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Short Hydraulic Retention Time Effluent Systems: A Guide

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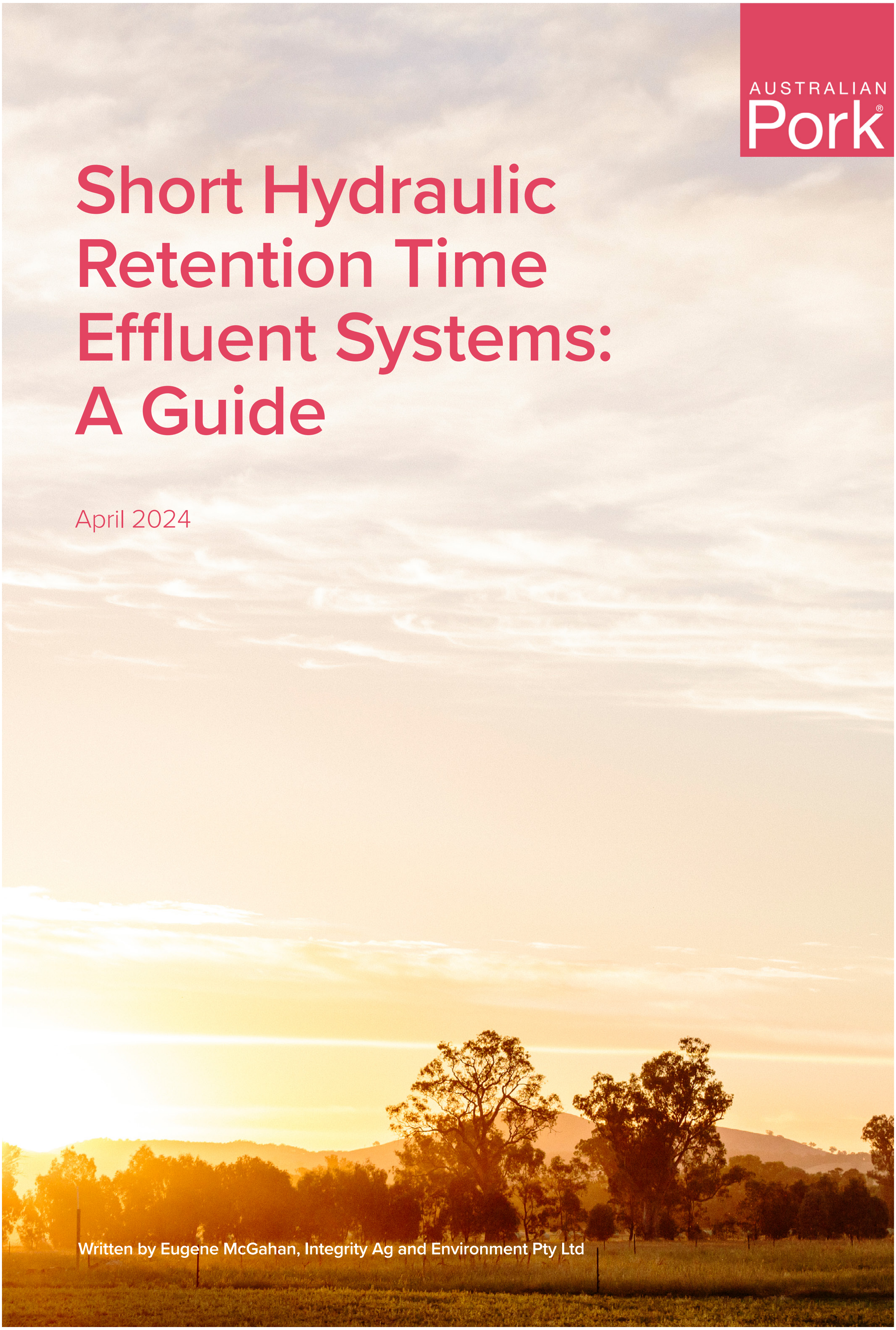

Written by Eugene McGahan, Integrity Ag and Environment Pty Ltd

Information sources

Guidance and Operation of Short Hydraulic Retention Time Effluent Systems

Progress Report #2 (Milestone 4) – How-to Guide

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Integrity Ag & Environment Pty Ltd

Eugene McGahan

10 Neil Street

Toowoomba City QLD 4350 Australia

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Contents

1. Background

Emissions associated with manure management are a key contributor to greenhouse gas (GHG) generation from animal production systems. Significant research and investment over the last few decades have developed a range of viable methods for reducing manure related GHG emissions (methane and nitrous oxide) or improving the utilisation of the resources (including carbon and nitrogen) contained within livestock waste streams. Methane (CH_4) is the primary GHG gas generated from piggery manure systems. Its main source is from the anaerobic decomposition of carbon in effluent treatment ponds at conventional (liquid-based) piggery systems.

In the last 10 to 15 years, some piggeries have installed covered ponds and engineered digesters to capture and use the methane as an energy source or simply destroy it to both generate income and lower their emissions. Due to their high capital cost, these systems have mostly only been adopted by larger piggeries (i.e. >10,000 SPU or ~1,000 sows farrow to finish).

However, there are other options that can be highly effective at reducing GHG emissions, such as solids separators and short Hydraulic Retention Time (HRT) systems. Compared to methane capture and destruction systems, the main advantage of short HRT systems is the lower capital construction cost. Short HRT systems also benefit from utilising more of the valuable resources in piggery manure (carbon, nitrogen and phosphorus) as soil additives to improve both health and fertility.

Hydraulic Retention Time (HRT) is defined as the average time that effluent is retained in a treatment system.

This How-To Guide provides details on short HRT systems:

1. How they reduce GHG emissions.
2. Advantages and disadvantages.
3. Best operational practices by region.
4. Likely GHG abatement potential (stand-alone or combined with other systems, e.g. solids separators).

2. What is a short HRT system?

Short HRT systems are an alternative method for managing effluent for conventional piggeries. They reduce methane generation by decreasing the opportunity for anaerobic conditions to develop. This is the opposite of the common design principle of traditional long HRT (often >100 days) ponds. Short HRT systems can also be combined (or operated) in tandem with other systems that reduce GHG emissions, such as solids separation devices. This combined system will both enhance GHG emission reduction potential and improve the characteristics of remaining effluent to make it easier to irrigate.

Short-HRT systems are defined as: a tank/sump outside the animal confinement building used for storing effluent for short periods. Short-HRT systems are combined with frequent application of effluent to land by using either a tanker, or a system designed to handle effluent with high solids content.

3. Which piggeries are short HRT systems suited to?

As of 2022, around 60% of the Australian pig industry had liquid-based manure management systems, with the remainder being deep litter or outdoor production. Most effluent from these conventional pig farms is treated in large uncovered anaerobic ponds. Nationally, around 10 – 15% of the effluent passes through solids separation systems before anaerobic pond treatment. Another 30 to 35% of the effluent is managed with either covered anaerobic ponds (CAP) or engineered digestors, which leaves over half of all effluent produced at piggeries across Australia passing directly to uncovered ponds, that are large emitters of methane (CH_4) – a powerful GHG.

Short HRT systems are best suited to small and medium sized piggery operations, where methane capture is not economically viable. They can also benefit larger operations (>10,000 SPU), where energy capture via AD not economic or feasible.

4. How short HRT systems reduce emissions

The anaerobic digestion (AD) of pig effluent in conventional ponds occurs in a series of biological processes where the organic matter (volatile solids) is broken down by numerous microorganisms that function without oxygen. The final products are methane (CH_4), carbon dioxide (CO_2) and other minor gases. The AD process occurs naturally in many oxygen-free environments, such as the stomachs of mammals.

The four stages in anaerobic decomposition are:

1. Hydrolysis – Enzymes break down solid organic material into soluble molecules.

2. Acidogenesis – Soluble molecules are degraded by acid-forming bacteria into acetate, hydrogen and CO_2,

3. Acetogenesis - Volatile fatty acids are converted into acetic acid, CO_2, and hydrogen.

4. Methanogenesis – The final stage, where two groups of methanogens produce methane from either acetate or hydrogen plus CO_2.

Ensuring all four stages are complete and methane generation is maximised requires several key components, including an oxygen-free environment, sufficient retention times, and correct ranges of temperature and pH.

In large and deep uncovered effluent treatment ponds, anaerobic digestion occurs naturally, providing an ideally suited environment for the four-stage process listed above. The issue is that the resulting biogas is released directly to the environment.

Storing flushed effluent for short periods (< 30 days) before reuse can disrupt the last stage of the anaerobic digestion process (methanogenesis) to avoid the large amount of methane generated in traditional large, uncovered ponds.

Desk-top assessments have shown that short HRT systems can achieve GHG reduction similar to those achieved using a covered anaerobic pond or engineered digester. Successful operation of short HRT systems will significantly reduce GHG emissions at a farm scale. It can also be part of an overall GHG reduction strategy to minimise emissions for the Australian pork industry.

5. Are short HRT systems used elsewhere?

Short HRT systems are common in Europe and North America in the pig and dairy industries, where manure is often stored in pits beneath the shed flooring before land application with slurry tankers, including direct injection equipment spreaders. In these regions, farms don't generally utilise any treatment/storage ponds to manage effluent. In Australia, short HRT systems are not common practice in the pig industry, as effluent is generally managed using large uncovered anaerobic ponds or methane capture systems.

6. How much GHG reduction do short HRT systems offer?

An assessment has been undertaken to compare the GHG reduction potential of short HRT systems compared to traditional long retention time treatment of effluent in anaerobic ponds for four geographical regions in Australia. The results of this are shown in Table 1.

The GHG reduction of short HRT systems is very high compared to traditional uncovered anaerobic ponds. When the GHG intensity was assessed on total GHG emissions (Scope 1, 2 and 3), the GHG abatement ranged between regions between 64 and 66%. This assessment was based on modelling, assuming 100% of the effluent was managed via a short HRT system. Abatement, however, would still be high (around 50%) if at least 80% of the effluent was managed via a short HRT system.

Table 1. Comparison of the Carbon Footprint of traditional and short HRT treatment systems

	GHG emissions (kg CO_2-e/kg LW sold)		GHG Reduction (%)
Diet	Traditional Pond	Short HRT	
South Australia	3.7	1.2	66
Southern Qld	4.1	1.5	64
Northern Victoria	3.9	1.4	64
South-west WA	3.9	1.4	65

Table 2 shows further detail for the south-west Western Australia region, using it as an example, with emissions disaggregated by Scope and process. The short HRT assessment was performed assuming all effluent from the piggery was managed in the system, with no effluent needing to be stored in a traditional pond. The table cells are highlighted as a "heat-map" to show the relative contributions of each process. Scope 1 manure emissions (methane and nitrous oxide) reduced from 2.66 to 0.13 kg of CO_2-e/kg LW sold, representing a 95% reduction in Scope 1 GHG emissions.

Table 2. Comparison of the Carbon footprint of traditional and short HRT treatment systems by Scope for the southwest WA region

Emission Source	GHG emissions (kg CO_2-e/kg LW sold)	Contribution (%)	GHG emissions (kg CO_2-e/kg LW sold)	Contribution (%)
	Traditional Pond		Short HRT	
Scope 1				
Piggery enteric methane	0.15	3.8%	0.15	10.8%
Piggery manure methane	2.66	68.0%	0.10	7.5%
Piggery manure direct nitrous oxide	0.00	0.0%	0.03	2.5%
Piggery services	0.03	0.8%	0.03	2.1%
Feedmilling and feed production	0.04	1.0%	0.04	2.8%
Scope 2				
Piggery services	0.14	3.5%	0.14	9.9%
Feedmilling and feed production	0.04	0.9%	0.04	2.6%
Business GHG emissions - Scope 1 & 2	**3.06**	**78.0%**	**0.53**	**38.4%**
Scope 3				
Manure indirect nitrous oxide	0.02	0.6%	0.01	0.9%
Piggery services	0.01	0.1%	0.01	0.4%
Feedmilling and feed production	0.76	19.4%	0.76	55.0%
Transport	0.02	0.6%	0.02	1.7%
Off-farm emissions - Scope 3	**0.81**	**20.7%**	**0.80**	**58.0%**
Land Use Change emissions - (kg CO_2-e/kg LW sold)	**0.05**	**1.3%**	**0.05**	**3.6%**
Carbon footprint GHG emissions	**3.92**	**100%**	**1.38**	**100%**

7. Key infrastructure required and operating considerations

A sufficiently large enough storage tank/s is important infrastructure for these systems, as it holds the effluent before irrigation. The tank's size will depend on the size of the piggery, water use and desired storage time. If you assume one SPU will produce about 10L of effluent per day, then for every 1,000 SPU you will produce about 10,000 L/day. If the desired storage time is five days, this equates to a 50,000 L tank. Another way to estimate effluent production is if you know your water use, you can assume you will recover about 90% of this in the effluent, with 10% loss via respiration and evaporation in sheds. The storage tank could consist of one or several above-ground tanks or in-ground sumps, depending on the amount of effluent generated and the layout of the piggery.

The storage tank/s will need to be fitted with an agitator to ensure all solids are kept in suspension when being pumped out. The size of the agitator will depend on the tank's size and the solids content in the effluent. Good solids separation prior to the storage tank can help remove a large proportion of the solids, and nutrients. It is important that any solids removed aren't allowed to decompose anaerobically, as they can generate further GHG emissions and reduce abatement potential.

A pump and irrigation system or a slurry tanker will be required to apply the effluent from the short HRT storage tank sustainably. With short HRT systems, the concentration of major nutrients (e.g. nitrogen and phosphorus) in the irrigation water will be much higher than with conventional treatment systems. This is due to lower nitrogen losses via ammonia volatilisation than occurs off conventional ponds, and lower losses of phosphorus and nitrogen normally deposited to the sludge in traditional uncovered anaerobic ponds.

Modelling with a 2,000 SPU piggery has shown that for short HRT systems over traditional pond effluent, the total nitrogen concentration is 3.8 times higher, and phosphorus 5.3 times higher. When the short HRT system is combined with solids separation, it will reduce these concentrations. The modelling predicted that the effluent irrigation water had total nitrogen 2.4 times higher than the conventional and 3.1 times higher for phosphorus.

Effluent irrigation area/s will need to be much larger than for traditional pond treatment as there are a lot more nutrients available for crop/pasture production due to lower losses of nitrogen to the atmosphere and partitioning of phosphorus and nitrogen to sludge.

Figure 1. *Square effluent storage tank*

Other alternatives, such as slurry tanks and those fitted with direct injection (see Figure 2), could utilise the effluent from short HRT systems, which could be done with central mainlines that allow the tanker to tap into the effluent line at various locations in the irrigation area and save travel time.

To ensure that methanogens do not accumulate in the tank and therefore generate methane emissions, the storage tank needs to be fully emptied at least every 30 days to meet the requirements of short HRT systems under the National Inventory. Clean water will also need to be used to flush the sheds, as any effluent that has passed through an anaerobic treatment system will likely still have sufficient anaerobic bacteria to generate methane in the storage tank quickly.

Depending on the number of days of storage available in the tank, the size of the available irrigation area, and the climatic zone in which the piggery is located, additional wet weather storage is likely required to hold effluent when irrigation is not possible. Any effluent not managed in the short HRT system is assumed to generate methane emissions equivalent to those of an uncovered anaerobic pond. Some evaluation has been done on this for various pig production regions in Australia, and it is presented in section 9.

Figure 2. *Direct injection slurry tanker with disc openers*

Short HRT systems can be operated as a stand-alone system or as a treatment and management process component (to simplify manure handling and maximise emission reductions). The process may include removing solids before short HRT storage and/or chemically modifying effluent pH.

As with short HRT, solid separation systems operate as an avoided emission process by removing organic matter (volatile solids - VS) from effluent streams before it enters anaerobic pond systems.

The GHG reduction potential is dependent on the system and its' solid removal efficiency. To achieve an overall reduction in GHG emissions for farms using both solids separation combined with short HRT, the removed solids must be treated in an aerobic manner (i.e. stockpiled or composted) to avoid significant methane production.

Many different methods are used for removing solids from liquids and generally rely on either a gravitational process or a mechanical device. Details on these can be found in the NEGIP.

Solids separation before a short HRT system will:

- Reduce clogging of irrigators
- Reduce the quantity of solids entering storage tanks
- Remove nutrients from the effluent and thus reduce the size of irrigation areas.
- Will convert a proportion of the liquid nutrients to solids that can then be readily sold off-farm.

Figure 3. *Option for operating a short HRT system*

8. Some advantages and disadvantages of short HRT

The main advantage of short HRT systems over other methane reduction strategies at conventional piggeries (i.e. covered ponds and digesters) is that the capital cost is much lower . Estimated to be 20 to 40% of a CAP, depending on infrastructure choices and requirements – tanker for spreading, solids separators, sumps, pumps etc. This provides small to medium-sized conventional piggeries an option to significantly reduce GHG emissions, with lower capital input. The downside over a traditional large, uncovered pond system, is that they will require more management, with effluent irrigation required weekly or less, rather than a few times a year.

One important consideration with short HRT systems is the differences in the concentration of nutrients in the effluent at the point of irrigation. Conventional anaerobic pond systems have a high HRT, resulting in a large loss of nitrogen from the effluent to the atmosphere and a high proportion of the phosphorus and nitrogen deposited to the sludge. As short HRT systems have a low HRT and no sludge generation before irrigation, the nutrient levels remain high. Note that for conventional systems, if all the sludge is applied on the same site, the required application areas would be the same as the short HRT scenario without solids separation.

Nutrient concentrations applied through irrigation must be balanced against the nutrient demand of the crop, to minimise any loss of nitrogen and phosphorus from a site. Nutrient loss from the agricultural system can contribute to elevated nutrients in ground and surface waters which may increase the risk of eutrophication. Regulatory approval of new short HRT systems will likely depend on an operator's ability to demonstrate sustainable irrigation practices for a particular location.

9. How does a short HRT system affect the size of irrigation areas?

A series of modelling runs were undertaken to investigate how much additional land area would be required if a conventional piggery switched to a short HRT system. This process was undertaken for 13 traditional pig production areas in Australia. Irrigation areas for each scenario were determined using daily time-step modelling to ensure the nutrient loadings were not excessive and the concentrations of nutrients did not exceed sustainable application rates. Modelled irrigation areas and nutrient loadings for a range of locations for the 2,000 SPU piggery scenario are provided in Table 3. Note that these are "typical" scenarios and site-specific design and management will change these.

The results in Table 3 are scalable. For example, for a 10,000 SPU piggery the size of the irrigation areas would need to about 5 times greater than for a 2,000 SPU piggery.

Table 3. Required irrigation areas and nutrient application rates for 2,000 SPU operation

	Conventional			Short HRT			Short HRT with SS		
	Area (ha)	N applied (kg/ha.yr)	P applied (kg/ha.yr)	Area (ha)	N applied (kg/ha.yr)	P applied (kg/ha.yr)	Area (ha)	N applied (kg/ha.yr)	P applied (kg/ha.yr)
Oakey, Qld	12	200	31	110	136	42	65	144	42
Goondiwindi, Qld	10	172	38	110	136	42	65	144	42
Kingaroy, Qld	10	2094	38	110	131	40	65	138	40
Young, NSW	10	179	39	100	131	41	60	137	40
Casino, NSW	10	261	38	95	133	41	55	144	41
Corowa, NSW	10	169	40	110	134	42	65	141	42
Bendigo, Vic	10	174	39	100	132	41	65	132	37
Shepparton, Vic	10	172	39	110	133	42	65	141	41
Murray Bridge, SA	15	112	25	110	149	41	65	158	41
Naracoorte, SA	10	172	38	90	142	39	50	160	41
Roseworthy, SA	10	159	389	95	146	40	65	133	34
Narrogin, WA	10	155	40	105	139	41	65	140	39
Mount Barker, WA	10	148	39	80	127	38	45	142	39

The results show that the required irrigation area for short HRT systems is around ten times greater than for conventional treatment systems. Short HRT with solids removal requires smaller irrigation areas (30 – 40% less) than straight short HRT due to the reduced concentration of nutrients in the irrigation water. Other options to reduce irrigation areas could include the production of crops with higher nutrient levels and/or yields. However, additional clean irrigation water would be required to increase crop yields and nutrient removal.

Generally, the limiting factors determining the required irrigation area for short HRT systems will be phosphorus loading and, in some cases, where local soils are highly permeable, the nitrate leaching rate through the soil.

10. Can short HRT operate without any storage pond?

The short answer is No unless you are in a dry climate. Desktop modelling has investigated the proportion of effluent that can be sustainably irrigated from short HRT systems in various locations around Australia. Using the irrigation areas defined in Table 3, the proportion of effluent produced for a 2,000 SPU piggery was determined (see Table 4). The short HRT storage tank selected was 125 m³ (125,000 L) – roughly five to six days storage. Table 4 also shows the size of wet weather storage required to hold the excess effluent compared to a conventional piggery.

Short HRT systems rely on the frequent application of relatively small effluent volumes. The results of the modelling showed that short HRT systems could be used to manage a high proportion of effluent in most pig production regions, with only two of the 13 sites modelled utilising less than 80% of the effluent generated from small and medium-sized operations.

Regions with higher rainfall and cooler temperatures are less suited to short HRT systems due to the lower requirement for frequent effluent application.

Table 4. Proportion of effluent usage and pond sizes for 2,000 SPU operation

	Conventional			Short HRT			Short HRT with SS		
	% Use	Pond 1 (m³)	Pond 2 (m³)	% Use	Pond 1 (m³)	Pond 2 (m³)	% Use	Pond 1 (m³)	Pond 2 (m³)
Oakey, Qld	100%	7,500	3,000	97%	125	510	98%	125	510
Goondiwindi, Qld	100%	6,500	3,000	97%	125	780	98%	125	780
Kingaroy, Qld	100%	7,300	3,000	94%	125	2600	94%	125	2,600
Young, NSW	100%	8,600	3,200	84%	125	5,700	84%	125	5,700
Casino, NSW	99%	6,500	3,000	82%	125	11,000	82%	125	11,000
Corowa, NSW	100%	8,600	3,000	94%	125	1,400	94%	125	1,400
Bendigo, Vic	99%	8,600	3,000	85%	125	4,900	85%	125	4,900
Shepparton, Vic	100%	8,200	3,000	94%	125	1,800	94%	125	1,800
Murray Bridge, SA	100%	7,700	3,000	95%	125	850	95%	125	850
Naracoorte, SA	100%	7,700	4,000	74%	125	8,000	74%	125	8,000
Roseworthy, SA	100%	7,700	3,000	81%	125	3,400	80%	125	3,400
Narrogin, WA	100%	7,800	3,000	87%	125	1,900	87%	125	1,900
Mount Barker, WA	98%	8,800	4,400	61%	125	11,000	61%	125	11,000

To minimise environmental risk from the application of high-strength effluent, it must be ensured that spreading occurs evenly over a dedicated area. Due to the relatively high land areas and low irrigation rates, spreading for short HRT systems is often undertaken using a tractor and spreader, like the one in Figure 4. Buffer distances from sensitive receptors such as waterways, native vegetation, groundwater bores and residences should also be considered when selecting spreading areas.

A range of factors can impact the effluent volume and composition, including feed wastage, hosing/flushing volumes and drinking water wastage. Changes in these can impact required ponds sizes and associated effluent irrigation areas for both conventional and short HRT systems, due to the changes in HRT and VS loading rates and individual sites should be assessed on a case-by-case basis.

Figure 4. *Effluent spreading with a tanker – direct injection would also reduce off-site odour impacts*

11. Summary

Short HRT would likely best function via a systems approach to maximise GHG mitigation, with solids separation as a pre-treatment. The system is also most suited to areas of Australia with lower rainfall and high mean temperatures, allowing for frequent effluent application.

Separating solids before effluent enters a short HRT storage would reduce the amount of organic matter and nutrient concentrations in the irrigation water, reducing the land area required for effluent irrigation. The separated solids could be managed on-site via stockpiling and composting before removal off-farm as an organic fertiliser, reducing the nutrient loads on the piggery farm operation.

Another advantage of solid separation before short HRT, is that irrigation would be easier to undertake, with the larger particles removed and this would both reduce the effort required to agitate the storage tank at removal and enable a wider range of irrigation equipment to be used.

Cleaning the short HRT storage after each batch would be simpler as removing solids would cause less settling in the tank. Removal of all organic material would be important between each effluent batch to ensure that new effluent added would not be reseeded with anaerobic bacteria.

The short HRT approach could work with piggeries that currently manage their effluent streams with uncovered anaerobic ponds. The infrastructure requirements to direct effluent from an anaerobic treatment system to a short HRT system is reasonably straight forward but will require increased management.

More information

For a copy of the report, contact the APL Extension Team at extension@australianpork.com.au

For technical information, contact Gemma Wyburn at gemma.wyburn@australianpork.com.au