Queensland Sedimentation and Evaporation Pond System (SEPS) Trial

Final Report
APL Project 2009/2248

June 2013

Department of Agriculture, Fisheries and Forestry
Agri-Science Queensland
Alan Skerman
PO Box 102 203 Tor Street
Toowoomba Qld 4350

Acknowledgements

This project is supported by funding from Australian Pork Limited and the Department of Agriculture.

Mr and Mrs Gary and Wendy Maguire, owners of 'Summerhill' piggery, and Mr Eddie Sloane, piggery manager, for cooperation and assistance provided throughout the project.

Messrs Gary Collman, Grant Brown, David Duperouzel, Jim McAuley and Brendan Marquardt, DAFF (Qld) for assisting in the planning and delivery of this project.

Messrs Michael Atzeni and Ross Knight, DAFF (Qld) for operating the dynamic olfactometer.

Ms Janine Price, APL Manager Environment & Climate Change, Research & Innovation.

Toowoomba Regional Council for laboratory services.

Executive Summary

Sedimentation and Evaporation Pond Systems (SEPS) are a relatively-recently developed piggery effluent treatment system consisting of two or three parallel earthen channels which are long, narrow, shallow and trafficable. Raw effluent from piggery sheds is directed into the first of these channels, typically over a six-monthly cycle. At the end of the first six-monthly cycle, the raw effluent is then directed into the second channel, enabling the solids that have settled in the first channel to dry out prior to removal, generally using conventional farm machinery.

SEPS were originally developed by Mr Dugald Walker (Windridge Farms, Young NSW) to overcome the difficulties and high costs involved in removing wet sludge from the large, deep anaerobic ponds typically used to treat piggery waste, and to access manure solids annually for application onto cropping and pasture land. In comparison to typical anaerobic ponds, SEPS have a significantly smaller total storage capacity, potentially reducing earthworks costs in comparison to constructing and lining large, deep anaerobic treatment ponds designed according to the current standards adopted in most Australian states.

While SEPS have been shown to work effectively in southern NSW and WA (Payne *et al.*, 2008), which experience winter-dominant rainfall and hot, dry summers, their operational effectiveness had not been demonstrated in summer-dominant rainfall climates such as Queensland (Qld) and northern New South Wales (NSW). SEPS rely on evaporation to dry out the channels that are not receiving effluent over the six month cycles. In winter-dominant rainfall areas, this drying process typically occurs during the hot, dry summers. It was previously unknown whether sufficient drying could be achieved during the hot, humid and typically wet summers experienced in Qld and northern NSW.

This project was undertaken to investigate the feasibility of using SEPS to treat piggery effluent and manage piggery solids in the summer dominant rainfall area of southern Qld, which is a major pork-producing region. The results of this project will enable producers, industry and regulatory authorities to evaluate the merit of wider adoption of this potentially valuable effluent management technology throughout Qld and northern NSW.

Several southern Qld pig producers were approached in order to find a suitable commercial piggery to carry out the SEPS trial. Following a number of site visits and discussions with producers, Mr Gary Maguire agreed to allow the SEPS trial to proceed at the 'Summerhill' piggery which is operated as a 450 sow farrow-to-finish unit, with an approved capacity of 4450 standard pig units (SPU). This piggery is located near the Town of Bowenville, on the Darling Downs, in southern Qld.

A SEPS was designed to suit the 'Summerhill' piggery operation based on the recommendations provided in the draft NSW DPI Primefact / WA DA&F Farmnote entitled ‘Sedimentation and Evaporation Pond Systems’ (Kruger, Payne, Moore & Morgan, 2008).

Earthworks were completed in July 2010 at a cost of $32,000. Soil testing was carried out to demonstrate that the materials, moisture content and level of compaction met recognised standards to achieve the required level of impermeability. The SEPS commenced operation on 30 September 2010.

The extreme wet summer experienced from December 2010 to January 2011 delayed project progress due to inundation of the SEPS.

Odour samples were collected on five occasions from the active and drying SEPS channels and the return drain, using both the wind tunnel and flux chamber methods. These samples were analysed using the Agri-Science Queensland olfactometer in Toowoomba to determine odour emission rates. The treated effluent was sampled on three occasions and the SEPS inflow was metered throughout the trial. The PigBal model (Casey *et al*., 1996) was used to estimate the manure load entering the SEPS.

The odour emissions from the SEPS recorded in this project were very similar to levels recorded previously for the southern NSW SEPS (Hayes *et al*., 2008 and Payne *et al*., 2008). The maximum odour emissions recorded in this project were also within the range recorded from conventional anaerobic ponds (Hudson, 2004) and a highly-loaded pond (Skerman *et al.,* 2008) located in southern Qld.

These results suggest that overall odour emissions from SEPS are likely to be lower than for conventional ponds due to the significantly smaller surface area of the active and drying SEP channels and similar or lower emission rates per unit area.

Some problems were experienced with the operation of the SEPS overflow pipes which conveyed treated effluent to the return drain. There is a need for further evaluation of SEPS drainage methods to determine the most practical, cost-effective solution.

The effectiveness of effluent treatment is often measured in terms of the reduction in volatile solids (VS). In this trial, a VS reduction of 83% was recorded. This is superior to many recognised standards for anaerobic effluent treatment, such as Kruger *et al.* (1995) which suggests a 75% reduction in VS and BOD in primary anaerobic ponds. In terms of reductions in TS, VS, N, P & K, the performance of the SEPS studied in this trial was similar to that recorded by Payne *et al*. (2008) for SEPS previously constructed in southern NSW and WA.

Experience gained in this project suggests that SEPS should be regularly monitored to observe any potential problems such as blockages of overflow pipelines, excessive solids deposition or excessive crust formation; all of which could impede the effective operation of the system.

SEPS also require timely management with regard to rotation of the channels at the designated time interval (six months in this case) and the removal of solids as soon as the off-line SEP channels have dried out sufficiently. This will require ready access to suitable solids removal machinery or a suitable contractor. During relatively wet seasons, there may be limited opportunities to remove solids at the optimal moisture content. Use of a vacuum tanker and mechanical agitator may be required when solids are too wet for removal using a front end loader or excavator.

APL was unable to approve an additional extension to this project to complete the planned evaluation of the removed solids characteristics, in terms of odour emissions, recovered quantities and their nutrient and economic value as an organic fertiliser. To maximise the benefits derived from the significant investment in time and resources made at this site, it is recommended that APL consider funding a follow-up trial. This would be conducted at a later date; specifically, at a time after which the producer has implemented an effective solids management program. Such a follow-up trial would evaluate the characteristics of the recovered solids and would also involve performing a comprehensive cost: benefit analysis.

This trial was carried out during a relatively wet period in southern Qld, which included the extreme wet summer of 2010/11. While the climatic conditions undoubtedly hampered efforts to remove solids from the SEPS, the unavailability of a suitable contractor was probably the overriding factor in delaying the scheduled solids removal. While it is difficult to predict how the SEPS may have performed under more typical climatic conditions, it seems likely that there may be fewer opportunities for removing settled solids at a suitable moisture content, in southern Qld, when compared with sites located in southern NSW and WA. Nevertheless, in terms of odour emission and the effectiveness of effluent treatment, the 'Summerhill' SEPS performed similarly to the previously constructed SEPS.

Based on the findings of this trial, there does not appear to be any valid reason for restricting the wider adoption of SEPS for managing piggery effluent and solids in regions such as southern Qld and northern NSW. However, producers need to pay careful attention to the timely rotation of the SEPS channels and the removal of solids, as the opportunities for doing so may be limited during seasons receiving higher than average rainfall.

Contents

Figures

Tables

1. Background

Sedimentation and Evaporation Pond Systems (SEPS) are a relatively recently-developed piggery effluent treatment system consisting of two or three parallel earthen channels which are long, narrow, shallow and trafficable. Raw effluent from piggery sheds is directed into one of these channels, typically over a six-month cycle. The raw effluent is directed into another channel at the end of the cycle enabling the solids that have settled in the first channel to dry out prior to removal, generally using conventional farm machinery.

SEPS were originally developed by Mr Dugald Walker (Windridge Farms, Young NSW) to overcome the difficulties and high costs involved in removing wet sludge from large, deep anaerobic ponds used to treat piggery waste, and to access manure solids annually for application onto cropping and pasture land. In comparison to typical anaerobic ponds, SEPS have a significantly smaller total storage capacity, potentially reducing earthworks costs in comparison to constructing and lining large, deep anaerobic treatment ponds designed according to current standards adopted in most Australian states.

The prototype SEPS was designed and constructed in 1996 by Windridge Farms in association with the NSW Department of Land and Water Conservation's Soilworks Team, based at Young. The storage capacity of the prototype SEPS proved to be too small. Mr Ian Kruger (NSW Department of Primary Industries) assisted Windridge Farms in revising the original design by increasing the storage capacity of the SEPS to 0.5 m^3 per standard pig unit (SPU) per year, based on published total solids loading rates and sludge accumulation rates observed in anaerobic lagoons.

A full-scale system was then constructed a year later based on this design capacity. SEPS have since been constructed on three other large Windridge piggeries near Young, three other NSW piggeries, and on one dairy. The Windridge Farm SEPS has now been operating successfully for 16 years.

A smaller, modified SEPS system was more recently constructed near Mingenew (WA) by a producer with a 200 sow farrow-to-finish piggery who was required to upgrade the piggery's effluent treatment system under new licensing conditions. The design of this system was modified to suit the sandy soil conditions.

While SEPS have been shown to work effectively in southern NSW and WA which experience winter-dominant rainfall and hot, dry summers (Payne, Moore *et al*, 2008), their operational effectiveness has not currently been demonstrated in summer-dominant rainfall climates such as Qld. SEPS rely on evaporation to dry out the channels that are not receiving effluent over the six month cycles. In winter-dominant rainfall areas, this drying process typically occurs during the hot, dry summers. It is currently unknown whether sufficient drying will be achieved during the hot, humid and typically wet summers experienced in Qld.

This project was undertaken to investigate the feasibility of using SEPS to treat piggery effluent and manage piggery solids in the summer dominant rainfall area of southern Qld, which is a major pork producing region. The results of this project will enable producers, industry and regulatory authorities to evaluate the merit of wider adoption of this potentially valuable effluent management technology throughout Qld and northern NSW.

This project builds on the findings included in the Final Report for APL Project No 2130 (Payne, Moore, Morgan and Kruger, April 2008). The outcomes of this research were also incorporated in a draft (currently unpublished) NSW DPI Primefact / DA&F WA Farmnote (Kruger, Payne, Moore and Morgan, May 2008) which includes detailed design, construction and management recommendations. Australian Pork Ltd (APL) also commissioned a concurrent study examining odour emissions from SEPS. This study was conducted by The Odour Unit Pty Ltd (TOU). The findings of this study are contained in the Final Report for APL Project No 2139 (Hayes *et al*., 2007).

2. Objectives

The objectives of this project, as specified in the research agreement, were as follows:

1. To design and construct SEPS to treat the effluent discharged from a southern Qld piggery, based on the standards recommended by Kruger, Payne, Moore and Morgan (2008).
2. To measure odour emission from active and drying SEPS, over a three-year period encompassing varying operational, climatic and seasonal conditions.
3. To estimate the composition of the influent entering the SEPS using the PIGBAL model.
4. To sample and analyse the effluent discharged from the SEPS.
5. To sample, analyse and quantify the solids removed from the SEPS.
6. To estimate the value of the solids removed from the SEPS in terms of replacing inorganic fertiliser use.
7. To develop a cost : benefit analysis for SEPS in comparison to conventional effluent pond systems commonly used to manage piggery effluent.

Due to wet weather experienced throughout the project, including some extreme wet weather during the summer of 2010/11, and the unavailability of a suitable contractor to remove solids from the SEPS within the scheduled timeframe, it was not possible to complete objectives 5, 6 and 7 listed in Section 2 of this report, prior to the May 2013 deadline. APL was unable to approve a further extension of this project to enable the required work to be carried out beyond this date.

3. Research Methodology

3.1 Research Site Selection

Several southern Qld pig producers were approached in an effort to find a suitable commercial piggery to carry out the SEPS trial. Following a number of site visits and discussions with producers, Mr Gary Maguire agreed to allow the SEPS trial to proceed at the Summerhill Piggery which is operated as a 450 sow farrow-to-finish unit, with an approved capacity of 4450 standard pig units (SPU). This piggery is located at 2076 Bowenville - Blaxland Road, approximately 4 km west-north-west of the Town of Bowenville on the Darling Downs (approximately 60 km west of Toowoomba).

3.2 SEPS Design

A SEPS was designed to suit the Summerhill Piggery operation based on the recommendations provided in the draft NSW DPI Primefact / WA DA&F Farmnote entitled 'Sedimentation and Evaporation Pond Systems' (Kruger, Payne, Moore & Morgan, 2008). This document was distributed at the APL National Environmental Guidelines workshop held in May 2008, but it is understood that it was not formally published. The recommendations in this Primefact / Farmnote were derived from the findings of APL Project 2130 (Payne, Moore, Morgan and Kruger, 2008).

The SEPS was designed having three parallel channels. Each channel had an effluent storage capacity of 0.25 m^3/SPU, based on a six-monthly rotation, resulting in a total storage capacity of 1113 m^3/channel, to service the maximum piggery operating capacity of 4450 SPU.

Each of the three SEPS channels was approximately 166 m long, with horizontal longitudinal bed gradients over the first 116 m. The bed gradient over the final 50 m of each channel increased to 0.40%. The SEPS channels were designed to store effluent to a maximum depth of 0.80 m over the first 100 m, increasing to 1.00 m at the downstream end of the SEPS. A freeboard of 0.50 m was provided throughout the SEPS, resulting in a total channel depth ranging from 1.30 m to 1.50 m from the bed to the crest of the channel banks. The three SEPS channels had bed widths of 6 m with 1 vertical to 3 horizontal batters.

The return channel was designed to convey liquid effluent that drained from the downstream (eastern) end of the SEPS channels back to an earthen sump located near the upstream (western) end of the SEPS. The liquid effluent was to be pumped out of the earthen sump into the nearby secondary effluent pond or directly into piggery shed flushing tanks. The return channel was designed with a bed gradient of 0.50% throughout and a 3 m bed width. Channel batters of 1 vertical to 4 horizontal were selected to enable compaction of the batters using a sheep's foot roller or similar. The depth of cut in the return channel ranged from 1.15 (eastern end) to 1.98 m (western end).

To enable vehicular and machinery access, the external SEPS channel banks incorporated crest widths of 4 m. The internal channel banks featured crest widths of 8 m, which allowed for some temporary storage of removed solids and/or enabled a truck to pass an excavator operating on the channel banks.

Earthen ramps were provided on the eastern ends of the two internal SEPS channel banks, as well as on the northern and southern ends of the bank running along the western end of the SEPS channels. These ramps, at a gradient of approximately 1:10, permitted vehicular access to the SEPS channel banks. The SEPS channel banks were constructed with a uniform longitudinal elevation. To enable drainage of stormwater runoff away from the adjacent SEPS channels, the 4 m wide external banks featured 2.5% cross-slopes (0.1 m in 4 m). The 8 m wide internal SEPS channel banks had 2.5% cross-slopes falling from the centre of the banks towards the adjacent SEPS channels.

The SEPS design characteristics are summarised below:

SEPS channel design characteristics:

Bed width:	6 m
Batters:	1 vertical : 3 horizontal
Storage depth:	0.8 m (increasing gradually to 1.0 m over last 50 m)
Channel length:	166 m
Bed gradient:	0.0% (0 – 116 m)
	0.4% (116 – 166 m)
Freeboard	0.50 m
External bank width:	4.00 m
Internal bank width:	8.0 m
Bank gradient:	0.0%
Initial depth of cut	0.60 m

Return drain design characteristics:

Bed width:	3 m
Batters:	1 vertical : 4 horizontal
Bed gradient:	0.5%

Estimated earthworks volumes:

Stripping:	1101 m^3
Total cut volume:	5435 m^3
Total fill volume:	4383 m^3
Nominal cut/fill ratio:	1.24

3.3 SEPS Earthworks

During April 2010, a detailed document requesting quotations for the SEPS construction, entitled 'Earthworks required for the construction of a Sedimentation and Evaporation Pond System (SEPS) at the Summerhill Piggery, Bowenville', was produced and distributed to four Darling Downs earthmoving contracting firms. This document has been included in Appendix 1 of this report.

Following site visits, three of these contractors submitted written quotations. A verbal cost estimate (based on unit rates) had previously been received from the fourth contractor in November 2009. The written quotes ranged from $32,000 to $35,000 (excluding GST). The quotations were evaluated and a preferred contractor was selected based on price, experience, availability of suitable machinery and capacity to undertake the required work within the project time frames. Cattell Earthmoving Pty Ltd, based in Pittsworth, was selected to carry out the required earthworks at a cost of $32,000 (excluding GST).

The earthworks for the SEPS were carried out over a 2 week period from 24 June to 6 July 2010. The machinery used in the earthworks construction included a scraper, dozer, grader, vibrating pad foot roller and water truck. As shown in Figure 1, the SEPS were constructed within a disused effluent evaporation pond. Figures 2 to 6 show various stages of the SEPS earthworks construction.

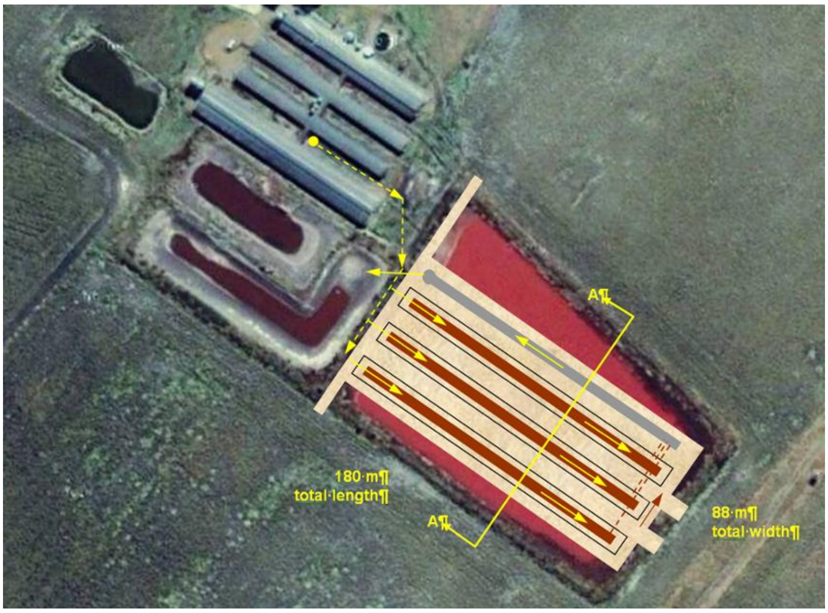

Figure 1: Aerial photograph of the piggery with the proposed SEPS overlaid.

Figure 2: Stripping piggery solids from the base of the disused effluent evaporation pond in preparation for construction.

Figure 3: A scraper was used to remove material from the base of the SEPS channels for placement on the banks.

Figure 4: A grader was used to trim the earthworks following placement with the scraper and compaction using the vibrating pad-foot roller.

Figure 5: Vibrating pad foot roller compacting the base of one of the SEPS channels

Figure 6: Completed SEPS channel.

3.4 Soil Testing

Soiltech Testing Services Pty Ltd, based in Toowoomba, were employed to carry out soil testing at four sites on the completed SEPS earthworks, to confirm whether the material and compaction characteristics complied with the standards outlined in the DPI&F note 'Clay lining and compaction of effluent ponds' (Skerman *et al*, 2005) included in Appendix 2. This document provides technical guidance to producers, contractors, consultants, and project managers involved in constructing effluent ponds, with regard to meeting acceptable permeability standards, to minimise the risk of contaminants leaching into underlying groundwater resources. These standards have been recognised by delegated officers of the DAFF (Qld) Intensive Livestock Environmental Regulation Unit (ILERU) who are responsible for administering 'pig keeping' under the State Environmental Protection Act 1994.

The soil testing involved collecting four samples from the SEPS site when the earthworks were nearing completion. These samples were taken back to the Soiltech laboratory in Toowoomba for Atterburg testing to give the liquid and plastic limits, plasticity index and linear shrinkage, in accordance with AS 1289.3.9, AS 1289.3.2.1, AS 1289.3.3.2 and AS 1289.3.4.1, respectively. These tests also assisted in determining the soil classification under the Unified Soil Classification system.
In-situ dry density ratio (compaction) testing was also carried out in accordance with AS 1289.5.8.1, at two sites in the beds of the SEPS channels and at two sites on the tops of the SEPS banks. Moisture content testing was carried out on samples collected from these sites in accordance with AS 1289.2.1.1.

3.5 Drainage Pipe Installation

The SEPS drainage pipelines were installed on 5 August 2010. Separate 150 mm diameter PVC pipelines were installed from the lower (eastern) ends of each of the three SEPS channels, to the return drain. Each drainage pipeline was laid perpendicular to the SEPS channels, on a constant gradient of 0.5%, without any bends, to reduce the risk of blockages. A backhoe contractor was employed to assist with the pipe laying. A laser level was used to control the trench excavation and pipe laying process to ensure that a uniform pipeline gradient was achieved. Figures 7 and 8 show stages of the SEPS drainage pipeline installation.

Figure 9 is an aerial photograph showing the completed SEPS. The drainage pipelines are shown as dotted lines near the eastern (downstream) ends of the SEP channels.

Figure 7: Laying individual 150 mm diameter PVC drainage pipelines from each of the SEPS channels to the return drain.

Figure 8: Backfilling the pipeline trench where the three SEPS drainage pipelines enter the return drain.

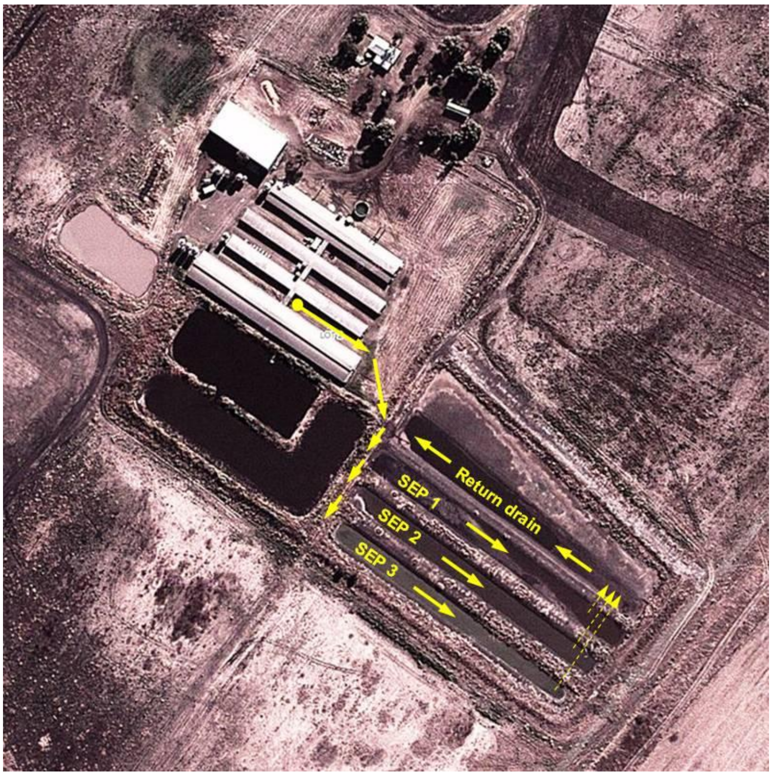

Figure 9: Aerial photo showing completed SEPS.

3.6 SEPS Overflow Structures

An adjustable overflow pipeline and fittings were initially installed on the upstream end of the first SEPS drainage pipeline, as shown schematically in Figure 10. This arrangement was intended to allow the first SEPS channel to fill up with raw effluent pumped from the piggery sheds, before overflowing by gravity through the SEPS drainage pipeline into the return channel.

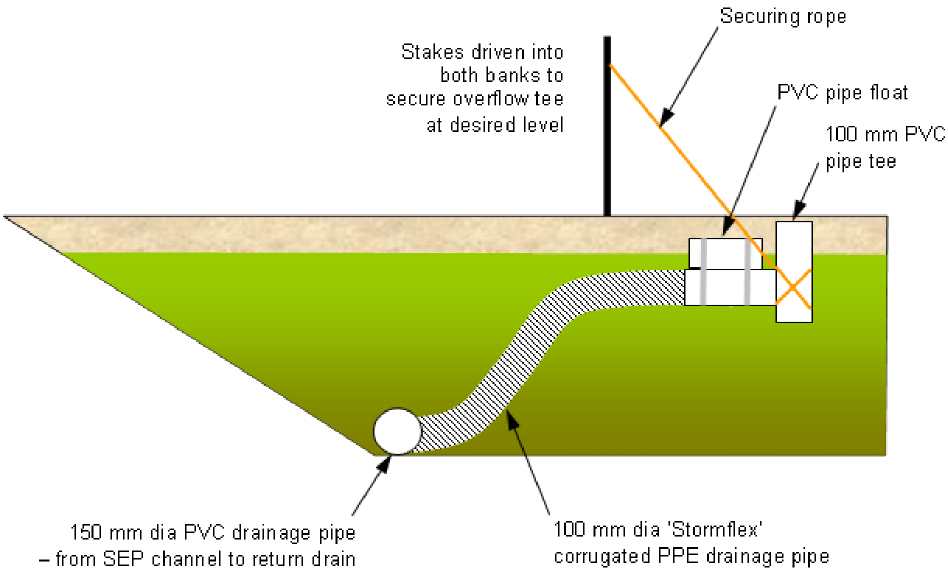

Figure 10: Schematic drawing of overflow arrangement initially installed on the first SEPS channel.

The overflow arrangement was fitted with a tee on the upstream end to draw effluent from just below the surface, thereby preventing the entry of floating solids that could potentially result in blockages. The overflow tee was secured at the desired overflow level using ropes tied to stakes driven into the adjacent banks of the SEPS channel. At the end of the 6 month active filling cycle, it was planned to release the securing ropes, allowing the SEPS channel to gradually drain down to bed level. The float was intended to ensure that effluent was drawn from just below the surface during the drainage cycle, thereby minimising the export of settled solids into the return drain.

Due to the flexibility of the 'Stormflex' pipe, it was found that the overflow arrangement described above did not operate successfully. Air locks in the 'Stormflex' pipe frequently impeded drainage of the SEPS. Replacement of the 'Stormflex' pipe with less flexible pump suction pipe improved the overflow operation. Prior to commencing pumping of effluent into SEP 3, the overflow arrangement shown in Figure 11 was installed. This arrangement used a fixed 150 mm diameter PVC riser and tee to prevent floating crust material from entering the drainage pipe. This system was found to work relatively successfully.

Figure 11: Revised overflow arrangement trialled in SEP 3 using 150 mm dia PVC riser and tee and 100 mm dia. flexible pump suction pipe.

3.7 SEPS Operation

The piggery owner commenced pumping raw shed effluent into SEP 1 on 30 September 2010. Figure 12 is a photograph showing SEP 1 and the return drain after approximately one month of operation. The piggery owner also installed a new effluent pumping system to enable the effluent stored in the return drain to be used for, variously; flushing the sheds, pumping into the secondary ponds, or irrigating the surrounding cultivation paddocks which are used to produce a range of winter and summer grain and forage crops.

Southern Qld experienced an extremely wet summer 2010-2011, which resulted in severe flooding of many areas. The December 2010 rainfall at Bowenville (Bureau of Meteorology Station No 41008) was 305 mm, the second highest December rainfall recorded since records commenced in 1889. The January 2011 rainfall was 217 mm, which exceeded the 97th percentile monthly rainfall for January. Under the extreme wet conditions, the piggery manager was forced to pump effluent into each of the three SEPS channels and the return drain, as all wet weather storage capacity available on the farm was full. Figure 13 shows the inundated SEPS on 17 January 2011.

It took several months before the effluent irrigation areas on the farm dried out sufficiently to allow the SEPS and return drain to be pumped out. After the SEPS channels and return drain had been pumped out, raw piggery effluent was initially pumped into SEP 1 until the end of July 2011. Commencing in August 2011, all raw piggery effluent was pumped into SEP 2 while SEP 1 was allowed to dry out. Pumping into SEP 3 commenced on 28 March 2012, approximately 8 months after commencement of pumping into SEP 2.

Based on experience with SEPS in other states, it was expected that the stored solids would dry out sufficiently to allow removal using either a front-end loader, or a tractor with a bucket, provided the bed of the SEPS was trafficable. Alternatively, if the bed of the SEPS was too wet for machinery access, the solids could be removed using an excavator operating from the adjacent bank.

Following the extended wet weather, and whilst the stored solids were still relatively wet, the piggery owner had considered using a vacuum tanker, possibly with the assistance of a tractor-PTO-driven stirrer (agitator), to remove the solids from the SEPS. This solids removal method would allow the solids to be applied directly onto cultivated land located near the SEPS, negating the need for drying and double handling the removed solids. However, the vacuum tanker contractor was delayed due to the need to fulfil other work commitments and was therefore unable to commence removing the solids from the SEPS at the scheduled time.

Due to wet weather and the inability of the piggery owner to arrange for a suitable contractor to remove solids from the SEPS, it was not possible to complete objectives 5, 6 and 7 listed in Section 2 of this report, prior to the May 2013 deadline. These objectives involved sampling, analysing, quantifying and estimating the value of the solids removed from the SEPS. APL was unable to approve a request for a further extension to this project to enable these objectives to be met.

Figure 12: Photograph of the first SEPS channel and return drain on 5 November 2009, after approximately one month of active operation.

Figure 13: Photograph of the SEPS on 17 January 2011. All three SEP channels and the return drain were filled with effluent following the extreme wet conditions experienced over the summer of 2010-11.

3.8 *Odour Sampling and Analysis*

3.8.1 Odour Sampling Schedule

Odour samples were collected using both the wind tunnel and flux chamber methods. This allows comparison of results with previous odour research undertaken for the Australian pork industry using both of these methods. Regulatory authorities have also developed odour standards based on measurements derived using both of these sampling methods. The odour sampling dates and locations are summarised in Table 1.

Table 1: Summary of odour sampling dates, methods and locations.

Sampling date	Sampling method	Sampling location	SEP operational stage	Sampling end
25/11/2010	Wind tunnel	Blank		
25/11/2010	Wind tunnel	SEP 1	Active	Eastern (downstream)
25/11/2010	Wind tunnel	SEP 1	Active	Western (upstream)
14/09/2011	Wind tunnel	Blank		
14/09/2011	Wind tunnel	SEP 1	Drying	Eastern (downstream)
14/09/2011	Wind tunnel	SEP 1	Drying	Western (upstream)
14/09/2011	Wind tunnel	SEP 2	Active	Eastern (downstream)
14/09/2011	Wind tunnel	SEP 2	Active	Western (upstream)
14/12/2011	Wind tunnel	Blank		
14/12/2011	Wind tunnel	SEP 1	Drying	Eastern (downstream)
14/12/2011	Wind tunnel	SEP 1	Drying	Western (upstream)
14/12/2011	Wind tunnel	SEP 2	Active	Eastern (downstream)
14/12/2011	Wind tunnel	SEP 2	Active	Western (upstream)
14/12/2011	Flux chamber	Blank		
14/12/2011	Flux chamber	SEP 2	Active	Eastern (downstream)
14/12/2011	Flux chamber	SEP 2	Active	Western (upstream)
11/04/2012	Wind tunnel	Blank		
11/04/2012	Wind tunnel	SEP 3	Active	Eastern (downstream)
11/04/2012	Wind tunnel	SEP 3	Active	Western (upstream)
11/04/2012	Wind tunnel	SEP 2	Drying	Eastern (downstream)
11/04/2012	Wind tunnel	SEP 2	Drying	Western (upstream)
12/04/2012	Wind tunnel	Return drain		Western (downstream)
12/04/2012	Flux chamber	Return drain		Western (downstream)
12/04/2012	Flux chamber	SEP 2	Drying	Eastern (downstream)
28/08/2012	Wind tunnel	Blank		
28/08/2012	Wind tunnel	SEP 3	Active	Eastern (downstream)
28/08/2012	Wind tunnel	SEP 3	Active	Western (upstream)
28/08/2012	Wind tunnel	SEP 2	Drying	Eastern (downstream)
28/08/2012	Wind tunnel	SEP 2	Drying	Western (upstream)
29/08/2012	Flux chamber	Blank		
29/08/2012	Flux chamber	SEP 2	Drying	Eastern (downstream)
29/08/2012	Flux chamber	SEP 2	Drying	Western (upstream)
29/08/2012	Flux chamber	SEP 3	Active	Eastern (downstream)
29/08/2012	Flux chamber	SEP 3	Active	Western (upstream)

The first odour sampling was carried out on Thursday, 25 November, 2010, approximately 8 weeks after pumping into the first SEPS channel commenced. This sampling date had been delayed by approximately 2 weeks due to wet weather preventing vehicle access to the site.

Following the extreme wet weather experienced during the summer of 2010/11, it took several months before the effluent irrigation areas on the farm dried out sufficiently to allow the SEPS and return drain to be pumped out. This resulted in the postponement of the second odour sampling, which had originally been scheduled for February 2011. After the SEPS channels and return drain had been pumped out, raw piggery effluent was initially pumped into SEP 1 until the end of July 2011. Commencing in August 2011, all raw piggery effluent was pumped into SEP 2 while SEP 1 was allowed to dry out. The second odour sample collection was carried out on SEPs 1 and 2 on 14 September 2011; approximately six weeks after pumping into SEP 2 commenced.

Further odour sampling using both the wind tunnel and flux chamber was carried out on 14 December 2011, 11 and 12 April 2012, and 28 and 29 August 2012. On 14 December 2011, it was not possible to carry out odour sampling on the drying SEP (SEP 1) because it had filled with effluent that had overflowed from the active SEP (SEP 2) after the outlet pipeline on the downstream end of SEP 2 developed an air lock, preventing drainage of effluent to the return drain. For this reason, an additional flux chamber sample was collected from the drying SEP (SEP 2) on 12 April 2012.

The first sampling of emissions from the western (downstream) end of the effluent return drain was carried out on 12 April 2012, using both the wind tunnel and flux chamber.

Further odour sampling from the active and drying SEPs (using both wind tunnel and flux chamber) was carried out on 28 and 29 August 2012.

Pumping of raw effluent into SEP 3 commenced in early April 2012. It was planned to discontinue pumping the raw effluent into SEP 3 and to commence pumping into SEP 1 in early October 2012, as each of the three SEP channels was designed to receive raw effluent for a six month period. However, it was not possible to commence pumping the raw effluent into SEP 1 at the scheduled date in early October 2012 because the pig producer was unable to arrange for the solids to be removed from SEP 1.

3.8.2 Wind Tunnel Sampling Method

The Agri-Science Queensland wind tunnel used for odour sampling was originally constructed based on a University of New South Wales (UNSW) design. Modifications, as described by Wang *et al.* (2001), were made to the wind tunnel to improve sampling efficiency. This involved the manufacture of a curved 90-degree manifold, along with the installation of a hollow, stainless steel cross with equidistant spacings in the discharge vent of the wind tunnel.

Carbon-filtered air was forced into the wind tunnel using a 240-volt fan assembly to generate an internal air velocity of between 0.3 and 0.5 m/s in the working section of the tunnel, as proposed by Jiang *et al.* (1995). The velocity of air in the tunnel was determined by measuring the velocity at the fan air intake. This air then passes through a carbon filter, via a length of V-Flex® ducting into the wind tunnel. Air flow velocities were measured using a Thermo Systems Incorporated (TSI) Model 80125 or 8324 rotating vane anemometer.

Two cableways spanning the three SEPS channels were installed near the western (upstream) and eastern (downstream) ends of the SEPS. The cableways were supported between two demountable steel frames erected at the northern and southern ends of the SEPS. The cableways allowed the wind tunnel to be suspended over the surface of any of the three SEPS channels. Additional stands were manufactured to provide increased cable elevation near the centres of the cableways. The wind tunnel is fitted with two remotely controlled 12-volt electric servo-motor driven winches that are used to vertically position the wind tunnel onto the surface of the SEPS for sample collection.

Duplicate odour samples were collected using the Agri-Science Queensland wind tunnel, from near the upstream and downstream ends of the first (active) SEPS channel, based on standard Agri-Science Queensland odour sampling procedures. Odour samples were drawn into 120 L Melinex™ sample bags (Polyethylene Terephthalate) through polytetrafluoroethylene (PTFE) tubing, using the lung method. The sample bags were placed in rigid sample containers (drums) and the air inside the container was evacuated at a controlled rate using a diaphragm pump to fill the bags. All components used for sampling were manufactured from stainless steel or PTFE to minimise potential contamination of the odour samples. All bags were pre-conditioned by filling with odorous air from the SEPS surface before being purged prior to sample collection.

At the start of each sampling day, blank samples were collected by placing the wind tunnel on a stainless steel sheet that had been cleaned using acetone. Blank samples are required to demonstrate that the equipment does not contain any odour contaminants and to establish a baseline for comparison with the actual samples. Clean, slightly damp sand was placed around the perimeter of the wind tunnel base to minimise leakage.

Each duplicate pair of samples was collected from the SEPS surface over a period of approximately ten to twelve minutes. The sampling drums were then sealed and transported to the Agri-Science Queensland laboratory in Toowoomba for analysis by dynamic olfactometry. All samples were analysed within two to six hours of collection in order to minimise the effects of sample storage. Each bag was used once and discarded after analysis.

Figures 14 to 19 show examples of odour sampling using the Agri-Science Queensland wind tunnel.

Figure 14: Collecting a blank odour sample using the Agri-Science wind tunnel positioned on a stainless steel sheet adjacent to the SEP channel (November 2011).

Figure 15: Wind tunnel collecting odour sample from near the eastern end of the SEPS channel (25 November 2010).

Figure 16: Odour sampling near eastern end of SEPS channel (25 November 2010).

Figure 17: Wind tunnel collecting odour sample from near the western end of the SEPS channel, close to the location where the shed effluent enters the SEPS (28 August 2012).

Figure 18: Wind tunnel sampling near the western end of the return drain (12 April 2012).

Figure 19: Odour sampling from the upstream end of SEP 3 (active SEP) on 28 August 2012 using the wind tunnel.

3.8.3 Flux Chamber Sampling Method

The Agri-Science Queensland flux chamber used to collect samples from the SEPS surface was designed in accordance with the US EPA standards, as described in Appendix B of AS/NZS 4323.4 2009.

At the beginning of each collection day, a blank sample was collected in accordance with the above standard, by placing the chamber on a clean sheet of stainless steel.

The flux chamber was suspended on floats constructed using PVC pipe fittings and manually pulled into position on the SEPS surface using ropes. The height of the flux chamber was adjusted so that the rim was immersed to a depth of approximately 25 mm below the effluent surface. A shade cloth frame was provided above the flux chamber to provide protection from direct sunlight during sampling. Shading ensures that chemical processes are not accelerated by concentrated sunlight or increased temperatures inside the chamber.

Cylinders of 'zero grade' air provided the flushing air to the flux chamber. The flushing air flow rate was set at 5 L/minute with the aid of a TSI Series 4143 flow meter (TSI Incorporated, Tennessee) and monitored visually using an Influx Uniflux 0-13 L/minute rotameter (Influx Measurements Ltd, Hampshire).

SKC model PCXR8 Universal Pumps (SKC Inc, Pennsylvania) set at 2.3 L/minute were used to collect the odour samples. Tygon® tubing was attached to the SKC pump and sample drum in order to draw the air from between the inner surface of the drum and outer surface of the sampling bag, thereby drawing odorous air into the bag.

The chamber was allowed to stabilise for 25 minutes before sample collection commenced. During this time, the bag was preconditioned with odorous air from the SEPS surface. The bags were then filled over a 40 minute time frame.

Odour samples were sourced by drawing, through PTFE tubing, air from within the chamber. One end of the PTFE tube was connected to the stainless steel probe on the flux chamber, whilst the other end was attached to the sampling drum fitted with a Melinex® bag. Air samples were drawn into Melinex® bags in a similar manner to that used for collecting samples using the wind tunnel.

All components of the sampling train that were in contact with the odour sample were manufactured from either stainless steel or polytetrafluoroethylene (PTFE). The maximum volume of sample collected was 120 L. Once filled, the drums were sealed and transported to the olfactometry laboratory for analysis. All samples were analysed within six hours of collection. Each bag was used once and discarded after analysis.

Photographs of odour sampling using the flux chamber are provided in Figures 20 to 23.

Figure 20: Odour sampling from the downstream end of SEP 2 (drying SEP) on 29 August 2012 using the flux chamber.

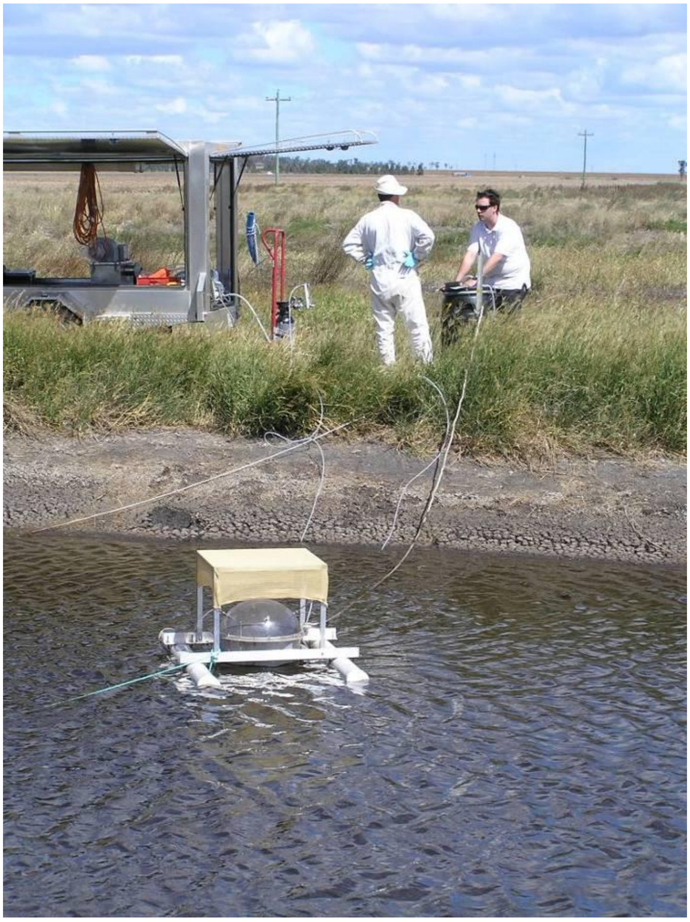

Figure 21: Odour sampling from the return drain using the flux chamber (12 April 2012)

Figure 22: Close-up view of the flux chamber collecting odour sample from the return drain (12 April 2012).

Figure 23: Flux chamber sampling from the drying SEP 2 on 29 August 2012.

3.8.4 *Olfactometry*

Following delivery of the sampling drums from the SEPS site, odour concentrations were determined using an eight panellist, triangular, forced-choice dynamic olfactometer developed by Agri-Science Queensland (formerly Department of Primary Industries and Fisheries (DPI&F)), as shown in Figure 24. This olfactometer was constructed to meet the requirements of the Australian/New Zealand Standard for Dynamic Olfactometry (AS4323.3). The development of the olfactometer has been described previously.

Panellists were first screened with the reference gas (*n*-butanol), according to the above Australian Standard, to ensure their detection thresholds for the reference gas were between 20 and 80 parts per billion. Odour concentration calculations have been previously described by Skerman *et al*., 2009.

Figure 24: The Agri-Science Queensland olfactometer in operation showing panellists sniffing at ports.

3.8.5 *Odour Emission Rate Calculations*

Odour emission rates were calculated from the odour concentrations determined by olfactometry. The equations used in these calculations are outlined below for both the wind tunnel and flux chamber sampling methods.

Wind Tunnel

The odour emission rate, commonly defined as OER or E, was calculated using Equation 1.

$$E = CV_t \frac{A_t}{A_s} \quad \textbf{Equation 1}$$

Where:
C is the odour concentration in the bag;
V_t is the wind speed inside the tunnel;
A_t is the cross sectional area of the tunnel; and
A_s is the surface area covered by the tunnel.

Equation 1 assumes that all background odour is removed from the air introduced into the wind tunnel by the carbon filter, and there is complete mixing between the emissions and the airflow in the tunnel.

The calculated OER was then scaled to a standard tunnel wind speed of 1 m/s according to Smith and Watts (1994), who compared two different sized wind tunnels and concluded that the emission rate E_v at a particular tunnel wind speed V_t could be related to the emission rate E_1 at a tunnel wind speed of 1 m/s. This relationship is shown in Equation 2.

$$\frac{E_v}{E_1} = V_t^{0.63}$$ **Equation 2**

The exponent of 0.63 was derived as a factor for wind tunnels from research conducted on solid surfaces at feedlots. This exponent does not apply to liquid surfaces such as anaerobic ponds. However, Pollock (1997) recommended the use of an exponent of 0.5 for liquid surfaces (based on work of Bliss *et al.* [1995]). This value has been adopted for all calculations of odour emission rate for this project.

Flux Chamber
Flux chamber odour emission rates were calculated using Equation 3.

$$F_i = C_i Q / A_c$$ **Equation 3**

Where:

F_i	=	Zone atmospheric contaminant flux emission rate (ou.m³/m².s) (at 0°C and 101.3 kPa)
C_i	=	Zone chamber atmospheric contaminant concentration (ou)
Q	=	Chamber flow rate (m³/s (at 0°C and 101.3 kPa)
A_c	=	Area enclosed by chamber (m²)

3.9 *Effluent Treatment Performance*

The characteristics of the raw effluent from the piggery sheds entering the SEPS were estimated using the PigBal model. Feed consumption and dietary data was obtained from the piggery owners for entry into the model.

The volume of effluent entering the SEPS was measured using a MagMaster flow meter, which was installed in the delivery pipeline between the effluent collection sump (located near the piggery sheds) and the SEPS.

The PigBal output and flow volumes were used to estimate the loading rate entering the SEPS.

Samples of effluent treated by the SEPS were collected on 21 September 2011, 12 April 2012 and 29 August 2012 from the pipeline that conveys recycled effluent into one of the flushing tanks located on the eastern end of the piggery sheds. This effluent had been freshly pumped from the return drain which receives all overflows from the SEPS (recycled effluent is used for shed flushing throughout the piggery). Two samples were collected on each respective occasion; these were then placed in a cooler box. One of the collected samples was transported to the Toowoomba Regional Council laboratory, where it was then subjected to a full chemical analysis. The remaining sample was transported back to the Agri-Science Queensland laboratory in Toowoomba for total and volatile solids analyses.

The treatment performance of the SEPS was evaluated by comparing the characteristics of the raw shed effluent entering the SEPS, with the treated effluent pumped from the return drain.

4. Results and Discussion

4.1 Climatic Conditions

As previously noted, SEPS have been shown to work effectively in southern NSW and WA (Payne *et al.*, 2008) which experience winter-dominant rainfall and hot, dry summers. One of the major objectives of this project was to investigate the feasibility of using SEPS to treat piggery effluent and manage piggery solids in the summer-dominant rainfall areas of southern Qld and northern NSW, which are major pork producing regions. It was therefore important to assess whether the rainfall received over the trial period was representative of 'normal' conditions which could be expected at the site.

The average monthly rainfalls recorded at the Jondaryan Post Office (Bureau of Meteorology Station No 41053) are provided in Figure 25, along with the actual recorded values over the trial period. This rainfall recording station, which is situated 16.6 km south-east of the piggery site, has more comprehensive rainfall records than the closer Bowenville station.

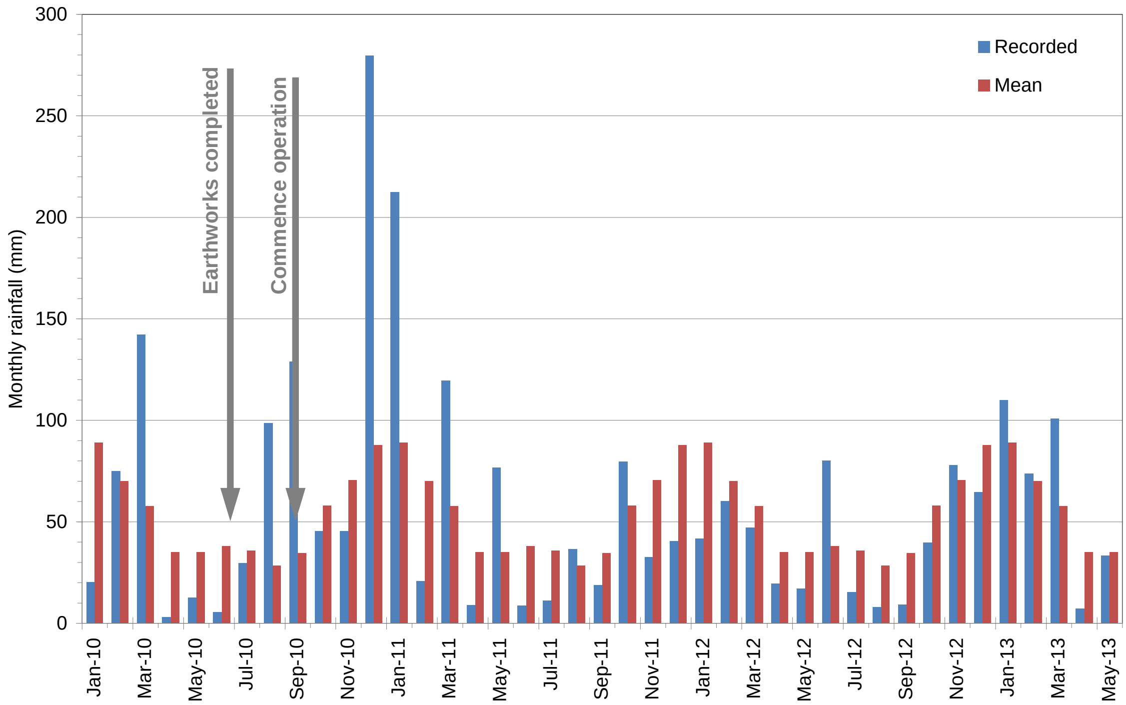

Figure 25: Monthly and average monthly rainfalls recorded at the Jondaryan Post Office (Bureau of Meteorology Station No 41053) over the trial period.

As previously noted, southern Qld experienced an extremely wet summer 2010-2011 resulting in wide-spread severe flooding. The December 2010 rainfall at Bowenville (Bureau of Meteorology Station No 41008) was 305 mm, the second highest December rainfall recorded since records commenced in 1889. The January 2011 rainfall was 217 mm which exceeded the 97th percentile monthly rainfall for January. The total rainfall received during December 2010 and January 2011 was 2.9 times the average total for these months. This trend can be clearly observed from Figure 25. It is therefore not surprising that these extreme conditions delayed progress with this project.

Further observations from Figure 25 indicate that the summer of 2011-2012 was drier than average, whilst the summer of 2012-2013 was generally slightly wetter than average and the winters of both 2011 and 2012 were both drier than average. While monthly rainfall totals may not always provide a good indication of the feasibility of removing dried solids from the inactive SEP channels, it appears that there would have been opportunities for solids removal during the winters of 2011 and 2012 and also during the period from November 2011 to May 2012.

4.2 Soil Testing

The Atterburg tests gave liquid limit results for the four samples ranging from 66% to 78%, with plasticity index values ranging from 51 to 56. These results indicate that the material used in the construction of the SEPS had a high plasticity, being classified as CH (high plasticity) clay, under the Unified Soil Classification system. Skerman *et al*. (2005) suggests that materials with liquid limits in the range from 30% to 60% are suitable for clay lining and that materials having liquid limits up to 80% may be suitable with the addition of a covering layer to prevent drying and cracking of the underlying clay material.

It is anticipated that the SEPS will be storing piggery effluent or moist piggery solids for the majority of the time. These layers should effectively protect the underlying clay material from excessive drying and cracking.

While cracking of the base of effluent ponds (particularly feedlot holding ponds which may be empty for extended periods) can provide a line for leakage into underlying groundwater resources at sites with shallow soil profiles, excessive cracking is unlikely to be an issue of concern at the SEPS site where the black vertosol soils are understood to be relatively deep. The plasticity index values substantially exceed the minimum value of 10% suggested by Skerman *et al.* (2005).

The moisture contents of the samples collected from the SEPS varied from 3% dry of optimum to 2.5% wet of optimum. Skerman *et al.* (2005) suggest a range between 2% dry and 2% wet of optimum for material placed in the effluent pond liner. The samples were collected several days after the material was originally placed in the SEPS. This may account for the relatively small variation outside the suggested values.

The field dry densities ranged from 95% to 104.5% of the maximum laboratory dry density. These results are equal to, or in excess of, the minimum ratio of 95% suggested by Skerman *et al*. (2005).
In summary, the results of the compaction and material testing suggest that a very low level of permeability is likely to have been achieved in the construction of the SEPS.

4.3 Odour Sampling

4.3.1 Odour Emission Rates: Wind-Tunnel

Table 2 reports, for samples collected using the wind tunnel, the odour emission rates calculated from concentrations determined by olfactometry.

Table 2: Odour emission rates for samples collected from the surfaces of the SEPS and return drain channels using the Agri-Science Queensland wind-tunnel, on various dates.

Sampling date	SEP	Stage of operation	Sampling end	Surface description	Odour emission rate (ou.m³.m⁻².s⁻¹)		
					Rep 1	Rep 2	Average
25/11/2010	Blank				3.0		3.0
(8 weeks)*	SEP 1	Active	Eastern (downstream)	Clear	114.5	89.4	102.0
	SEP 1	Active	Western (upstream)	Light crust	130.6	85.2	107.9
14/09/2011	Blank				2.4		2.4
(6 weeks)*	SEP 1	Drying	Eastern (downstream)	Clear	38.8	27.4	33.1
	SEP 1	Drying	Western (upstream)	Light crust	52.7	37.9	45.3
	SEP 2	Active	Eastern (downstream)	Light crust	55.2	70.8	63.0
	SEP 2	Active	Western (upstream)	Clear	76.5	76.5	76.5
14/12/2011	Blank				4.7		4.7
(19 weeks)*	SEP 1	Drying	Eastern (downstream)				
	SEP 1	Drying	Western (upstream)	Light crust			
	SEP 2	Active	Eastern (downstream)		54.4	34.3	44.3
	SEP 2	Active	Western (upstream)	Light crust	108.9	99.9	104.4
11/04/2012	Blank				0.0		
(2 weeks)*	SEP 3	Active	Eastern (downstream)	Clear	107.5	103.0	105.3
	SEP 3	Active	Western (upstream)	Medium crust	62.3	88.1	75.2
	SEP 2	Drying	Eastern (downstream)	Clear	25.9	7.3	16.6
	SEP 2	Drying	Western (upstream)	Medium crust	60.6	82.1	71.4
12/04/2012	Return drain		Western (downstream)	Clear	0.0	4.8	2.4
28/08/2012	Blank				2.7		2.7
(22 weeks)*	SEP 3	Active	Eastern (downstream)	Clear	95.6	113.7	104.7
	SEP 3	Active	Western (upstream)	Medium crust	151.4	121.6	136.5
	SEP 2	Drying	Eastern (downstream)	Clear	5.3	4.2	4.8
	SEP 2	Drying	Western (upstream)	Clear	13.0	9.0	11.0

* Period of time elapsed since pumping of raw effluent into active SEP commenced.

As can be seen from the above table, some of the measured odour emission rates were higher than the maximum value of 84 ou.m^3.m^{-2}.s^{-1} reported by Hudson *et al.* (2004) for six southern Qld piggery ponds, over three seasons (APL Project 1628). The maximum emission rate was virtually identical to the maximum value of 136 ou.m^3.m^{-2}.s^{-1} determined by Skerman *et al.* (2008) for the newly-constructed, highly-loaded pond at a Dalby piggery, soon after effluent was initially directed into the pond (APL Project 2108). Hayes *et al.* (2008) reported a maximum emission rate of 251 ou.m^3.m^{-2}.s^{-1} at the active SEPS inlet for Templemore Piggery, Young, NSW (APL Project 2139).

Based on these comparisons, it appears that the maximum odour emission rates were within the range previously measured for conventional effluent ponds at six southern Qld piggeries and at a previously constructed SEPS in southern NSW.

4.3.2 Odour Emission Rates: Flux Chamber

Table 3 reports the odour emission rates calculated from concentrations determined by olfactometry, for samples collected using the flux chamber.

Table 3: Odour emission rates for samples collected from the surfaces of the SEPS channels and return drain using the Agri-Science Queensland flux-chamber on various dates.

Sampling date	Sampling location	Operational stage	Sampling end	Surface description	Odour emission rate ($ou.m^3.m^{-2}.s^{-1}$)
14/12/2011	Blank				0.02
14/12/2011	SEP 2	Active	Eastern (downstream)	Light crust	0.36
14/12/2011	SEP 2	Active	Western (upstream)	Light crust	2.87
12/04/2012	Return drain		Western (downstream)	Clear	0.08
12/04/2012	SEP 2	Drying	Eastern (downstream)	Clear	0.04
29/08/2012	Blank				0.01
29/08/2012	SEP 2	Drying	Eastern (downstream)	Clear	0.05
29/08/2012	SEP 2	Drying	Western (upstream)	Clear	0.37
29/08/2012	SEP 3	Active	Eastern (downstream)	Medium crust	6.71
29/08/2012	SEP 3	Active	Western (upstream)	Clear	5.58

Hayes *et al.* (2008) reported a maximum emission rate of 22 $ou.m^3.m^{-2}.s^{-1}$ at the active SEPS inlet for Templemore Piggery, Young, NSW (APL Project 2139). The average value one quarter of the way down the active SEPS was 2.6 $ou.m^3.m^{-2}.s^{-1}$, which is very similar to the maximum value recorded in this study.

4.3.3 Odour Emission Rates from Specific Areas

The odour emission rates recorded for specific areas of the SEPS, over the various sampling days, using both the wind tunnel and flux chamber sampling methods, are summarised in Table 4 and in Figure 26 and Figure 27 for the wind tunnel and flux chamber sampling methods, respectively.

Table 4: Odour emission rates ($ou.m^3.m^{-2}.s^{-1}$) recorded for specific areas of the SEPS, using both the wind tunnel and flux chamber sampling methods.

Date	Blank	Active upstream	Active downstream	Drying upstream	Drying downstream	Return drain
Wind tunnel						
25-Nov-10	3.0	107.9	102.0	45.3	33.1	
14-Sep-11	2.4	76.5	63.0			
14-Dec-11	4.7	104.4	44.3	71.4	16.6	2.4
11-Apr-12	0.0	75.2	105.3	11.0	4.8	
28-Aug-12	2.7	136.5	104.7			
Average	2.6	100.1	83.8	42.5	18.1	2.4
Flux chamber						
14-Dec-11	0.02	2.87	0.36			
12-Apr-12	0.00			0.04		0.08
29-Aug-12	0.01	5.58	6.71	0.37	0.05	
Average	0.01	4.22	3.54	0.21	0.05	0.08

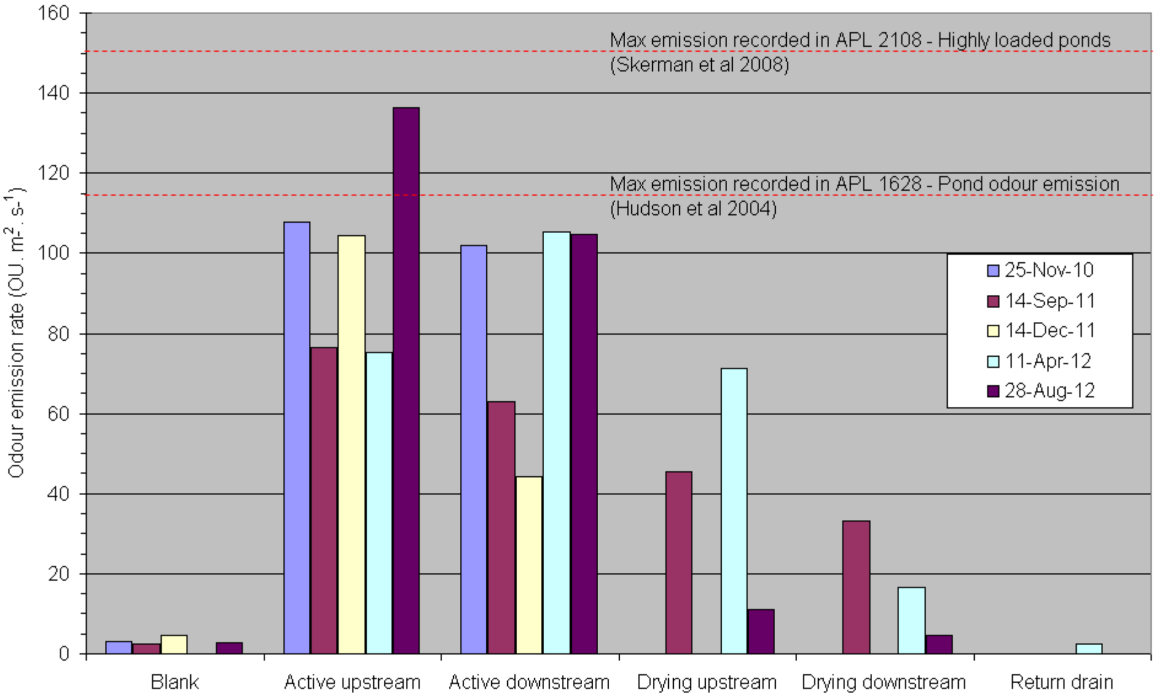

Figure 26: Odour emission rates for samples collected using the wind tunnel, arranged by various areas of the SEPS.

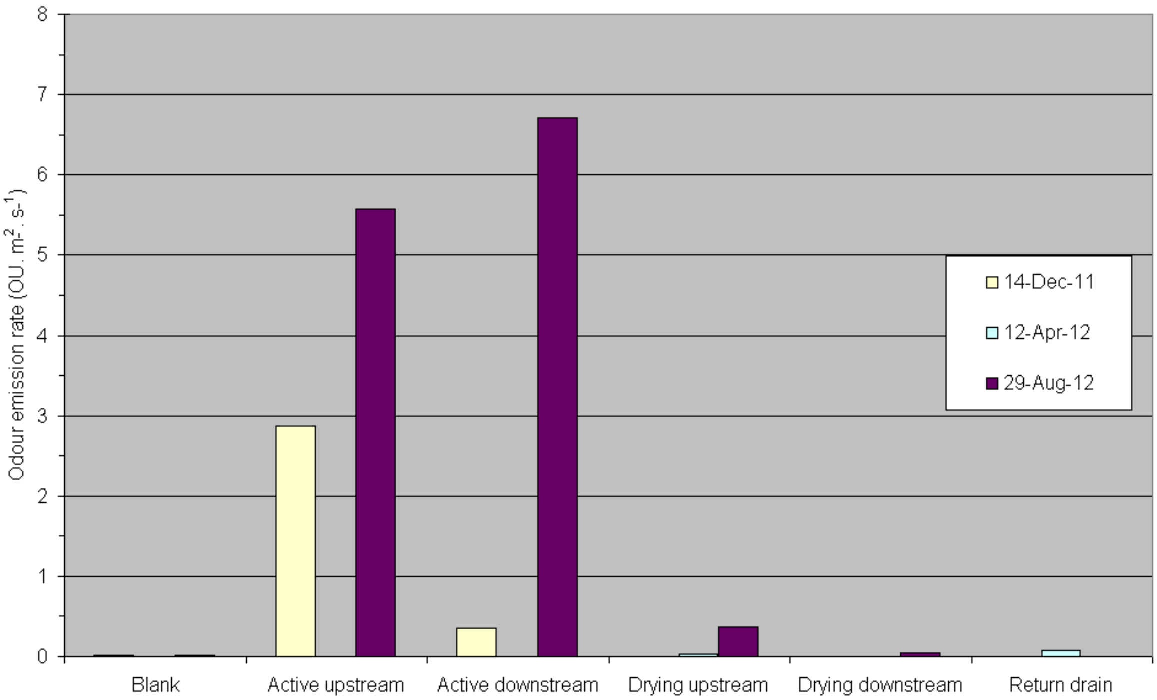

Figure 27: Odour emission rates for samples collected using the flux chamber, arranged by various areas of the SEPS.

The data, summarised in Table 4 and in Figure 26 and Figure 27, suggests that odour emission rates were generally highest near the inlet (upstream) end of the active SEPS. Based on the wind tunnel data, the average emission rate near the inlet end of the SEPS (100 $ou.m^3.m^{-2}.s^{-1}$) was approximately 20% higher than near the outlet end (84 $ou.m^3.m^{-2}.s^{-1}$). The odour emission rates from the drying SEPS were generally lower than for the active SEPS, while the odour emission rates from the return drain were barely detectable using olfactometry.

The odour emissions determined using the flux chamber sampling method were generally within the range reported by Hayes *et al.* (2008) for the southern NSW SEPS.

4.3.4 Relationship between Wind Tunnel and Flux Chamber Odour Emission Rates

Figure 28 shows the relationship between odour emission rates determined using the wind tunnel and flux chamber sampling methods. From this graph, it is clear that there is a relatively poor correlation between the odour emission rates determined for samples collected using these two methods. In general, the wind tunnel odour emission rates are approximately 20 times the flux chamber values. This is consistent with the findings of previous researchers [Hayes *et al.* (2008), Kaye and Jiang (1999) and Hudson (1995)].

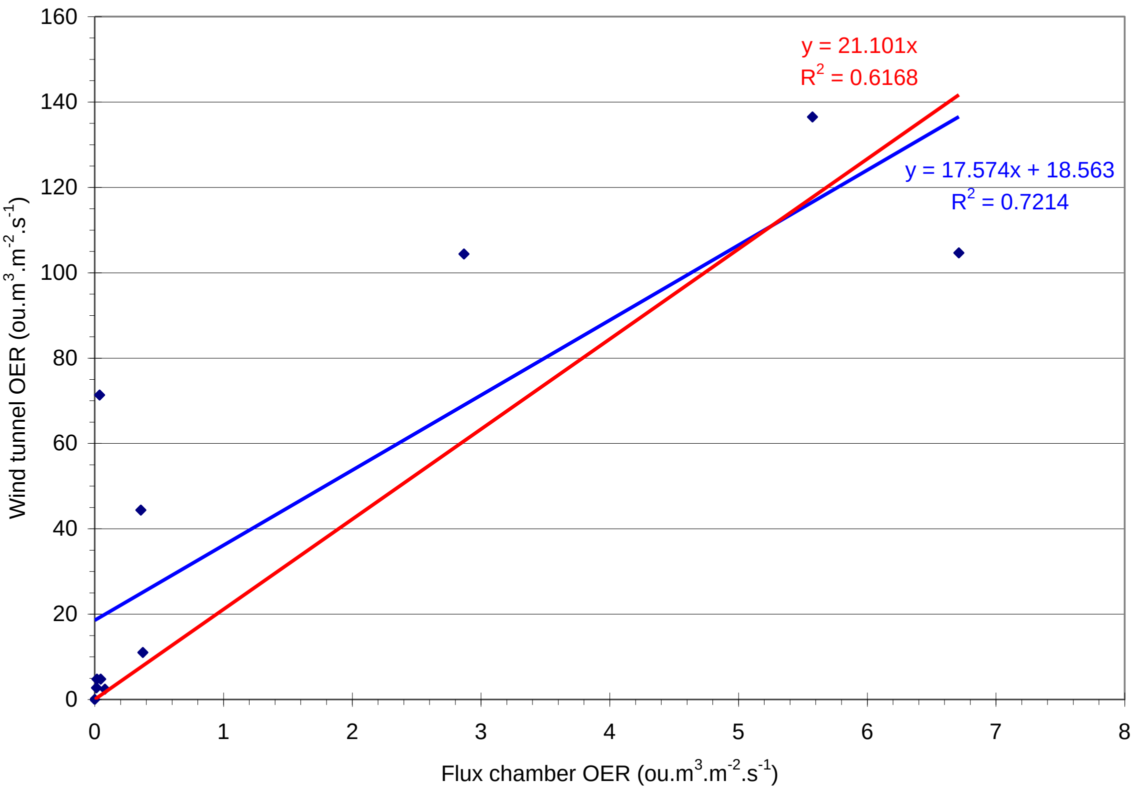

Figure 28: Relationship between odour emission rates determined using the wind tunnel and flux chamber sampling methods.

4.4 SEPS Influent Characteristics

The masses of total solids (TS), volatile solids (VS), nitrogen (N), phosphorus (P) and potassium (K) in the raw effluent entering the SEPS from the piggery sheds, was estimated using the PigBal model (Casey *et al.*, 1996). Based on piggery stocktaking records, the average number of sows accommodated in the piggery over the trial period was approximately 400. The pigs were grown out to an average market live weight of 105 kg resulting in an average occupancy of 4038 SPU. This is lower than the full capacity of 450 sows (4450 SPU) used in the original design calculations.

The piggery owner provided monthly dietary data for much of the trial period. The PigBal model was run using three diets, fed at approximately six-monthly intervals, during the trial period. The modelling results are presented in Table 5.

Table 5: SEPS influent total solids (TS), volatile solids (VS), nitrogen (N), phosphorus (P) and potassium (K) masses estimated using the PigBal model (Casey *et al.*, 1996) for diets fed at three six-monthly intervals over the trial period.

Parameter	**Nov 2010 diet** (kg/year)	**July 2011 diet** (kg/year)	**Jan 2012 diet** (kg/year)	**Average** (kg/year)
Total solids	472,133	470,063	474,427	472,208
Volatile solids	376,187	370,239	379,977	375,468
Nitrogen	40,025	40,410	40,055	40,163
Phosphorus	10,180	9,479	9,403	9,687
Potassium	11,960	11,914	11,903	11,926

Based on the average VS mass entering the SEPS during the trial period (as outlined in Table 5 above) and a SEPS channel storage volume of 1113 m^3 (equivalent to 0.25 m^3/SPU x 4450 SPU), the volatile solids (VS) loading rate was 0.92 kg $VS.m^{-3}.day^{-1}$. This is slightly less than the 1.00 kg $VS.m^{-3}.day^{-1}$ recommended by Kruger *et al.* (2008), as the piggery was not operating at full capacity during the trial period. However, the estimated VS loading rate was greater than 11 times the loading rate recommended in the National Environmental Guidelines for Piggeries (NEGP, Tucker *et al.*, 2010) for conventional 'large' anaerobic ponds in warm climates (80 g $VS.m^{-3}.day^{-1}$).

4.5 SEPS Effluent Characteristics

The results of the analyses of the treated effluent pumped from the return drain are provided in Table 6. This data will be used to evaluate the SEPS performance in treating the raw effluent discharged from the piggery sheds.

Table 6: Chemical analysis results for effluent treated by the SEPS, sampled from the pipeline supplying the shed flushing tank, on three dates.

Method	Analysis	Units	LOR	21/09/11	12/04/12	29/08/12
QP-KYN-037	Ammonia Nitrogen	mg/L	0.05	763	209	346
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<5	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	<5	4.3	1.3
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	<0.03	0.97	0.3
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	891	276	558
Derived*	Total Nitrogen	mg/L	0.3	891	277	558
QP-KYN-039	Total Phosphorus	mg/L	0.02	27.2	25.5	24
QP-KYN-001	pH	UNITS		8.2	8.4	8.1
QP-KYN-002	Conductivity	µS/cm	1	9,550	6,740	7,750
QP-KYN-017	Total Hardness	mg/L $CaCO_3$	1	354	421	526
QP-KYN-015	Total Alkalinity	mg/L $CaCO_3$	2	4,120	2,570	3,190
QP-KYN-019*	Molybdate Reactive Silica	mg/L	1	92.6	118	101
QP-KYN-014	Total Iron	mg/L	0.01	1.22	0.68	0.9
QP-KYN-014	Total Manganese	mg/L	0.01	0.39	0.3	0.34
QP-KYN-016	Calcium	mg/L	1	107	92.9	145
Derived*	Magnesium	mg/L	2	20.9	46	39.8
QP-KYN-014	Sodium	mg/L	0.5	622	693	604
QP-KYN-014	Potassium	mg/L	0.1	529	391	439
QP-KYN-058	Sulphate	mg/L SO_4	1	<50	107	55
QP-KYN-058	Chloride	mg/L	1	733	799	674
QP-KYN-058	Nitrate	mg/L NO_3	0.1	<5	4	1.3
QP-KYN-022	Phosphate	mg/L PO_4	0.02	57.5	21.5	38.9
	Temperature	° C		20	20	
QP-LSB-A013	Temporary Hardness	mg/L $CaCO_3$	1	354	421	526
QP-LSB-A013	Bicarbonate Alkalinity	mg/L $CaCO_3$	1	4,120	2,500	3,150
QP-LSB-A013	Carbonate Alkalinity	mg/L $CaCO_3$	2	<2	74	44
QP-LSB-A013	Hydroxide Alkalinity	mg/L $CaCO_3$	2	<2	<2	<2
QP-LSB-A013	Free Carbon Dioxide	mg/L	0.1	52	19.9	50.1
QP-LSB-A013	Total Dissolved Ions	mg/L	1	7,090	5,240	5,860
QP-LSB-A013	Total Dissolved Solids	mg/L	1	4,630	3,810	4,010
QP-LSB-A013	Figure of Merit		0.1	0.3	0.3	0.4
QP-LSB-A013	Saturation Index			2.24	2.18	2.16
QP-LSB-A013	Residual Alkalinity	meq/L $CaCO_3$		75	43	53
QP-LSB-A013	Sodium Adsorption Ratio		0.1	14.4	14.7	11.5
DAFF (Qld)	Total Solids	% (by mass)		0.51	0.47	0.45
DAFF (Qld)	Volatile solids	% (by mass)		0.22	0.14	0.14

LOR = Limit of Reporting

Total and volatile solids analyses carried out at Agri-Science Queensland laboratory, Toowoomba.

All other analyses carried out at Toowoomba Regional Council Mt Kynoch laboratory.

4.6 *SEPS Effluent Treatment Performance*

The MagMaster flow meter installed on the shed effluent delivery line showed an average discharge into the SEPS of 103,000 L/day. Based on a SEP channel capacity of 1113 m^3/channel, the resulting hydraulic retention time was 10.8 days, prior to settled solids encroaching on the storage volume.

Table 7 shows estimates of the total solids (TS), volatile solids (VS), nitrogen (N), phosphorus (P) and potassium (K) masses entering the SEPS, based on PigBal modelling. The concentrations have been determined from the estimated masses and the measured daily inflow volume. The performance of the SEPS in reducing the parameter values has been evaluated by comparing the influent and effluent concentrations to give a percentage reduction in the concentration values.

Table 7: SEPS influent and effluent TS, VS, N, P and K mass and concentrations used to determine treatment performance, for comparison with previous data for NSW and WA SEPS reported by Payne et al. (2008).

Parameter	**Influent mass (from PigBal)** (kg/year)	**Calculated influent conc** (%)	**Measured effluent conc** (%)	**Reduction S Qld** (%)	**Reduction NSW A[1]** (%)	**Reduction WA B[1]** (%)
TS	472,208	1.26	0.48	62	65	88
VS	375,468	1.00	0.17	83	81	85
N	40,163	0.11	0.058	46	33	39
P	9,687	0.03	0.003	88	85	94
K	11,926	0.03	0.045	0	4	3

[1] Payne et al., 2008

The reductions in TS, VS, N, P and K recorded at the Summerhill piggery were consistent with the values reported by Payne *et al.* (2008) for SEPS operating in southern NSW and WA.

The above volatile solids reduction results exceed the range normally expected for anaerobic treatment lagoons. Kruger *et al.* (1995) suggests that primary anaerobic ponds reduce BOD and VS by about 75%. Skerman *et al.* (2008) reported TS and VS reductions of 57% and 70%, respectively, for stage 1 trials on a highly loaded anaerobic pond (APL Project No 2108).

5. Implications and Recommendations

The odour emissions from the SEPS recorded in this project were very similar to levels recorded previously for the southern NSW SEPS (Hayes *et al.*, 2008 and Payne *et al.*, 2008). The maximum odour emissions recorded in this project were also within the range recorded from conventional anaerobic ponds (Hudson, 2004) and from a highly loaded pond (Skerman *et al.,* 2008) in southern Qld.

These results suggest that overall odour emissions from SEPS are likely to be lower than for conventional ponds due to the significantly smaller surface area of the active and drying SEP channels and similar or lower emission rates per unit area. At the trial site, the surface area of each of the three individual SEP channels was 1730 m^2. Based on the recommended conventional anaerobic pond volume of 4.9 m^3/SPU (National Environmental Guidelines, Tucker *et al.,* 2010), for a five-year desludging interval and a square shaped pond with a depth of 5 m, the resulting surface area would be 5782 m^2. Consequently, the overall odour emission from the SEPS is likely to be lower than that from a conventional pond, given the similar emission rates per unit area measured in this trial for the active SEP channels, and lower emission rates measured for the drying SEP channels.

Some problems were experienced with the operation of the SEPS overflow pipes which conveyed treated effluent to the return drain. The light, flexible nature of the 'StormFlex' pipe made it vulnerable to floating to the surface and forming air locks which prevented effective drainage. The heavier grade, less flexible pump suction pipe used in SEP 3 appeared to operate more effectively in this regard. There is a need for further evaluation of SEPS drainage methods to determine the most practical, cost-effective solution.

The effectiveness of effluent treatment is often measured in terms of the reduction in volatile solids (VS). In this trial, a VS reduction of 83% was recorded. This is superior to many recognised standards for anaerobic effluent treatment, such as Kruger *et al.* (1995) which suggests a 75% reduction in VS and BOD in primary anaerobic ponds. In terms of reductions in TS, VS, N, P & K, the performance of the SEPS studied in this trial was similar to that recorded by Payne *et al.* (2008) for SEPS previously constructed in southern NSW and WA.

Experience gained in this project suggests that SEPS should be regularly monitored to observe any potential problems such as blockages of overflow pipelines, excessive solids deposition or excessive crust formation; all of which could impede the effective operation of the system.

SEPS also require timely management with regard to rotation of the channels at the designated time interval (six months in this case) and the removal of solids as soon as the off-line SEP channels have dried out sufficiently. This will require ready access to suitable solids removal machinery or a suitable contractor. During relatively wet seasons, there may be limited opportunities to remove solids at the optimal moisture content. Use of a vacuum tanker and mechanical agitator may be required when solids are too wet for removal using a front end loader or excavator.

APL was unable to approve a further extension to this project to complete the planned evaluation of the removed solids characteristics, in terms of odour emissions, recovered quantities and their nutrient and economic value as an organic fertiliser. To maximise the benefits derived from the significant investment in time and resources made at this site, it is recommended that APL consider funding a follow-up trial at a later date (after the producer implements an effective solids management program) to evaluate the characteristics of the recovered solids and to perform a comprehensive cost: benefit analysis.

This trial was carried out during a relatively wet period in southern Qld, which included the extreme wet summer of 2010/11. While the climatic conditions undoubtedly hampered efforts to remove solids from the SEPS, the unavailability of a suitable contractor was probably the overriding factor in delaying the scheduled solids removal. While it is difficult to predict how the SEPS may have performed under more typical climatic conditions, it seems likely that there may be fewer opportunities for removing settled solids at a suitable moisture content, in southern Qld, when compared with sites located in southern NSW and WA. Nevertheless, in terms of odour emission and the effectiveness of effluent treatment, the 'Summerhill' SEPS performed similarly to the previously constructed SEPS.

Based on the findings of this trial, there does not appear to be any valid reason for restricting the wider adoption of SEPS for managing piggery effluent in regions such as southern Qld and northern NSW, provided producers pay careful attention to the timely rotation of the SEPS channels and the removal of solids, as the opportunities for doing so may be limited during periods when higher than average rainfall is received.

6. Initial Solids Removal

Following the submission of the draft Final Report to APL, the piggery owners were successful in arranging for a vacuum tanker contractor to commence removing wet solids from the SEPS on 7 June 2013. The contractor used a Giltrap tractor-PTO-driven pond stirrer to resuspend the settled solids before transfer from the SEPS channel into the Giltrap 7500 L slurry spreader (vacuum tanker).

The vacuum tanker spread the slurry onto a cultivated paddock located directly south from the SEPS. It is anticipated that a wheat crop for hay production will be planted in this paddock in the near future. Very little odour was observed throughout the solids removal and application process.
It is understood that most of the accumulated solids were successfully removed from SEP 3 and approximately half the solids were removed from SEP 1 over a period of approximately 4 days. The contractor had not advised the number of tanker loads applied to the cultivation at the time that this report was completed. The piggery manager is expecting to receive this report from the contractor in the near future.

Photographs of the vacuum tanker and agitator in operation at the SEPS site on 7 June 2013 are provided in Figures 29 to 32.

Figure 29: **Giltrap slurry spreader lifting agitated slurry from SEP 3.**

Figure 30: **Giltrap slurry spreader and pond stirrer operating on SEP 3.**

Figure 31: Giltrap slurry spreader and pond stirrer operating near the upstream end of SEP 3.

Figure 32: Giltrap slurry spreader applying slurry to nearby cultivation paddock.

7. References

Barth, C. L. (1985). The Rational Design Standard for Anaerobic Livestock Lagoons. Proceedings of the 5th International Symposium on Livestock Wastes, ASAE, 638-647

Bliss, P.; Jiang, K.; Schulz, T. (1995). The development of a sampling system for the determination of odor emission rates from areal surfaces: Part II. Mathematical model, Journal of Air & Waste Management Association 1995, 45, 989-994.

Casey KD, McGahan EJ, Atzeni MA, Gardiner EA and Frizzo R, 1996. 'PIGBAL Version 1.0, a nutrient mass balance model for intensive piggeries'. Department of Primary Industries, Queensland.

Greenberg, A.E., Clesceri, L.S. and Eaton, A.D. (eds.) (1992). Standard Methods for the Examination of Water and Wastewater, American Public Health Association, Washington.

Hayes S., Schulz T., and Cantlay A. 2007. 'Odour Emissions from Sedimentation and Evaporative Ponds'. Final Report Project No. 2139, Australian Pork Limited, Canberra, Australia, December 2007.

Hudson, N., Bell, K., McGahan, E., Lowe, S., Galvin, G., and Casey, K. (2007b). Odour emissions from anaerobic piggery ponds. 2: Improving estimates of emission rate through recognition of spatial variability, Bioresource Technology. 98: 1888–1897.

Hudson, N., Duperouzel, D., Dunlop, M., Collman, G. and Gallagher, E. (2007). Assessing the medium-term impact of permeable pond covers on pond performance and odour management. Final report for Australian Pork Limited, Project 1829. Department of Primary Industries & Fisheries, Toowoomba, Queensland.

Hudson, N., Galvin, G. and Lowe, S. (2004). The effect of loading rate and spatial variability on pond odour emission, Final report for Australian Pork Limited, Project 1628. Department of Primary Industries & Fisheries, Toowoomba, Queensland, Australia.

Hudson, N., McGahan, E., Casey, K., Lowe, S., Galvin, G., Jeston, P. and Dunlop, M. (2007a). Odour emissions from anaerobic piggery ponds. 1. Results of a three season, 14-month survey, Bioresource Technology. 98: 1877–1887.

Jiang, K.; Bliss, P.; Schulz, T. (1995). The development of a sampling system for determining odor emission rates from areal surfaces: Part I. Aerodynamic performance, Journal of Air & Waste Management Association 1995, 45, 917-922.

Kruger, I., Taylor, G and Ferrier, M. (compiled and edited by) (1995). Effluent at work, Australian pig housing series, NSW Agriculture, Tamworth NSW.

Kruger, I. Payne, H., Moore, K. and Morgan, J. (2008) Draft NSW DPI Primefact / WA DA&F Farmnote entitled 'Sedimentation and Evaporation Pond Systems', unpublished.

Martin F., Kruger I. and Walker D. 2001. 'Sediment and Evaporation Ponds – Design and Construction Requirements.' Natural Resource Management. Vol. 4, No. 1, March 2001, pp31-34.

Payne H., Moore K., Morgan J and Kruger I. (2008) 'Solids Separation in Sedimentation and Evaporation Pond Systems (SEPS)'. Final Report Project No. 2130, Australian Pork Limited, Canberra, Australia, April 2008.

Skerman, A., Collman, G., Duperouzel, D., Sohn, J., Atzeni, M. and Kelly, A. (2008). Improved piggery effluent management systems incorporating highly loaded primary ponds, Final report to Australian Pork Limited (APL), Project 2108, Department of Primary Industries and Fisheries (DPI&F), Toowoomba, Queensland.

Skerman, A. G., Redding, M. and McLean, D. (2002). Clay Lining and Compaction of Effluent Ponds, DPI Note, DPI Intensive Livestock Systems Unit, Toowoomba, Qld.

Smith, R.; Watts, P. (1994). Determination of odour emission rates from cattle feedlots: Part 1, A review, Journal of Agricultural Engineering Research 1994, 57, 145-155.

Standards Australia and Standards New Zealand (2001). Stationary source emissions. Part 3: Determination of odour concentration by dynamic olfactometry. AS/NZS 4323.3:2001, Standards Australia: Strathfield, New South Wales.

Tucker, R.W., McGahan, E.J., Nicholas, P.J. and Howard, M.R. (2006). National Environmental Guidelines for Piggeries, (Australian Pork Limited, Deakin, ACT, 2600).

Wang, X, Jiang, J. and Kaye, R. (2001). Improvement of wind tunnel sampling system for odour and VOC's. 147-154 p. 1st IWA International Conference on Odour and VOCs: Measurement, Regulation and Control Techniques, University of New South Wales, Sydney.

Appendix I - Earthworks Required for the Construction of a Sedimentation and Evaporation Pond System (SEPS) at the Summerhill Piggery, Bowenville

1. Piggery Location

The Summerhill Piggery is located at 2076 Bowenville - Blaxland Road, approximately 4 km west-north-west of the Town of Bowenville on the Darling Downs in southern Queensland.

2. Sedimentation and Evaporation Pond System (SEPS) Operation

The SEPS consists of three relatively shallow, parallel, trapezoidal earthen channels which are to be constructed within a disused evaporation pond located on the south-eastern side of the piggery sheds, as shown in Figure 1. Raw effluent from the piggery sheds will be pumped from a sump located between the sheds into the western end of the first of the SEPS channels, for an initial period of 6 months. As solids settle out of the effluent in the SEPS channels, pipelines installed through the downstream ends of the SEPS channel bank will allow the liquid effluent to drain into a gravity return drain located on the northern side of the SEPS channels. The return drain will convey the liquid effluent in a westerly direction back to an earthen sump located on the north-western corner of the SEPS.

After the initial 6 month period, all piggery effluent will be diverted into the second SEPS channel, while the solids deposited in the first SEPS channel dry out. After the second 6 month period, all piggery effluent will be diverted into the third SEPS channel. By this time, the settled solids stored in the first SEPS channel should have dried out sufficiently to allow removal using either an excavator operating from the adjacent bank, or alternatively, a front end loader working within the SEPS channel. In this manner, the three SEPS channels will be operated on a six-monthly rotational cycle, involving active, drying and solids removal phases.

3. SEPS Description

As shown in Figures 1 and 2, each of the three SEPS channels is approximately 166 m long, with horizontal longitudinal bed gradients over the first 116 m. The bed gradient over the final 50 m of each channel increases to 0.40%. The SEPS channels are designed to store effluent to a maximum depth of 0.80 m over the first 100 m, increasing to 1.00 m at the downstream end of the SEPS. A freeboard of 0.50 m is provided throughout the SEPS, resulting in a total channel depth ranging from 1.30 m to 1.50 m from the bed to the crest of the channels banks. The three SEPS channels will have bed widths of 6 m with 1 vertical to 3 horizontal batters.

To enable vehicular and machinery access, the external SEPS channel banks will have crest widths of 4 m. The internal channel banks will have crest widths of 8 m to allow for some temporary storage of removed solids and/or to enable a truck to pass an excavator operating on the channel banks.

The SEPS channel banks will be constructed with a uniform longitudinal elevation. To enable drainage of stormwater runoff away from the adjacent SEPS channels, the 4 m wide external banks will have 2.5% cross-slopes (0.1 m in 4 m). The 8 m wide internal SEPS channel banks will have 2.5% cross-slopes falling from the centre of the banks towards the adjacent SEPS channels.

4. Return Channel Description

The return channel is designed to convey liquid effluent that drains from the downstream (eastern) end of the SEPS channels back to an earthen sump located near the upstream (western) end of the

SEPS. The liquid effluent will be pumped out of the earthen sump into the nearby secondary effluent pond or directly into piggery shed flushing tanks.

The return channel has been designed with a bed gradient of 0.50% throughout and a 3 m bed width. Channel batters of 1 vertical to 4 horizontal have been selected to enable compaction of the batters using a sheep's foot roller or similar.

The depth of cut in the return channel will range from 1.15 at the eastern end to 1.98 m at the western end.

5. *Bank Access Ramps*

Earthen ramps are to be provided at the following locations to allow vehicles and machinery to access the SEPS channel banks:

- On the eastern ends of the two internal SEPS channel banks.
- On the northern and southern ends of the bank running along the western end of the SEPS channels.

The ramp gradient should be approximately 1 vertical to 10 horizontal.

6. *Earthworks Quantities Estimates*

All piggery manure solids, vegetative material and topsoil remaining on the base of the disused evaporation pond will have to be removed prior to commencing construction of the SEPS channels. Based on a stripping depth of 75 mm, it is estimated that the stripping volume will be approximately 1100 m^3. This material should be transported and stockpiled on the northern side of the existing evaporation pond embankment.

It is estimated that balanced cut and fill volumes will be achieved by excavating the SEPS channel beds to a depth of 0.60 m below the stripped surface, over the first 116 m of the SEPS channels. This depth of cut will increase to a maximum of 0.80 m at the downstream ends of the SEPS channels. The resulting height of fill will be 0.70 m from the stripped pond base to the top of the channel banks. It is estimated that 5500 m^3 of material will be excavated from the SEPS channels and return drain, transported, placed and compacted in the SEPS channel banks.

7. *On-Site Soil Characteristics*

No detailed soil investigations have been carried out on the construction site. Published soil information and observation of the surface soil at the site suggests that the soils are likely to be deep, black or dark brown cracking clays. Under the Unified Soil Classification System, these soils are likely to be classified as CL, CH or CL/CH material.

8. *Construction and Compaction Standards*

It is important to ensure that a high level of impermeability is achieved in the SEPS channels and return drain to minimise the risk of effluent leaching into underlying groundwater resources. Consequently, the earthworks must be carried out in accordance with the material, placement, moisture content and compaction standards outlined in the attached DPI&F Note (Clay lining and compaction of effluent ponds).

As outlined in Section 7, it is anticipated that the in-situ material will comply with the material specification provided in Section 1 of the attached DPI&F Note. Provided this is the case, excavated areas of the SEPS channels and return drain will not require over-excavation and clay lining with imported material. These excavated areas may be prepared by:

- Scarifying or ripping to a depth of 150 mm,
- Watering (if required) to produce the correct moisture content (in the range from 2% wet to 2% dry of optimum),
- Compaction to 95% of standard maximum laboratory dry density.

9. Trimming

Following the completion of compaction, final trimming shall be carried out to produce smooth, uniform surfaces, in accordance with the design gradients and dimensions provided in Figure 2.

10. Work to Be Carried Out by Others

The following work will be carried out by others and should not be included in quotations for the major earthworks component of the SEPS construction:

- Compaction testing
- Installation of pipelines

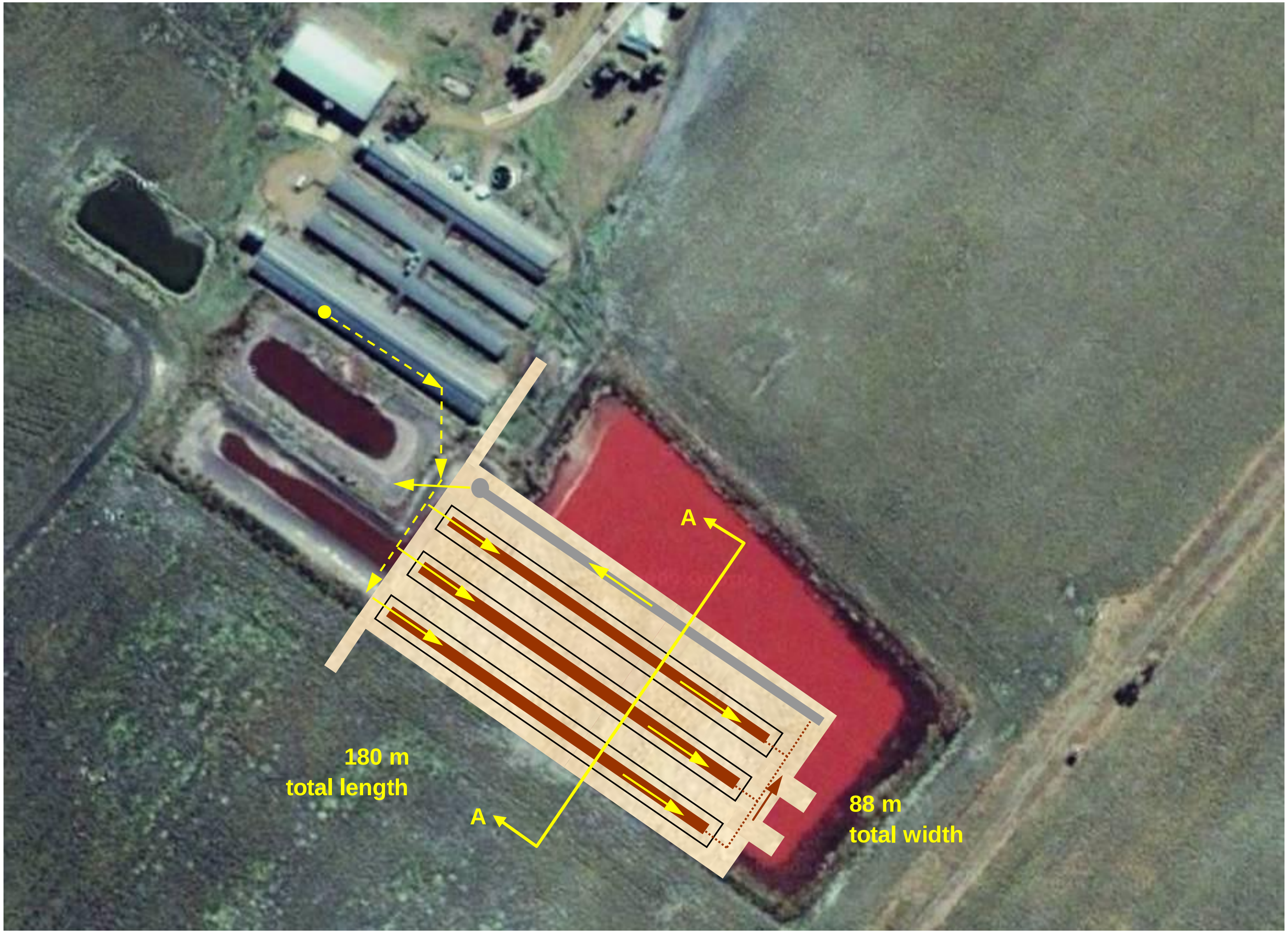

Figure 1: Aerial photograph showing approximate SEPS location

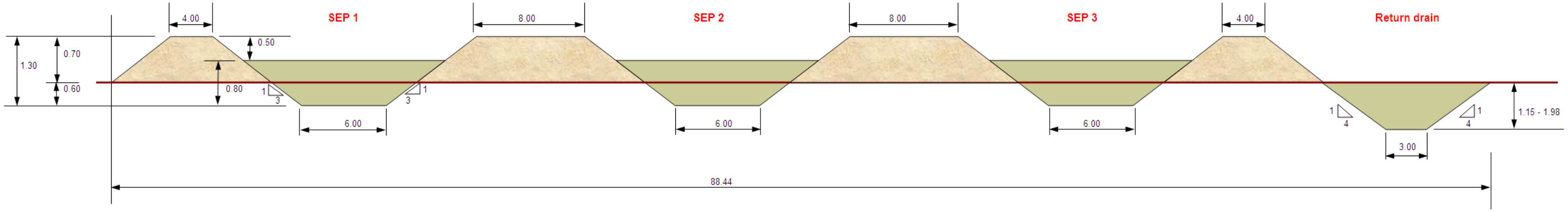

Figure 2: Sectional elevation through SEPS on 'AA'.

Appendix 2 - DPI&F Note -
Clay Lining and Compaction of Effluent Ponds

Clay lining and compaction of effluent ponds

Alan Skerman, Matthew Redding and Danette McLean, Delivery

Introduction

This DPI&F Note provides technical guidance to producers, contractors, consultants, and project managers involved in the construction of effluent ponds. It provides quantitative standards to assist the industry to meet the accepted maximum permeability of 0.1 mm/day.

Because in-situ and laboratory measurement of soil permeability is difficult and relatively inaccurate, rather than relying on permeability standards, this document provides recognised standards for clay lining materials and methods. By applying these standards, an acceptable degree of impermeability should be achieved consistently.

The information contained in this note is based on established engineering principles; however, the recommended methods may be revised from time to time, as new methods are developed. Proposals involving alternative materials or methods may be submitted to the Administering Authority (currently DPI&F) for consideration.

1.0 Material

The material used to clay line the ponds shall be well-graded impervious material, classified as either CL, CI, CH, SC or GC in accordance with the soil classification system described in Appendix A (Table A1) of AS 1726.

Note: The classification symbols represent inorganic clays having low, intermediate and high plasticity, clayey sands and clayey gravels, including gravel-clay-sand mixtures, respectively.

Furthermore, the lining material shall conform with the following particle size distribution and plasticity limits:

(i) Particle size distribution:

AS metric sieve size (mm)	Percentage passing (by dry weight)
75.000	100
19.000	70 -100
2.360	40 - 100
0.075	25 - 90

(ii) Plasticity limits on fines fraction, passing 0.425 mm sieve:

Liquid limit W_L	30 – 60%
Plasticity index I_p	> 10%

Note No: 8841
ISSN 0155 – 3054
Revised: February 2005
Replaces Note No: IL0068
No of pages 3

Produced by: Delivery

Queensland Government
Department of Primary Industries and Fisheries

If materials complying with the above plasticity limits are not readily available, clays having liquid limits between 60% and 80% may be used as lining material, provided that the clay lining layer is covered with a layer of compacted gravel (or other approved material). The compacted gravel layer should have a minimum thickness of 100 mm to prevent the clay lining from drying out and cracking.

Testing of materials to determine compliance with the above requirements is to be carried out in accordance with the appropriate sections of AS 1289. The Administering Authority may direct the licensee to provide test results certified by a soils laboratory accredited by the National Association of Testing Authorities (NATA), or having equivalent accreditation for the tests undertaken.

Topsoil, tree roots and organic matter must not be used as clay lining material. Furthermore, any other material, which does not compact properly, must not be placed in any of the areas to be clay lined.

Wherever non-dispersive materials are available, they are to be used in preference to materials shown to be dispersive using the Emerson test, as described in Method 3.8.1 of AS 1289. **Note:** A Class 8 material is considered to be non-dispersive.

2.0 Placement of material

Effluent ponds capable of storing water up to a maximum depth of 2 m, are to be lined with a minimum total thickness of 300 mm of material complying with the requirements of Clause 1 above. Ponds capable of storing water at depths in excess of 2 m, are to be lined with a minimum total thickness of 450 mm of material complying with the requirements of Clause 1. This is to be achieved by placing the material at the correct moisture content (as defined in Clause 3 below), in progressive, uniform, horizontal layers, not exceeding 150 mm in thickness, after compaction.

Under no circumstances is the compacted thickness of clay lining material to be less than the required minimum thickness, as specified above.

3.0 Correct moisture content

Prior to compaction, all material used for lining purposes shall be conditioned to have a moisture content within the range of 2% wet to 2% percent dry of the optimum moisture content required to produce the maximum dry density when compacted in accordance with Method 5.1.1 of AS 1289.

Note: As a guide, the required moisture content is as wet as can be rolled without clogging a sheep's-foot roller. A preliminary assessment of the required moisture content can be made by rolling a sample of the material between the hands. If it can be rolled to pencil thickness without breaking, it should be satisfactory.

4.0 Compaction

Each layer of material placed in accordance with Clause 2 above, shall be compacted to produce either a field dry density of at least 95% of the standard maximum laboratory dry density determined in accordance with Method 5.4.1 of AS 1289, or alternatively, a Hilf density ratio of at least 95% when tested in accordance with Method 5.7.1 of AS 1289.

Note: This degree of compaction may generally be achieved by rolling each layer of material, placed at the correct moisture content, with at least eight (8) passes of a sheepsfoot roller of the configuration described in Clause 5 below. As a guide, compaction will generally be sufficient when there is a clearance of 100 mm between the drum of the roller and the compacted material.

5.0 Sheep's-foot roller

The following specifications describe a sheep's-foot roller, which is suitable for fulfilling the compaction requirements described in Clause 4 above:

(i) The diameter of the drum(s) shall be not less than 1 m.

(ii) The length of each drum(s) shall be approximately 1.2 times the drum diameter.

(iii) The feet shall extend approximately 175 mm radially from the drum and be of the taper-foot type, with a cross-sectional area close to the outer end of not less than 3200 mm^2 and not more than 4500 mm^2.

(iv) The number of feet shall be such that their total area close to the outer ends shall be between 5% and approximately 8% of the area of the cylinder, which would enclose all the feet (i.e. a cylinder having a diameter equal to the diameter of the drum plus twice the length of each foot).

(v) The weight of the roller ballasted, shall be such that the bearing pressure thus obtained shall be not less than 1750 kilopascals, in accordance with the following formula:

$$\text{Bearing Pressure (kPa)} = \frac{\text{Mass (kg)} \times 9.81 \times 1000}{\text{Area of contact of one row of feet (mm}^2\text{)}}$$

Rollers of other types and configurations may be used provided that the required compaction is achieved in accordance with Clause 4 above.

6.0 Test for adequate compaction

The Administering Authority may direct compaction testing to be carried out on appropriate sections of the works area. Compaction testing is to be performed in accordance with Clause 4 of this specification. The test results are to be certified by a National Association of Testing Authorities (NATA) accredited soils laboratory, or a laboratory having equivalent accreditation. A copy of the certified test results shall be forwarded to the Administering Authority.

Failure of the test results to comply with the compaction requirements described in Clause 4 will result in the need for remedial measures to be implemented, as directed by the Administering Authority, before the pond can be utilised.

7.0 Synthetic liners

Alternate material and installation specifications relating to the use of synthetic lining materials may be used in lieu of clay lining. Approval of synthetic lining proposals, in Queensland, will be subject to assessment by the Administering Authority.

Further information

- *Farm water supplies design manual* by A. Horton and G. Jobling (ed). (1992). Water Resources, Water Resources Commission, Department of Primary Industries and Fisheries, Brisbane.
- DPI&F website www.dpi.qld.gov.au
- DPI&F Call Centre open from 8.00am to 6.00pm Monday to Friday (telephone 13 25 23 for the cost of a local call within Queensland; interstate callers 07 3404 6999) or email callweb@dpi.qld.gov.au ■