Travelling irrigators and other sprinklers (e.g. low rate) are then attached to the hydrants to allow wider distribution of the effluent. Can be fitted with pressure release valves to ensure effluent from storage facilities is pumped to paddocks without spills.		May tolerate entrained solids if flow is maintained. Allows wider distribution of nutrients across the farm. Minimises the lengths of above ground hoses/piping.
	Subsurface irrigation	Subsurface irrigation is the application of the effluent below the surface of the soil to the root zone. It reduces run-off and evaporation and delivers the nutrients and moisture to the root zone for plant uptake. Minimises contact with humans and animals. Source: Waternsw.com.au	Red	High costs – pumping and installation. High maintenance, could be damaged by animals. Unsuitable for sandy soils or those areas with high water tables. Need high level solids removal to avoid blocking the system. More suited to high value crops and horticulture that utilise the nutrients and moisture. Pasture does not have a strong nutrient stripping ability.
Effluent irrigation monitoring and management system	**Fertiliser offsets**	Soil and effluent monitoring to determine soil fertility and nutrient requirements to reduce conventional soil fertiliser applications and target effluent to maximise benefits.	Green	Low cost-soil and effluent testing. Agronomist/fertiliser specialist advice can assist in determining requirements based on soil test results and formulate different fertilisers based on needs. Can save significant amounts in fertiliser costs. Reduce nutrient overloading and loss.

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	GPS trackers for irrigators  Dairy NZ  tracmap.com	GPS guidance systems that can provide such services as text message alarms for pump shutdown, blockages, pressure loss, tipping over, start and stop by text, shift and nutrient application records. Can be solar powered.	Green	No line of sight needed. Reduced labour checking on irrigator to see if on track or stopped moving. Reduced risk of nutrient overloading, leaching and run-off from irrigator remaining in the same spot for extended periods. Allows nutrient application monitoring if option included. Peace of mind operation. Could potentially utilise for geo-fencing to reduce risk of environmental incident (e.g. buffers from waterways, roads and other sensitive areas).

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Purpose	Technology or Practice (Other common names)	Brief description	Short-listing	Reasoning
	Travelling Irrigator Shut off systems  www.technipharm.co.nz/irrisafe-effluent-irrigator-shut-off-system	Automatically shuts off travelling irrigator if it stops moving or pressure drops. Can get optional GPS tracking.		Reduced labour checking on irrigator to see if on track or stopped moving. Reduced risk of nutrient overloading, leaching and run-off from irrigator remaining in the same spot for extended periods. Peace of mind operation.
	Yardmaster Halo system  Yardmaster	Dairy effluent monitoring and control system. Tailored system to match needs of farm. Enables the application of effluent at a controlled rate, adjust motor speed to required effluent disposal rate, monitor flow with auto shut-off when interrupted or compromised, text alerts when system stops, cause notification, pump run feedback with remote start/stop. Pressure guard, pond level management, including freeboard alerts, programmable application, metering of applied volumes. Manage up to six zones remotely. Additional options: travelling irrigator fail safe and proof of placement, pod placement and pressure guard, green water priority storage for flood wash management, geo fencing, sump control. http://www.dairypumpingsystems.com.au/products/yardmaster-pumps/yardmaster-halo	Green	System cost approx. $12,000 plus $1,500 if remote station needed and an ongoing $900 yearly fee. (2018) Monitoring of pond to minimise overflows, allows application rates to be varied and monitored to avoid overload. Auto shutdown minimises run-off, leaching and nutrient overload and reduces labour required to continually check system. Peace of mind operation.

5.0 Scenarios of Effluent Management Systems Relevant to SW Western Australian Dairies

Potential Scenario Options for SW WA Dairies

There are many options and combinations of potential scenarios available when designing an effluent system. The type of system and management requirements will be based on individual site constraints, needs and challenges meaning there will not be a one size fits all solution to dairy effluent management in SW WA. Systems can be complex and highly engineered or quite simple and low cost. The higher the cost and automation, generally the lower the labour and management inputs. Foremost the design and management of a system should be based on the reuse of the effluent, i.e. where you want to distribute and how you want to use it.

With respect to the effluent management system scenarios, it is important to understand that the given scenarios may not be suitable for a specific individual dairy, because of site specific constraints and drivers that may differ from one dairy to another. It is important that an effluent management system for any dairy be carefully planned and designed, so that it matches site specific requirements.

The scenarios listed in Table 5 below have been put together considering the main constraints identified in SW WA, which were noted to be high rainfall, sandy soils and shallow groundwater. The scenario analysis also takes into account that most farmers wanted a low-cost system that was low in complexity and easy to maintain.

Note that various scenarios in Table 5 include SEP systems which will need further investigation prior to implementation to assess suitability in SW WA.

Novel considerations:

Rainwater diversion has been included in all systems as rainwater contributes a significant volume to the storage, pumping and application requirements leading to increased costs and management. Rainwater diversion can be manual or automatic.

Sand gravel traps have been incorporated into each system as this was a major challenge on most farms visited during the consultation process. Sand entering the system is abrasive to equipment and creates blockages and breakdowns. A sand trap can be a small concrete area with water positioned prior to the yards to remove the sand from the cows hooves before entry or prior to a storage system. Sand traps are not needed if gravity is used to a SEP or storage.

SEPS:- **S**edimentation **E**vaporation **P**ond **s**ystems are shallow earthen channels which encourage solids separation and facilitate easy clean out due to narrow and shallow construction. Clean out frequencies are generally designed for every 6 months or 12 months reducing labour and management. Evaporation of the liquid effluent over the warmer months reduces handling and pumping requirements. SEPS could maximise benefits of nutrient reuse.

Covered storage ponds:- Covering the pond is a potentially lower-cost way of reducing the size of the storage requirements by excluding rain falling directly onto the pond. This combined with rainwater diversion in the yards could significantly reduce the size, capital and earthworks of the storage systems and reduce the volumes of manure that need to be handled.

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Using the Dardanup east scenario reducing rainfall on a 40 x 50 yard and a 50 X 30 m pond could reduce the volume entering the effluent system by 3.2 ML. It could also retain greater nitrogen in the system via reduced volatilisation and reduced evaporation of water in the warmer months when water is limited.

Tanks/bladders:**-** option for smaller volumes. May need to be agitated to keep solids from settling.

Umbillical Systems:- Utilises a tractor and feeder hose with various attachments such as splash plates and dribble bars to distribute effluent over a wide area.

Travelling Irrigators with GPS Trackers and auto shut down systems allow farmers to remotely manage irrigation systems, which reduces labour and time checking on irrigators, and can reduce the risk of irrigation faults and nutrient over application.

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Table 5: Illustrative scenarios of complete effluent management systems identified as potentially viable for SW WA dairies.

These scenarios aim to show how various effluent management components combine into an overall system. These systems can be mixed and matched based on a case-by-case situation, with consideration of site and management requirements.

System Type	Suitability	Comments
	Low Rate Sprinklers	
Scenario 1		
Rainwater Diversion Sand/gravel trap - if pump to sedimentation pond Sedimentation Pond - shallow Storage Pond – winter months* Travelling Irrigator with tracker alarm or low rate sprinkler *No irrigation required over winter	High Rainfall All soil types Flat to sloping land - less than 7^0 Low to medium capital Low-Med labour re: irrigator	Sedimentation trap rather than a trafficable solids trap reduces labour associated with cleaning out a trap regularly. Sedimentation ponds only need to be desludged every 1 to 2 years depending on size. No need for storage of solids over the year if desludge and apply at the same time. Pond must be constructed to achieve low permeability. This may require lining or addition of bentonite.
Scenario 2		
Rainwater Diversion Sand/gravel trap - if pumping to SEPS SEPS Small storage - may be required* Travelling Irrigator with tracker alarm or low rate sprinkler *No irrigation required over winter	High Rainfall All soils especially sandy soils and sensitive catchments Flat to sloping land - less than 7° Low to medium capital Low management and maintenance Low-Med labour re: irrigator	SEPS can be designed to hold at least 3 months water across a channel system so irrigation doesn't have to occur over winter. Desludging can be carried out using existing farm equipment as channels are shallow, and narrow. Will lose considerable effluent through evaporation in warmer months - good for farms with high nutrient levels.

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System Type	Suitability	Comments
Scenario 3		
Rainwater Diversion Sand trap - if pumping to SEPS SEPS system Small storage/sump may be required* Low rate sprinkler *No irrigation required over winter	High Rainfall All soils especially Sandy Soils and sensitive catchments Flat to hills >7° Low Capital Low-Med labour irrigator	SEPS can be designed to hold water across a channel system so irrigation doesn't have to occur over winter. Desludging can be carried out using existing farm equipment as channels are shallow, and narrow. Sprinklers will need to be manually moved. Will lose considerable effluent through evaporation in warmer months - good for farms with high nutrient levels.
Scenario 4		
Rainwater diversion Sand trap - optional - if pumping to pond Storage pond - winter months* Travelling irrigator with in-line filter	High Rainfall All soils especially sandy soils and sensitive catchments Flat to sloping land - less than 7° Low to medium capital Low management/maintenance Low labour re: irrigator	No sedimentation removal. Will need to desludge storage ponds when volume impacted. Simple VS test to determine desludging requirements. *Storage pond systems at dairies could include a large single pond, which requires more frequent desludging, or alternatively a two-pond system, with the first pond being a sedimentation pond for solids collection. This sedimentation pond reduces the need for desludging of the second pond and can improve water quality for reuse.
Scenario 5		
Rainwater diversion Sand trap Solids separation Bladder or tank* Low rate irrigator *No irrigation required over winter	Small-Medium herd size 0-600 High Rainfall All soil types Low rate: Flat to hills >7° Medium Capital Medium labour	Tanks will likely need to be agitated to prevent solids settling.

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System Type	Suitability	Comments
Scenario 6		
Rainwater diversion Sand trap Solids separation Bladder or tank* Travelling Irrigator *No irrigation required over winter	Small-Medium herd size 0-600 High Rainfall Sandy soils or sensitive areas All soil types Flat to sloping land - less than 7° Medium Capital Medium labour	Tanks will likely need to be agitated to prevent solids settling.
Tanker/Umbillical Systems		
Scenario 7		
Rainwater Diversion Sand trap - optional if pumping to pond Storage pond – winter months* Farm-owned Tanker*	High Rainfall. All soil types. Distribute effluent long distances or offsite. Flat to sloping land. Med-high capital. Moderate labour depending on how often you wanted to spread.	Distribute effluent long distances or offsite*. No need for solids separation but may need to agitate pond to create a slurry. Storage would want to incorporate enough time to avoid having to run the tanker over wet land to avoid pugging. * Applying effluent daily can maximise nutrient value by minimising volatilisation losses of nitrogen but can also increase labour significantly. Tankers can extract manure directly from a sump for daily application. It is still recommended to have a storage/contingency volume available in the wetter months to avoid applying effluent when the ground is wet and run-off/ leaching potential is high. Check regulatory requirements for transport and use offsite.
Scenario 8		
Rainwater Diversion Sand trap (optional if pumping to pond) Sump for pumping or gravity flow to pond Storage pond – based on frequency of desludging* Contract spreader *No irrigation required over winter	High Rainfall All soil types Distribute effluent long distances or offsite. Flat to sloping land Low capital Low labour	Distribute effluent long distances or offsite*. No need for solids separation. Pond size based on frequency of desludging. Whilst tankers can be good for distributing sludge, the carting of liquid effluent can be uneconomical. If using contractors, reducing the volume of effluent prior to spreading decreases the carting costs. * Check regulatory requirements for transport and use offsite.

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System Type	Suitability	Comments
Scenario 9		
Rainwater Diversion Sand trap - optional - if pumping to pond Storage pond - winter months* Umbillical system *No irrigation required over winter	High Rainfall All soil types Distribute effluent long distances Flat to moderate hills Medium Capital Medium labour depending on how often effluent is to be spread	Distribute effluent long distances or offsite*. Storage would want to incorporate enough time to avoid having to run the tanker over wet land to avoid pugging. No need for solids separation but may need to agitate pond to create a slurry. Slurry pumping requirements unknown. Agitated slurry may be suitable or may just be able to pump the liquid. Contractor removal of settled solids may be required on a less frequent basis. *Storage pond systems at dairies could include a large single pond, which requires more frequent desludging, or alternatively a two-pond system, with the first pond being a sedimentation pond for solids collection. This sedimentation pond reduces the need for desludging of the second pond and can improve water quality for reuse. Check regulatory requirements for transport and use offsite.
Scenario 10		
Rainwater diversion Sand trap Solids separation Bladder or tank Umbillical system *No irrigation required over winter	Smaller -Medium Herds 0-600 High Rainfall All soil types Flat to moderate hills Medium Capital Medium labour depending on how often effluent is spread	Tanks will likely need to be agitated to prevent solids settling.
Scenario 11		
Rainwater diversion Sand trap Tank or series of tanks* Tanker or umbilical system *No irrigation required over winter	Small to Medium herds 0-600 High Rainfall Sensitive soils and catchments Med-High Capital Med-High labour	Tanks will likely need to be agitated to prevent solids settling. * Would require appropriate wet weather storage. This will avoid having to run the tanker over wet land, preventing pugging and bogging.

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System Type	Suitability	Comments
Scenario 12		
Rainwater diversion Sand trap SEPS Small storage/sump may be required Tanker/umbilical system	All herds wanting to distribute nutrient over a wide area Flat to Moderate hills Medium capital Medium-High labour depending on how often you wanted to spread	SEPs can be designed to hold water across a channel system so irrigation doesn't have to occur over winter. Desludging can be carried out using existing farm equipment as channels are shallow, and narrow. Will lose considerable effluent through evaporation in warmer months - good for farms with high nutrient levels.
Multi line sprinklers		
Scenario 13		
Rainwater diversion SEPS Storage (optional depending on size of SEPS)* Multi line low-rate sprinkler *No irrigation required over winter	Larger Herds All soil types Low Capital Low-Medium labour-sprinkler movement	Ability to empty the pond faster over fewer days. Potential to reduce storage capacity over winter if the availability to irrigate is available, e.g. 7 days clear may reduce leaching and run-off potential.
Scenario 14		
Rainwater diversion Sedimentation pond or solids removal Storage* Multi line low-rate sprinkler *No irrigation required over winter	Medium-Larger Herds All soil types Especially good for high rainfall areas Low Capital Low-Medium labour-sprinkler movement	Ability to empty the pond faster over fewer days. Potential to reduce storage capacity over winter if the availability to irrigate is available, e.g. 7 days clear may reduce leaching and run-off potential.
Scenario 15		
Rainwater Diversion Sand trap Solids separation Tank or bladder* Multi line low-rate sprinkler *No irrigation required over winter	Small to medium herds All soil types Especially good for high rainfall areas Medium Capital Low-Medium labour- sprinkler movement	Ability to empty the tank faster over fewer days. Reduce storage capacity as rainfall excluded from storage.

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System Type	Suitability	Comments
Centre Pivots/Lateral		
Scenario 16		
Rainwater Diversion Mechanical separation Solids bunker Storage pond* Centre Pivot or lateral pivot *No irrigation required over winter	Existing centre pivots in place Flat land High capital Low-Medium labour - solids trap Medium-High labour – mechanical separation	Effluent guns that are attached to the ends of centre pivots generally provide uneven nutrient distribution and can increase risk of nutrient overload.

Notes:

(a) Note: These systems make the assumption that the correct pumps, pipes and pressures are available or are to be included. Many of the systems (particularly the application equipment) observed in SW WA were having issues not due to the equipment, but due to the use of incorrect pumps and pipes.

(b) Sand/gravel trap is a shallow walk through area filled with water that the cows step into prior to entering the yard to minimise sand travelling through into the effluent system and creating pump and pipe breakdowns and blockages.

(c) If a two-pond system is used, the first pond should act as a sedimentation basin which could largely remove the need for mechanical or trafficable solids traps prior to storage. This eliminates the labour and maintenance that would have been associated with such solids separation. There may need to be a sump or some kind of collection system to catch the yard run-off prior to going to the sedimentation pond.

(d) Travelling irrigators should operate at higher speeds on high-risk sandy soils and heavy soils to reduce nutrient application over the area.

(e) Travelling irrigators and low rate sprinklers should be able to distribute effluent over considerable distances. The removal of solids and the correct pipes and pumps are essential to being able to convey effluent over long distances. Often the irrigators are not the problem with distribution systems, rather the pumps and pipes create issues, whether by wear or by being inappropriately sized for the required capacity.

(f) Areas which store solids should be located on a compacted earthen or concrete base to reduce leaching and facilitate ease of scraping up solids (e.g. with a backing wall).

(g) Utilise gravity where possible to minimise pumping. Build up new systems to utilise gravity where possible.

(h) Ponds can be lined or bentonite added if required i.e. sandy soils and high water tables. Turkey nest dams can increase the clearance above the highest groundwater level.

(i) Current models determine storage requirements for effluent based on rainfall exceeding effective evaporation. There currently appears to be a disconnect between when farmers say they can irrigate and when model generated data indicate they can irrigate. A daily water balance model may reduce the effective wet-weather storage period for effluent but can increase management requirements for irrigation.

(j) If carting liquid effluent, sludge or manure offsite, check regulatory requirements for transport and use offsite.

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6.0 Recommendations

The following recommendations have been put together regarding the results of the review and includes some considerations for supporting the implementation and adoption of dairy effluent system design and management in SW WA. These recommendations take into consideration the needs and drivers of the farmers to support and increase their confidence in decision-making. Recommendations are:

- Workshops on viable and potential options identified in this review, to inform farmers in SW WA and gauge their interest in the technologies and practices.
- Establishment of demonstration/trial sites of technologies and practices such as SEPS, sand traps, covered ponds, rainwater diversions, pond additive sealants (new ponds), application equipment trackers and halo systems. Development of extension materials based on results.
- Research to measure, quantify and justify the benefits of the various technologies and practices to support business case development. Development of extension materials based on results.
- Establishment of a dairy effluent support program to provide independent expert advice regarding technologies and system to assist decision making confidence, i.e. someone to run past information they may have been given by a supplier or manufacturer. This review has discovered claims by equipment suppliers that appeared to be dubious.
- Development of an industry champion program and or focus farms, showcasing successes, challenges, and benefits of effluent management systems.
- Effluent workshops/farmer discussion groups on different topics with guest speakers.
- Nutrient value information workshops - Benefits of effluent.
- Expert panels roadshow.
- Effluent field days- demonstration of equipment and suppliers.
- Effluent bus tour - visiting different systems to discuss pros, cons.
- Service provider training, i.e. pumps, irrigation systems and earthworks.
- Review of dairy effluent system design models to assess suitability for SW WA conditions, e.g. by considering daily rainfall data instead of cumulative monthly data, which considers rainfall days exceeding evaporation. This may allow for days in which effluent can be applied during months for which application is currently excluded.
- Identification of effluent planning requirements for SW WA-farmers requesting more detail and justification of system designs.
- Consideration of different business models for managing dairy shed effluent, such as shared equipment i.e. tankers, umbilical systems - need to consider biosecurity
- Dairy Effluent Management Planner/Calendar outlining best management practices.
- Development of a Dairy effluent app/program to monitor applications and pond management.
- Dairy effluent fact sheets based on information to support viable systems, components and nutrient values in SW WA.

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7.0 Conclusion

The review identified a number of components and options for effluent systems taking into consideration regional constraints and needs and drivers of dairy farmers in SW WA. These regional considerations included high rainfall, sandy soils, flat to sloping terrains and shallow groundwater. The needs and drivers of the farmers required the systems and components to have low complexity, require low labour inputs, be low maintenance, maximise nutrient benefits and minimise impacts on the surrounding environment.

Many technologies and practice options available in other wastewater industries were determined to be not suitable or transferable at this point of time to dairy effluent systems. This is due to the scalability, complexity, effluent suitability, and costs associated with more industrial targeted treatment systems. Identifying unsuitable technologies and practises is as important as identifying viable options to ensure farmers do not invest in systems that have high potential for failure and subsequent environmental impacts.

The viable options identified included many technologies and practices already being implemented in the pasture-based dairy industry, but which may not have been adopted in SW WA or implemented incorrectly/"not fit-for-purpose". Some of the viable options identified have been observed as not functioning as designed in SW WA due to incorrect supporting equipment such as incorrectly sized or types of pumps and pipes.

It is important to note that having the right supporting equipment such as the correct pipes and pumps to deliver sufficient flow and pressure is essential in any effluent management system. Incorrectly sized or not fit-for-purpose equipment can significantly impact the efficiency, running costs, labour inputs, maintenance, and performance of effluent components such as conveyance/solids separation and irrigation equipment. Often these pieces of equipment are not well considered, overlooked, or not included as part of an effluent system. These components should not be viewed as ancillary to an overall effluent system, but rather as key components which are required to deliver maximum performance from the system and ultimately deliver the required outcomes of maximising nutrient benefits whilst minimising environmental impacts.

A few potential technologies and practices were identified not commonly used in the industry or in SW WA, including recycled effluent for yard washing, umbilical systems, tank and bladder storage systems, sedimentation pond, tracker equipment on travelling irrigators, rainwater diversions, sand traps and covered storage ponds. These components have the potential to have significant impacts on the overall outcome of a dairy effluent system. For example, diverting rainwater for the yards and pond area will have a significant impact on the volume of storage required and the volumes of effluent that need to be handled via pumping and application. Reducing these volumes reduces the overall size of the system, reducing capital costs, electricity costs, labour and ongoing maintenance. Another example is a shallow sedimentation pond instead of a trafficable solids trap, which will increase solids removal and reduce the desludging frequency from every 4 weeks to approximately once a year.

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Considering that a number of the feasible/potential options identified by the review are not commonly used in the SW WA dairy industry, there is a need to further investigate and trial these options to facilitate business case development that demonstrates suitability and benefits to farmers.

All options considered should follow an outcomes-focussed approach rather than being considered in isolation. That is, effluent systems should be designed working from the effluent end-use land-application back towards the shed from which the effluent originated, to ensure the end outcome is achieved.

All farms have individual site constraints, needs and challenges, meaning there is not a one size fits all solution to dairy effluent management in SW WA.

Multiple scenarios have been presented demonstrating that site specific constraints and drivers can be feasibly accommodated by a number of different combinations of the identified viable technologies and practices. This was important to illustrate that there is no one-size-fits-all effluent management solution.

The stakeholder engagement and site visit observations showed that many of the farms visited already had some of the necessary effluent components in place. Accordingly, the scenarios presented caters for completely new effluent management systems as well as retrofitting or upgrading of incomplete existing systems. Some of the options identified were low cost, simple to implement and could provide significant benefits.

The viable options identified in this review, if considered as part of an outcomes focussed approach, if implemented correctly and if accounting for site specific needs and constraints, should provide multiple benefits to farmers by maximising the nutrient value whilst minimising environmental losses via leaching and run-off.

---------------End of Main Body---------------

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10.0 APPENDICES

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Appendix 1: Situational Analysis

Regulatory Setting-Western Australia

DWER is the regulatory agency responsible for environment and water regulation in WA. DWER administers the *Environmental Protection Act 1986* (EP Act) and associated regulations with its main functions being approvals and licensing, monitoring, audit and compliance inspections, and enforcement including complaint and incident investigation.

The type of regulation undertaken by DWER depends on the classification of an industry or premise. 'Prescribed premises' trigger additional regulatory requirements under the *EP Act* including licensing and works approvals associated with on-going operation and planning/expansions. Prescribed premises are those classified as **industrial premises** with the potential to cause emissions and discharges to air, land or water.

Dairy farms are not currently classified as a 'prescribed premise' as per Schedule 1 of the *Environmental Protection Regulations 1987* and therefore would not trigger the regulatory requirements associated with licencing and works approvals. Consequently, as per all other non-prescribed premises in WA, dairy farms are regulated under the *EP Act* and other relevant regulations. Specifically, dairy farms are regulated in relation to dairy effluent under the *EP Act, the Environmental Protection (Controlled Waste) Regulations 2004* and the *Environmental Protection (Unauthorised Discharges) Regulations 2004.*

Environmental Protection Act 1986

Under Part V — Environmental regulation, Division 1 — Pollution and environmental harm offences - the following sections of the EP Act are relevant to dairy effluent; 49A. Dumping waste; 50. Discharging waste in circumstances likely to cause pollution; 50A. Causing serious environmental harm; 50B. Causing material environmental harm.

If dairy effluent management or reuse is suspected or likely to cause pollution or environmental harm under any of these sections, it could constitute a potential breach of the EP Act 1986.

Environmental Protection (Controlled Waste) Regulations 2004

Dairy effluent is classified as a controlled waste as per Schedule 1 of these regulations, i.e. animal effluent or residues (including abattoir effluent, poultry, and fish processing waste). This regulation is only triggered if dairy effluent is transported via off-site roads, requiring vehicles and transporters to be licenced to carry the effluent.

Environmental Protection (Unauthorised Discharges) Regulations 2004

Schedule 1 of these regulations, list the types of materials that must not be discharged into the environment. The list includes animal waste.

DWER Enforcement

As a regulator, DWER has an enforcement capability, environmental investigative capability and accountability for regulatory complaints to ensure compliance with the legislation it administers.

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Enforcement may include formal letters of warning, infringement notices, modified penalty fines or court prosecution. An Environmental Protection Notice (EPN) is a statutory notice given where it is suspected that there is, or is likely to be, an emission that has caused, or is likely to cause, pollution or environmental harm. The notice may require the persons served (being the owner or occupier or both) to take necessary measures in a specified time period to investigate, prevent and/or control the emissions from the premises.

Local Government

There are currently 139 Local Government areas in Western Australia that manage local issues such as planning within the requirements of the *Local Government Act 1995.* Each Local government may have different requirements regarding constructing or expanding of a new dairy or effluent system. It is anticipated that there will be some kind of local development assessment required prior to construction of an effluent management system. Checking with the local government planning department is essential prior to any construction to ensure the relevant approvals are obtained.

Regional and Farm-Specific Environmental Variables

The six catchments have variable soil types (Figure 3), terrain, groundwater depths and topography. These factors will all influence overall dairy shed effluent management practices as well as the type and suitability of the effluent system. Soils range from sand through to heavy clay, and aquifers from shallow (surface impact in winter) through to deep extensive and localised aquifers. Topography ranges from flat coastal plains to steeper upland areas. Farm types vary from relatively flat irrigated pastures through to rainfed pastures on the sloping/hill topography. Not only is there variability within catchments but also variability across individual farms within each catchment. This needs to be taken into account when managing and reusing effluent to maximise benefits to the farm and minimise risk to the surrounding environment and community.

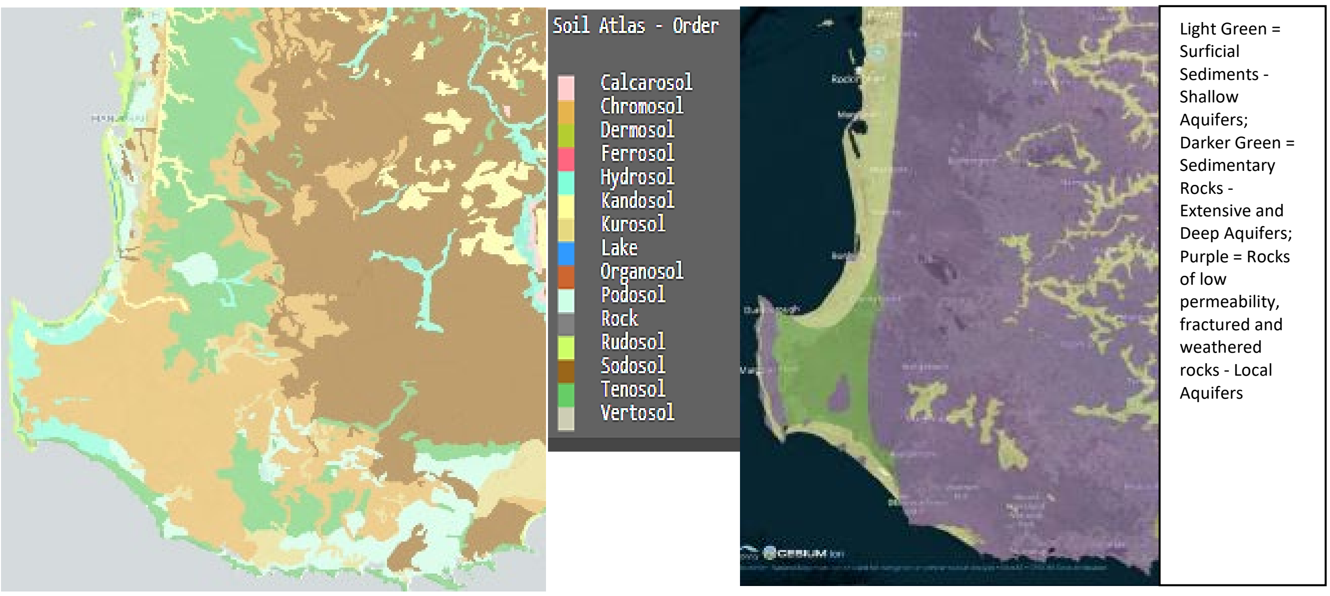

Figure 4: Generalised map of soil orders for Australia (State of the Environment 2016) and Water Table Aquifers (National Maps)

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Farm Visit/Survey Observations

Current Dairy Effluent Systems

Current dairy effluent systems in SW WA vary considerably due to a number of factors including location and topography, rainfed vs irrigation, age of system, expansion of herd and site-specific constraints such as shallow groundwater and sandy soils. Other factors which have influenced the type of system put in place, the reuse opportunities and ability to capture the effluent on site to minimise groundwater and surface water impacts include advice from advisors/suppliers, participation in dairy programs, ability to source information and confidence in available information.

The dairy farms observed all had some kind of effluent system in place which had varying degrees of management, capture and ability to minimise offsite impacts. Many of the farms had expanded their herd size over time but had not upgraded or expanded their effluent system to accommodate the larger herd size.

The size of the herds observed ranged from smaller 160 head herds through to larger 800+ head herds. Milking shed styles ranged from smaller 11-a-side milking sheds through to 50 stand rotaries with all herds milked year-round. Individual farm sizes ranged from 140ha through to 650ha, with some farms having access to additional leased land.

Most farms observed used a hose or yard blaster type cleaning system to wash down the yards with fresh water either from tanks or bore water. Only one flood wash system was observed. No dairies that were visited used recycled effluent to wash down the yard, with only one site observed to divert rainfall from the yards out of the effluent system. One farm dry scraped as much as possible prior to hosing down the yard to reduce the amount of water used. Some farmers wanted to catch the rainfall into the effluent system to use over the drier summer periods.

Many farms had a series of ponds often with a sump and or trafficable solids/weeping wall system prior to the ponds to remove some of the solids. These traps were generally at the end of the yards with one located a bit further away from the dairy closer to the pond system. These trafficable solids traps were generally cleaned out every 3-8 weeks with one cleaned out twice a year. There were no mechanical solids removal systems such as run-down screens or screw presses observed.

Those farms with pond systems ranged from one large pond through to a two or three-pond system with the first pond acting as a sediment pond either with or without a prior trafficable solids trap. These ponds were desludged generally every 1-3 years with more frequent 6 weekly sludge removal on one site and a longer 10-year period on another. It was acknowledged that many of the ponds overflowed during the wetter months when irrigation was difficult with some of the run-off leaving the property boundary and entering drains or creeks which ultimately ended up in the estuaries.

The sludge from the ponds and the trafficable solids traps is generally stockpiled near the traps or ponds or located out in paddocks nearby to dry prior to spreading. Most farms used a contractor tanker or excavator to remove the sludge prior to stockpiling with some farms spreading the sludge straight out onto the paddocks with a contractor slurry tanker/muckspreader.

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Liquid effluent was distributed via a number of application methods. On some sites effluent was stored/distributed in drains or in low lying areas using gravity to disperse in nearby paddocks or rely on evaporation to reduce volumes. Other systems used travelling irrigators, movable sprinklers, hydrants with travelling irrigators or centre pivots. An irrigated farm was able to utilise channels to shandy the effluent with fresh water to distribute the water over laser graded paddocks alongside a pipe and riser system.

Application areas were generally close to the ponds and dairy. Those utilising travelling irrigators or sprinkler systems spread over areas ranging from 5-10 ha. A centre pivot allowed 30ha to be utilised whilst an irrigated system was able to distribute effluent over 60ha. The drainage systems allowed gravity across 9-10 ha or on a smaller concentrated area. The farmers all acknowledged that they were concerned that the nutrients would be building up across the small areas and were keen to be able to distribute nutrients over a wider area and to maximise the fertiliser benefits.

There were a number of feedpads and sacrifice areas used to feedout during various times of the year, with use and time spent on the pads/areas also being seasonally dependant. The concrete/compacted feedpads were scraped when necessary with liquid evaporating or running into the surrounding paddocks. No feedpads were linked to yards or effluent systems.

Due to the topography and location of the dairies which were often situated close to roads and amenities, there was little opportunity to utilise gravity for all or part of the system except for one site in which the height of the dairy was above the ponds and application areas.

Farmers engaged as part of this review all acknowledged they had a substantial responsibility and obligation to minimise impacts on the environment. Many thought it was important that the industry regulated themselves before they had to be regulated by others. They did not want to see 'big stick' type regulation and wanted to work cooperatively with encouragement and support to achieve compliance. There was a strong sentiment that farmers did not want regulation to be too prescriptive or restrictive to the type of system they needed to have. They wanted the regulation to be outcomes-based so they could have the ability to choose the right system for their farm needs. They acknowledged that they should contain their effluent onsite and not let it run-off into waterways. To support their confidence in decision making and relating to dairy effluent system design and management, the farmers wanted access to informed advisors who are qualified to give good advice and options. Dairy effluent systems were seen as a big investment that they wanted to get right in order for farmers to stay ahead of regulators and to drive regulation. There was acknowledgement that the government had identified high nutrients in many of the dairy catchments and saw the industry as responsible for some of the contributions.

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Dairy Effluent Management Challenges

There were a number of challenges identified by the farmers that impacted their ability to manage and reuse the effluent to get maximum benefit and reduce potential environmental impacts. Generally, challenges were similar across all sites with some individual site-specific challenges.

A major challenge was the distribution of effluent over a wider area. All farmers were concerned about nutrient build up on their application areas. Most effluent was distributed over small areas generally close to the sheds or effluent ponds. These also included areas where cows are fed out and kept close to the dairy i.e. night paddocks. These areas are likely to be already high in nutrients. Continual application over these small areas was of concern to all farmers. They wanted the ability to distribute over a wider area or to areas on the farms identified as needing the nutrients and organic matter such as poorer soil types or areas in which they cropped.

Another major challenge was the maintenance and labour associated with keeping effluent equipment operational. Blocked pipes and pumps, pumping over distances and sloping terrain as well as dealing with irrigation equipment such as moving and unblocking sprinklers and travelling irrigators going off course were frustrations associated with the distribution aspects of the effluent. Solids traps all required unblocking of the weeping wall from time to time and regular cleaning out. Regularly clean outs of the trafficable solids traps and the storage and handling of the material prior to spreading was deemed to be labour intensive.

Ease of cleaning out ponds due to the shape and size and reliance on contractors to clean out/desludge were challenges alongside effluent build up on laneways especially around the dairy.

High rainfall, especially single events which contributed large volumes to the system, was a challenge for many in the area. So too were the groundwater levels, which often impacted the surface in winter and in some cases made it difficult to spread manure solids/sludge because paddocks were not trafficable under wet-weather conditions. Many noted they had too much water in winter and not enough in summer.

Sandy soils were a challenge regarding premature filling of solids traps, blocking and wearing out of effluent equipment such as pumps and irrigation equipment, and maintaining nutrients on sites by preventing its loss to groundwater.

Many farmers experienced Kikuyu growth rather than pasture growth on areas regularly receiving effluent. Weeds and other grass species became prolific in areas of high nutrients and outcompeted the desired species.

Other challenges identified included flat land and lack of gravity to distribute effluent (reliance on pumps that wear, clog or break down), time to clean yards and amount of water used, equipment not fit-for-purpose i.e. wrong size/type of pumps and pipes (possibly being undersized for progressively expanding herd sizes, see above) and the lack of clay on site to build or line ponds

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Needs, Drivers and Priorities for Dairy effluent Systems

Dairy farmers identified that they needed an effluent system that:

- Protects the environment
- Distributes the effluent over as wide an area as possible to maximise benefits
- Utilises the nutrients and valuable water resource
- Makes money and save on costs such as fertilisers
- Meets Industry Best Practice
- Is simple to manage, practical and functional
- Is low in complexity
- Runs efficiently and cost effectively
- Is designed to suit site-specific needs and constraints
- Meets requirements of consumers
- Minimal labour/automatic
- Reduces water use
- Stores effluent over winter when application was not suitable

To achieve an effluent system that provided the above outcomes the farmers identified the following drivers:

- Ongoing support and guidance
- Good knowledge and advice
- Confidence in advice from information providers and suppliers
- Funding/Grants
- Science to demonstrate benefits of effluent and systems types in order to support business case for future funding/loans and adoption
- Demonstrated return on investment
- System designs based on required site outcomes rather than set solutions
- Ability to view aspirational systems – ''across the fence"
- Ability to choose options best suited to site specific drivers, constraints and objectives
- Change in thinking from waste management to resource management

Priorities of Importance Rankings for Effluent Systems

Time and labour were the number one priority of importance for farmers when managing their effluent system followed by ease of management.

The cost of an effluent system was ranked next with a mixture of high and low rankings. Many saw it as highly important whereas others indicated it does not matter how much it cost as long as the system was right for them, was low maintenance, easy to manage and provided benefits to them while not causing environmental impacts.

Getting value from the manure products was next, closely followed by ensuring the environment was not adversely impacted.

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Water efficiency did not rank as high for effluent management, because farmers generally did not feel constrained by water, but did note the challenges of having too much water during winter and too little water during summer.

Each number below represents one farmer and the ranking they gave for each priority. Every farmer interviewed, ranked disposal of effluent (of little value) as the lowest priority.

• Time/labour	3, 1, 1, 1, 1, 3, 4,7*,1	(22)
• Ease	4, 6, 2, 2, 1, 3, 1,1,3	(23)
• Cost	2, 3, 3, 5, 5, 6, 3, 2,2	(31)
• Value of nutrients/fertiliser	5, 2, 6, 4, 2, 2, 5,4,4	(34)
• Environment	6, 4, 5, 3, 4, 1, 4,5,6	(38)
• Water efficiency	1, 5, 4, 6, 6, 3 ,6, 3,5	(39)
• Disposal	7, 7, 7, 7, 7, 7 ,7, 6, 7	(62)

* Farmer believed that if you have everything else sorted time/labour sorts itself out

Constraints/Barriers to adoption

The Barriers to adoption of effluent systems in SW WA included:

- Lack of confidence in available technologies and options
- Lack of knowledge, confidence in advice and minimal support
- Lack of money, funding, capital
- Cost of earthworks, infrastructure
- Information to support loans - inability to go to a bank with a business case – i.e. if a farmer could demonstrate that a slurry tanker replaced $40,000 in conventional fertilisers, they would be more confident to borrow money towards a new system/component
- Complexity of current systems
- No carrot (i.e. benefits demonstrated by substantiated evidence) or stick (i.e. regulatory) to enable farmers to secure funding for effluent upgrades
- Not knowing where to find the right set up or knowing where to start
- Lack of confidence that technologies and practices, once implemented, would actually achieve the desired environmental outcomes. Some noted being burnt in the past by going down the wrong track
- Other competing priorities, such as buying extra feed, getting mating right, laneway and milking shed upgrades
- Cost pressures and impact of $1/L milk - need supply chain to value product and how its produced, to enable farmers to be sustainable and implement best practice
- Cost of the systems - don't mind investing if it's the right system
- Wary of solids separation systems especially pumps and sand issue, limitations of pumps
- Uncertainty of future profitability and whether to keep milking - unwilling to commit to upgrade
- Future plans to upgrade and thus not investing in old system but waiting until new sheds developed
- Readily available finance/interest free loans
- Seasonal challenges - high fibre diets impact effluent systems

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- Static effluent management components lack the potential for multi-benefits featured by some mobile components, e.g. offset tractor for other needs
- Unsure of regulations and standards

Constraints identified as impacting on the design and management of dairy effluent systems in SW WA include:

- High rainfall- entering effluent system, restricting application, increasing run-off
- High individual rainfall events- i.e. 180mm in a day
- Sloping/Hilly topography- restricting application, increase run-off potential
- Poor or Sandy soils impacting application areas and blocking/breaking pumping equipment and traps
- Ponds and application areas - proximity to creeks/swamps and major rivers
- High water tables - can impact surface in winter
- Cashflow and competing priorities for funds
- Availability of power on some sites - no 3-phase power or not enough power to run multiple pieces of equipment at the same time or straight after milking
- Variability of soils across sites - sandy to heavy loam or clay
- Water availability – high in winter, low in summer
- Water quality - bore water can be salty and have high levels of iron
- No irrigation water available – no shandying of effluent
- Low lying flood areas
- No elevation - restricting the use of gravity
- Heavy clay - puggy areas
- Topography unsuitable to build ponds
- Cost of power

Opportunities

All of the farmers interviewed in the various catchments were aware of potential environmental impacts and obligations regarding dairy effluent management and were all very keen to obtain information on dairy effluent system components and identify potential upgrade opportunities.

The farmers all had a keen interest in developing solutions specifically suited to their site, taking into account site constraints and the need by all for a system that was simple, labour friendly and easy to manage whilst maximising the benefits of the nutrients and minimising offsite environmental impacts.

The farms were most interested in the value of their effluent, knowing exactly what is in it and how they can maximise nutrients on their farm. Encouragingly many farms tested their soils annually, biannually or every 3 to 4 years with some farms using the results to reduce or adjust fertiliser application rates and cut down on fertiliser costs. One farm even adjusted their fertiliser mixes which were specifically targeted to different areas of the farm based on the soil test results. Of the farms engaged, only 2 tested their effluent to assist in determining application rates of effluent. All farms commented that they knew there was value in the effluent as they could see the benefits in terms of grass growth and believed it improved their soils and added organic matter, but they couldn't quantify the benefits.

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Although there was significant interest in the value of effluent and manure, and high uptake of soil testing, there was a disconnection between value, benefits and test results. There is a great opportunity to provide this information and increase the knowledge of the benefits of effluent application and soil testing.

The value of the effluent is an important driver in effluent system design and management. How and where you want to reuse the effluent forms the basis of the type of system you need to capture and distribute the nutrients. Providing this information to farmers along with the considerations of site constraints provides a great opportunity to allow the best suited system options to be provided for a site. A system should be based on reuse needs firstly from which the design flows backwards towards the shed, incorporating the storage and capture components.

The other areas of interest from the farms were ranked fairly evenly and included further information on effluent water reduction, solids separation, effluent storage/capacity, application and reuse methods, expansion of application areas and automated checks/systems.

Effluent water reduction was of interest in reducing the overall volume of the water entering the system through such areas as stormwater diversions, reduced washdown water. The high rainfall in the SW significantly adds to the size of the systems if not diverted from the system. Reducing inputs into the effluent stream provides an opportunity to significantly reduce the overall size of the system, and to reduce handling and subsequent costs.

Solids separation was not seen favourably by many due to past or current issues relating to increased handling, labour and equipment breakdowns associated with components. Many believed suppliers had the best intentions but were not confident in the advice and follow up support resulting in breakdowns and pulling components offline. There is an opportunity to provide alternative options and advice on solids separation components that separate the solid-liquid components to reduce handling, whilst opening up many more options for reuse such as further distribution of the nutrients.

There was interest in alternative storage opportunities and the increase in capacity of current storage capabilities to reduce handling in winter or provide an alternative option to a pond. Tanks and storage bladders were of interest as was potential alternatives to plastic liners such as pond sealant additives.

Application and reuse methods and the ability to spread effluent over a wider area goes hand in hand with the interest in the value of manure. Many farms only spread their effluent over relatively small areas close to the shed likely resulting in nutrient build up. Other areas identified by the farmers such as soils with poor fertility or cropping paddocks further away from the dairy provide a great opportunity to maximise the value of the nutrients. Options such as tankers, types of pumps and shared resources/equipment were of particular interest to farmers.

Automated checks and systems were of interest due to the reduction in potential labour and ease of managing systems. Opportunities to investigate automated irrigation systems was one particular interest identified.

Energy generation from effluent on site was of interest to a few farmers, with all acknowledging that they didn't think it was a viable option as they had relatively small herd sizes, captured only a small proportion of effluent and manure, and that it was quite dilute due to rainfall.

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Many mentioned that biogas may be more suited to a barn/free stall arrangement, where additional manure is available to produce more biogas, but they were still interested in investigating biogas further, as a potential future option.

There was little interest in solids management, which seemed to be due to a lack of desire to change away from existing solids management practices. Solids were generally placed in paddocks next to traps or ponds and left to dry, often in large piles. There is a significantly low-cost opportunity to improve the management of solids on-farm to further reduce environmental impacts.

Effluent water reduction	(6)
Solids separation	(4)
Effluent storage/capacity	(5)
Solids management	(3)
Application and reuse methods	(6)
Expansion of application areas	(5)
Fertiliser value, products, maximising nutrients	(8)
Energy generation	(3)
Automated checks/controls/systems	(6)

General observations

It appeared on many sites that the effluent management systems had been designed many years ago when herd sizes were substantially less than the current operation. As production increased the effluent systems have not been upgraded or modified, resulting in a system outgrown in capacity and unable to effectively handle the increased volumes. This had led to effluent overflows, increased handling, increased frequency of desludging, equipment failures and likely nutrient overloading over small areas.

Many systems seemed to have been developed based on a 'piece-meal approach', modifying, replacing or adding components into the system as equipment and ponds broke down or could not handle the increase in flow/volume. There seemed to be very few systems that had been designed with an outcomes focus, i.e. what do we want to do with the effluent and working back from reuse to the shed. Effluent application in most situations was spread or applied using diffuse gravity around sheds with a number of systems unable to contain effluent onsite year-round. Effluent subsequently left the property via drains or overflows. Solids management was not observed on many sites with solids left next to ponds, trafficable solids traps or in paddocks. Minimal farms benefitted from being able to use gravity. All farms had individual site constraints, needs and challenges meaning there would not be a one size fits all solution to dairy effluent management in SW WA.

One farmer commented that "a healthy environment=healthy production". This strong sentiment to protect the environment together with the interest in obtaining information about system designs and the production benefits of effluent, is a great opportunity to provide information that would empower farmers to be able to address the needs and constraints of effluent management on their dairy farms in SW WA.

---------------------------------End of Document -----------------------------------

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