Sludge Management for a Covered Anaerobic Pond at Bears Lagoon Piggery

Final Report
APL Project 2009/2295

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AgSystems Design
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This report was prepared on behalf of Australian Pork Limited (APL) in fulfilment of project 2009/2295 "Sludge management for a covered anaerobic pond at Bears Lagoon piggery".

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Project commencement and completion

Project commencement date: 1/2/2010
Project completion date: 30/6/2013

Acknowledgements

The author would like to acknowledge the contributions of Russell Gladman and Ian Connaughton of Bears Lagoon piggery and for their assistance in conducting this project.

1. Executive Summary

Sludge management is an important aspect of effluent pond management but even more critical for a covered anaerobic pond (CAP). Inadequate sludge management can cause a CAP to fail – undermining a substantial capital investment and setting back the rate of adoption of such systems.

Bears Lagoon Piggery is a commercial grow-out operation accommodating, on average, 23 000 standard pig units (SPU). The effluent management system includes an 18ML CAP which had been in operation since mid-2004 without carrying out a significant desludging event. The CAP had been set up with an in-situ sludge extraction system designed to recover sludge from four separate points along the V-shaped base of the pond using a positive displacement helical rotor pump. The system had not been used to extract any sludge from the covered anaerobic lagoon as there was previously no option to discharge sludge out of the system

Three new drying bays, designed in accordance with SEPS criteria, were constructed to accept the settled solids pumped from the CAP sludge extraction system and hold them until dry enough to be spread onto cropland.

Surveys of the settled solids conducted prior to the start of desludging show clearly that both TS and VS increase with depth in the CAP and reveal typical TS and VS concentrations of 14-16% and 7-8% respectively at the lower depths. Recovering and pumping sludge of that consistency, particularly when containing struvite, was a significant challenge and two pumps failed to achieve the required duty.

The quantity of VS that had accumulated in the settled solids was significant but the rate of accumulation was estimated to be just 3% of the unscreened VS load entering the pond.

A new suction access sleeve was installed through the pond cover to allow a partial desludging event – lowering the pump suction down the batter to avoid the highest TS concentration solids found at the bottom. While this alleviated the significant build-up of sludge, the challenge of establishing a sludge extraction pump that can cope with the higher solids concentration material at depth remains.

Better information on the velocity required to keep solids in suspension, and the resulting pipe friction losses when pumping high solids content material are key pieces of information that the industry needs to commission robust sludge extraction systems. (This site was subsequently used to develop some of that information under APL Project No. 2012/1029.)

After 15 weeks of drying time, 120 m^3 of solids were recovered from the south and middle drying bays and spread onto cropland a rate of $3m^3$/Ha. With current fertiliser prices (June 2013, delivered to site, GST inclusive) each tonne of as-recovered solids (59% dry matter) should be worth \$85 considering the N,P,K content (equivalent to \$68/m^3).

After one ‘turn’ of the drying bays, both the farm manager and excavator operator were generally satisfied with the design and operation of the drying bays.

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2. Introduction

Sludge management is important in effluent ponds but even more critical for a covered anaerobic pond (CAP). Inadequate sludge management can cause a covered anaerobic pond to fail – undermining a substantial capital investment and setting back the rate of adoption of such systems.

Bears Lagoon piggery had operated a CAP since mid-2004 without carrying out a significant desludging event. This project was an opportunity to test an existing in-situ sludge extraction system and establish and trial three drying bays to receive the recovered solids.

3. Objectives

The objectives of this APL funded project were to:

1. Perform detailed sludge survey to verify quantity and fate of COD and VS partitioned to pond.
2. Document procedures for managing the in-situ sludge removal system to optimise performance.
3. Document the performance of evaporative drying bays/SEPs and the characteristics of the recovered sludge.
4. Provide data from objective 1 to AWMC UQ for validation of their anaerobic digestion model.

4. Milestones

1. Start of project (1/2/2010)
2. Evaporative bays/SEPs designed and set-out for construction (30/4/2010)
3. Sludge survey pre-desludging completed and analysis of extracted sludge (30/6/2010)
4. Sampling of material recovered during the desludging event and post desludging survey (15/6/2011)
5. One turn of evaporative bay/SEP completed including analysis of recovered sludge (15/5/2013)
6. Final report (28/6/2013)

5. Site description

Bears Lagoon Piggery is a commercial grow-out operation (accommodating nursery through to finisher pigs) located approximately 60 km north-west of Bendigo, Victoria. The operation is owned by George Weston Foods Limited.

Pig numbers on-site average 23 000 standard pig units (SPU) and effluent from both unit 1 (nursery through to weaner and grower pig groups) and unit 2 (finishers) is directed to the main pump pit located to the west of the winter storage. Most sheds have under floor flush alleys with bore water supplying the drinking water and water for flushing.

Table 1: Climate statistics for Bendigo Airport (BOM Station 081123, 1991-2009)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Max. (°C)	29.5	29.4	26.0	21.2	16.6	13.3	12.5	14.2	16.7	20.3	23.9	26.9	20.9
Mean Min. (°C)	13.9	14.1	11.3	7.4	5.2	3.6	2.4	2.4	4.3	6.3	9.3	11.5	7.6
Median Rain (mm)	22.9	22.2	12.9	22.5	32.5	39.8	57.8	48.4	40	42.4	39.7	31.4	452.4
Mean Rain Days >1 mm	3.9	2.9	3.2	4.0	6.4	7.7	8.9	7.4	7.9	5.6	5.7	4.7	68.3
Mean clear days	12.7	12.8	13.7	12.1	7.9	6.1	5.4	7.2	6.7	7.4	8.6	10.5	111.1
Mean cloudy days	6.8	4.7	4.4	6.8	11.2	12.4	13.2	11.5	10.6	8.3	7.8	7.6	105.3

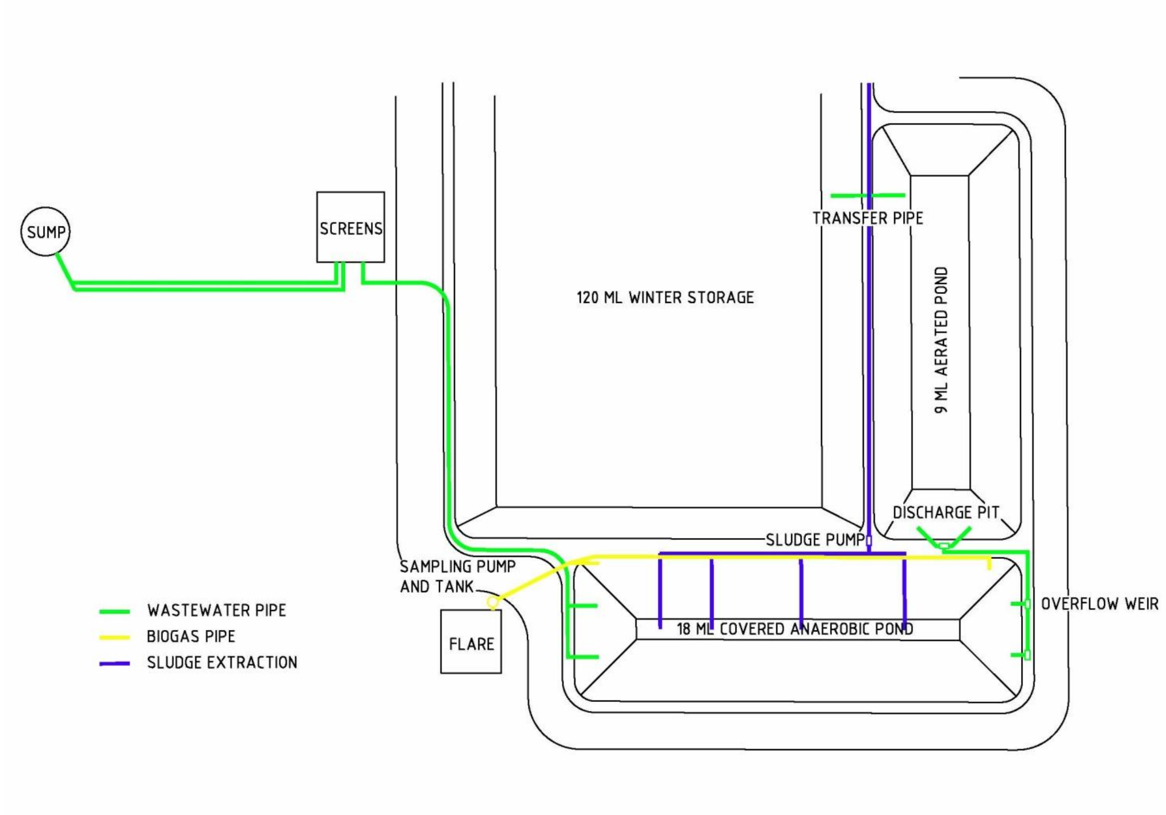

Figure 1: Wastewater treatment system

The effluent management system comprises a pair of static screens, an 18ML covered anaerobic pond (CAP), a 9ML partially aerated basin and a 120 ML winter storage. Treated effluent is then distributed over an area of flood irrigation on-farm.

Figure 2: The completed earthworks with cover shown prior to floating (2004)

6. Sludge extraction system

The sludge extraction system that was in existence at the start of the project was designed to recover sludge from four separate points along the V-shaped base of the pond. The original pump was a positive displacement helical rotor operating at ~380 rpm with a discharge of approximately 6 L s^{-1} or 0.85 m s^{-1} with suction and discharge pipes of DN 110 mm, PN 10 HDPE.

The system had not been used to extract any sludge from the pond since it was commissioned in 2004 as there was no option to discharge sludge out of the system (only return it the inlet end) until the drying bays were constructed in 2011.

The original pump was moved in late 2009 to improve performance while pumping from ports 3 and 4. The new location also minimised the additional pipe required to discharge to the site of the drying bays.

7. Design solids accumulation rate

During a previous sludge survey performed at this site (Birchall 2009), the solids accumulation rate was calculated to be 0.00094 m^3 kg^{-1} TS equivalent to 0.1 m^3 SPU^{-1} yr^{-1}. It was noted that this estimated solids accumulation rate was derived from screened wastewater only. Estimates from Birchall (2009) suggest that the run down screens were removing approximately 30% of the influent TS (and 40% of the VS). Consequently it was estimated that the solids accumulation rate for unscreened wastewater at Bears Lagoon would be approximately 0.15 m^3 SPU^{-1} yr^{-1} and this was adopted for the purpose of designing the drying bays.

Figure 3: Original sludge extraction pump (previous location at inlet end)

8. Drying bays or SEPS?

Sedimentation and evaporation pond systems (SEPS) are usually designed as a primary pond receiving daily inflows of wastewater. Solids settle out as the water moves along the bay and effluent storage is typically provided by a separate structure (unless volumes are very small). Three bays are typically required to allow for filling/drying/cleaning operations to continue concurrently. Design and management issues are discussed in more detail in the draft Primefact by Kruger *et al* (2008).
Drying bays differ in that they are typically designed to be filled in one operation or batch and then closed and left to dry. Given the large moisture deficit that prevails over the warmer months in their Mediterranean climate, it is expected that drying bays could achieve two 'turns' each year at Bears Lagoon. Desludging would then typically occur in early summer and late autumn each year.

At Bears Lagoon, only the settled solids/sludge is pumped from the covered anaerobic pond. Effluent continues to pass from the CAP to the partially aerated pond and will not enter the drying bays. As such, the system essentially operates as drying bays rather than SEPS. However, the suggested design principles for SEPS (depth, width, clean-out procedures, etc) from Kruger *et al* 2008 were adopted at Bears Lagoon:

- Sludge depth; up to 800 mm
- Base width; approx. 6 m
- Batters; 3:1

The anticipated solids accumulation rate adopted was 0.15 m^3 SPU^{-1} yr^{-1} rather than the default capacity for SEPS (0.5 m^3 SPU^{-1} yr^{-1}) which must accommodate additional hydraulic loading.

9. Constructing the drying bays

Three flood irrigation bays (paddock no. 42) were identified by piggery management as the preferred location for the drying bays. The site was within a Land Subject to Inundation Overlay thereby triggering the need for development consent from the Loddon Shire Council. In addition, floodway advice was sought from the North Central Catchment Management Authority to determine the 1% ARI flood elevation. An embankment was required around the bays to provide flood protection to a height of 600 mm above the 1% ARI flood elevation (109.5 m AHD).

A detailed geotechnical investigation was completed during March/April 2010. BM Civil Engineers drilled four boreholes across the site and determined that the soils were suited to the intended purpose provided that a 400 mm compacted clay liner was constructed. In-situ soil was suitable for the liner when compacted to 98% of maximum dry density.

The existing irrigation bays were approximately 150 m long by 30 m wide, therefore the total area available was 150 x 90 m. The north western corner of the site was approx 440 m from the sludge extraction pump (200 m from pump to disused anaerobic pond, 240 m from pond to irrigation bays).

A copy of the tender drawings is included in Appendix A. The total sludge capacity of the three bays was approximately 2,630 m^3 at a sludge depth of 800 mm (equivalent to 0.23 m^3 SPU^{-1} yr^{-1} if two turns can be achieved). It is noted that the flood protection embankment provides an additional 780 mm of freeboard over and above that provided by each drying bay (320 mm at a sludge depth of 800 mm). In the event of unusually high rainfall, this additional capacity would provide sufficient storage to contain runoff prior to excess water being pumped (using PTO pump) back up the delivery pipe to the winter storage.

Earthworks were completed in late February 2011 followed by installation of the delivery pipework over the following weeks. Figures 4 and 5 show the bays during construction and then at completion.

Figure 4: Earthworks underway for drying bays

Figure 5: Completed drying bays, February 2011

10. Settled solids/sludge surveys

10.1 Previous surveys (part of RIRDC PRJ2705)

During a preliminary sludge survey performed at this site in March 2009 (Birchall 2010), samples were collected at 0.5 m increments starting at a depth of 2.0 m and progressing to the bottom (or the depth at which the solids content of the sludge exceeded the pump capabilities) at three locations. Vents 2, 5 and 8 were surveyed with vent #2 being the second vent numbered from the inlet end of the covered anaerobic pond.

June 2010

The sludge survey of 2009 identified that the sludge composition (particularly over the lower portion of the column) was too viscous for a submersible bilge-type pump (the only submersible found that would fit inside the 50 mm emergency gas vents). A grab-sampler was then constructed for this project using a 50 ml capacity tube fitted with a 25 mm non-return valve at the base and a 13 mm air-release tube to the surface. The sampler was lowered by 500 mm depth increments on 1.2 m x 25 mm HDPE threaded extensions and, when at the correct depth, the air-release tube was opened allowing the material at depth to enter the sampler. The air-release tube was then closed-off before the sampler was raised to the surface where the sample was recovered by unseating the valve.

Once the material being sampled became thicker than 10-12% TS, it tended to clog the non-return valve and prevent sample recovery. At that point, an open tube was used to replace the non-return valve and the sludge profile was 'cored' using the tube attached to the probe.

A 4.5 m high frame was constructed from 90 mm PVC stormwater pipe to support the upper sections of the probe (8 m long when fully assembled) and prevent the need to attach/detach individual extensions during collection of the samples.

During June 2010, a survey of the settled solids/sludge was performed. While it had been intended that the sampling be performed at the same vents surveyed in 2009, damage to the rainwater collection system made some of the vents inaccessible (they were submerged under water). Sampling could therefore only be performed at vents 4, 6 and 9.

The results of the June 2010 sampling are shown in Figures 6 to 8 (red linework as noted in the legend).

"Pre-desludging" survey; April 2011

A survey of the settled solids/sludge at vents 7 and 8 was performed in early April 2011. Vent 8 was chosen as it sits immediately above an intake port (port number 4) for the desludging system. As the intent was to identify, if possible, the zone of influence at the intake port and across adjacent vents, the column under vent 7 was also surveyed. Vent 9 was inaccessible due to a build up of gas under the cover at that end. The results of the April 2011 sampling are also shown in Figures 6 to 8 (green linework).

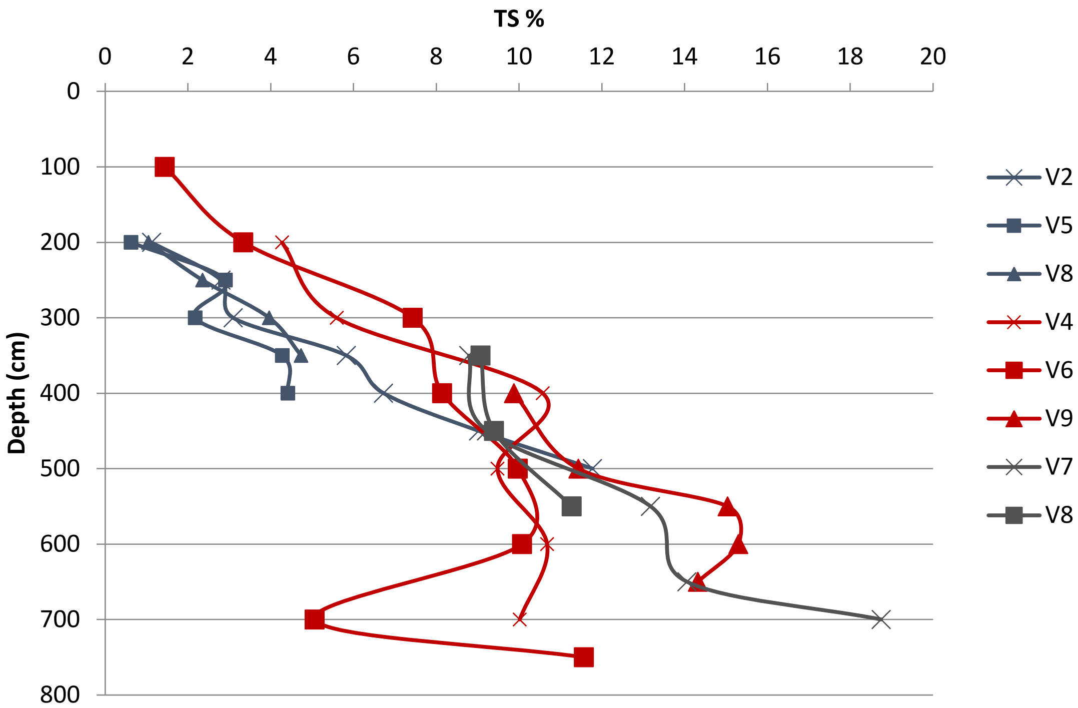

Figure 6: TS concentration with depth; 2009 (blue), 2010 (red), 2011 (green)

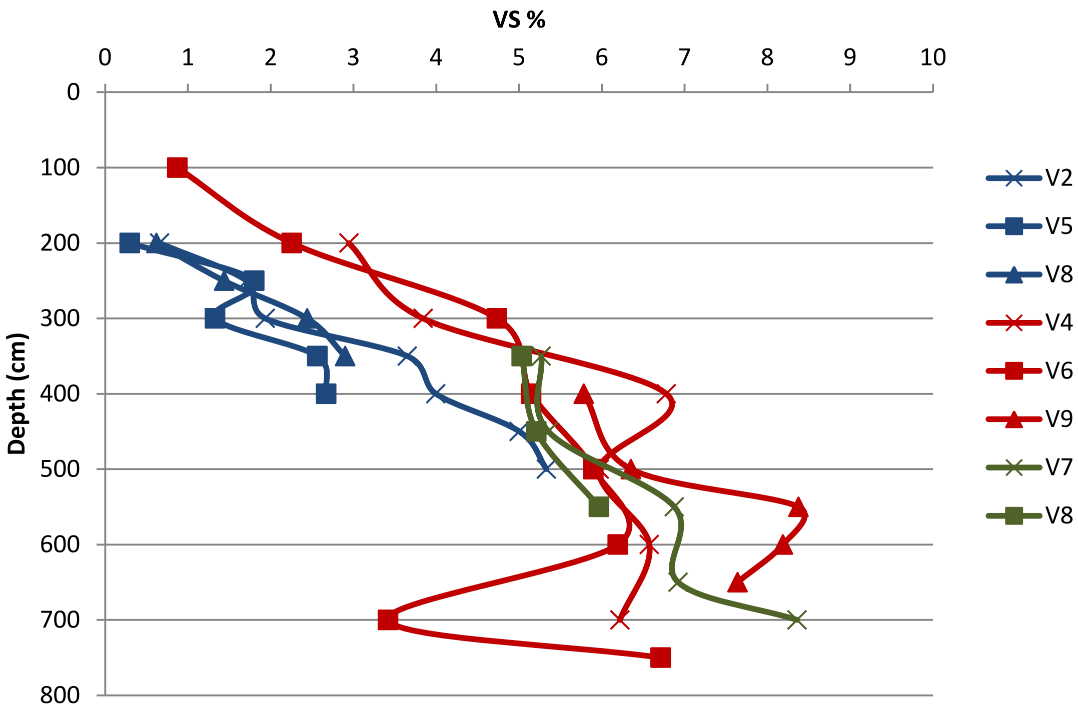

Figure 7: VS concentration with depth; 2009 (blue), 2010 (red), 2011 (green)

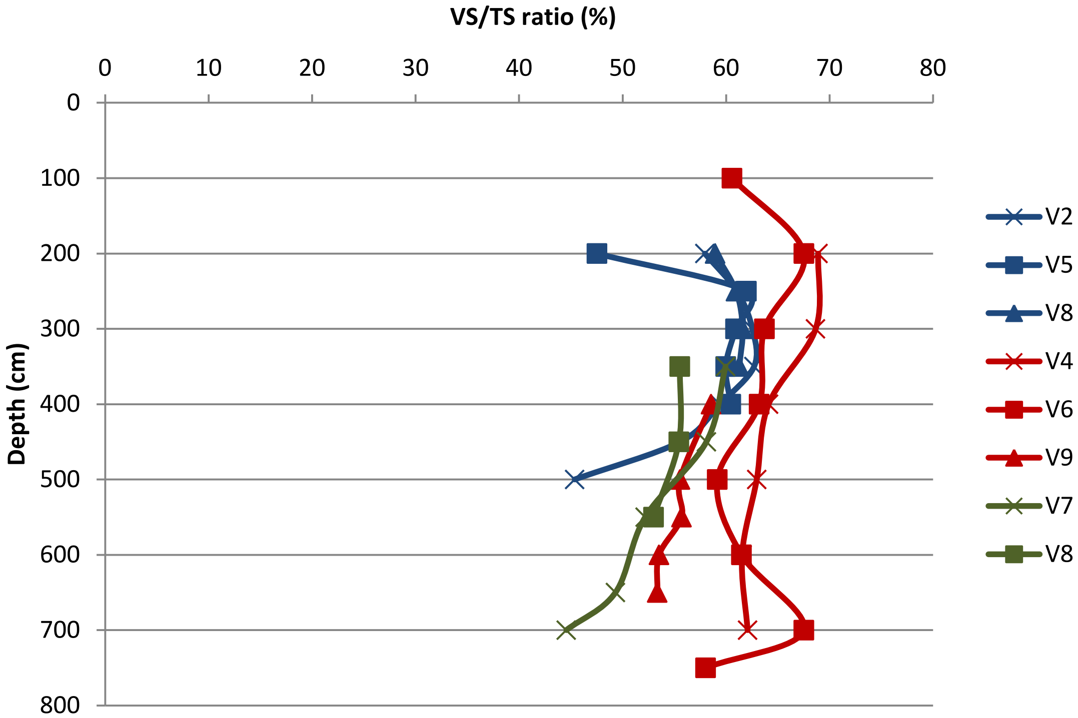

Figure 8: VS/TS ratio with depth; 2009 (blue), 2010 (red), 2011 (green)

Figures 6 and 7 show clearly that both TS and VS increased with depth in all three sampling events. The results support the expectation that solids concentrations will increase over time with the 2009 analysis returning lower concentrations at the same depth than subsequent events. However, the difference was not noticeable between the 2010 and 2011 events. Note that the result from vent 6 (V6) at 700 cm appears to have been subject to sampling error and should be disregarded.

Further analysis of the 2009 and 2010 survey results was carried out to investigate the rate at which solids (particularly VS) were accumulating. While Figure 9 shows the trendline for both datasets, it must be noted that the 2009 dataset is of limited use as it did not extend deeper than 5m below the surface). The 2011 dataset was not used as it was limited to depths of 3.5m and greater.

Based on the trendline from the 2010 results and the geometry of the CAP, Table 2 calculates the VS contained in each 500mm thick horizontal 'section' through the pond. In total, the survey reveals that there is approximately 480 tonnes of VS in the settled solids below 150 cm depth. While the limitations of the 2009 dataset make any comparison difficult, repeating the exercise for the survey completed 15 months earlier produces an estimate of approximately 370 tonnes – a difference of 110 tonnes or an increase of over 7 tonnes per month. It would be useful to understand how much contribution this reservoir of VS makes to methane production from the CAP.

It must be noted that during that 15 month period, the pre-treatment solids separation (inclined screens) were not being used whereas they had been employed for the previous 5 years of operation. Birchall 2010 documented a VS load of 4340 kg d^{-1} for screened wastewater and 7280 kg d^{-1} unscreened wastewater (the latter being based on 2 months data only). For comparison, the 7 tonnes of VS partitioned to sludge each month as identified above is just 3% of the estimated VS load.

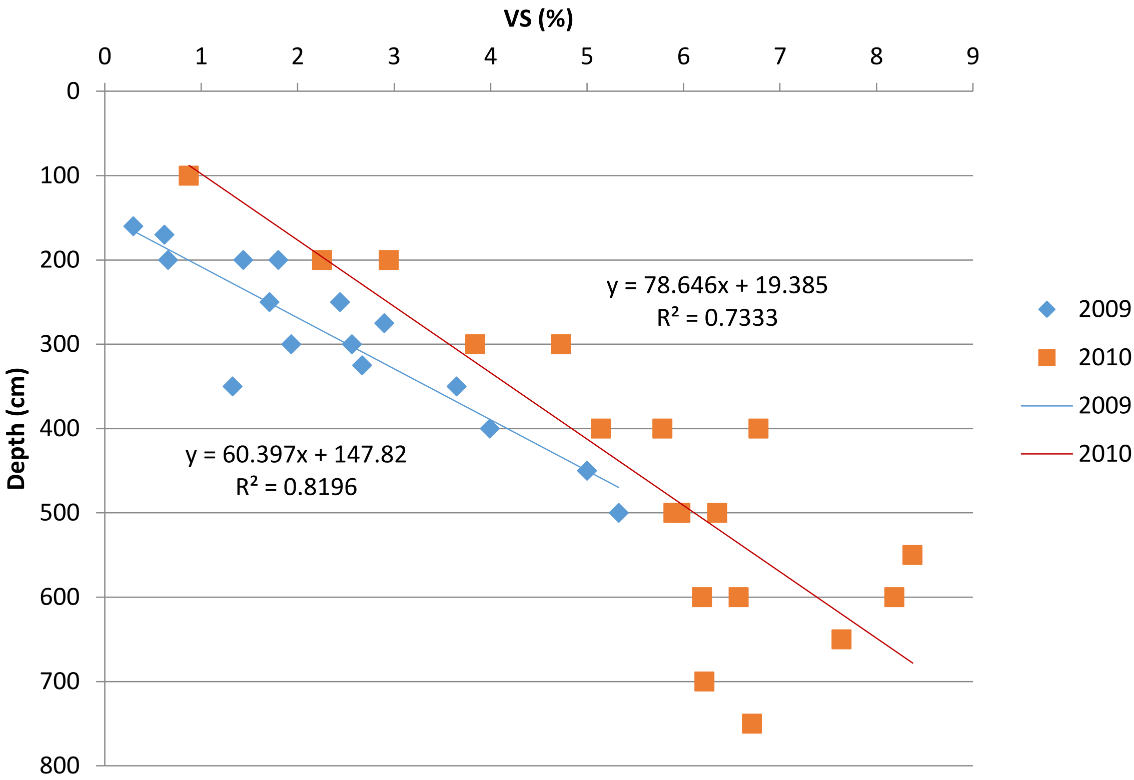

Figure 9: Trendlines for VS from 2009 (blue) and 2010 (red) sludge surveys

Table 2: Mass of VS in sludge during 2010 sludge survey

Arbitrary datum (m)	Depth (cm)	Section volume (kL)	Trend VS concentration (%)	VS mass in section (kg)	VS mass cumulative (kg)
92.15	750	49	9.3	4530	4530
92.65	700	213	8.7	18447	22976
93.15	650	336	8.0	26923	49899
93.65	600	464	7.4	34292	84191
94.15	550	599	6.7	40436	124627
94.65	500	740	6.1	45240	169867
95.15	450	887	5.5	48586	218453
95.65	400	1041	4.8	50359	268812
96.15	350	1200	4.2	50440	319252
96.65	300	1365	3.6	48714	367966
97.15	250	1537	2.9	45064	413031
97.65	200	1714	2.3	39374	452405
98.15	150	1898	1.7	31526	483930
98.65	100	2088			
99.15	50	2284			
99.65	0	1217			

The results shown Figures 6 & 7 do not identify a clear difference in solids concentration between inlet and discharge ends of the covered anaerobic pond.

Figure 8 confirms that there generally is a reduction in the VS/TS ratio with depth; the lower layers having been resident longer and undergone greater decomposition.

No data was collected for COD levels in the sludge column due to the laboratory's concern about the accuracy of the analysis on the high solids content material.

11. Desludging pump failure

Desludging was scheduled to begin immediately after the last sludge survey in April 2011. However, when pumping began, the stator within the helical rotor pump failed after only several hours of operation. The reason for failure was believed to be either that an air leak caused loss of prime and subsequently damage to the stator while running dry, or that the small grit-like grains of struvite that are present in the sludge damaged the stator. As this was the second time the stator had failed with relatively low hours of use, Bears Lagoon management decided to investigate replacing the pump with an alternative unit.

That process took much longer than anticipated with a number of pumps being investigated, and even trialled, before being ruled out. A replacement helical rotor pump was commissioned in February 2012 (Figure 10). The arrangement utilised two pumps – one pump (blue in Figure 10) to extract sludge from the CAP and direct it to the drying beds, the second pump (black) to pump green water from the winter storage to backflush the suction or purge the delivery line.

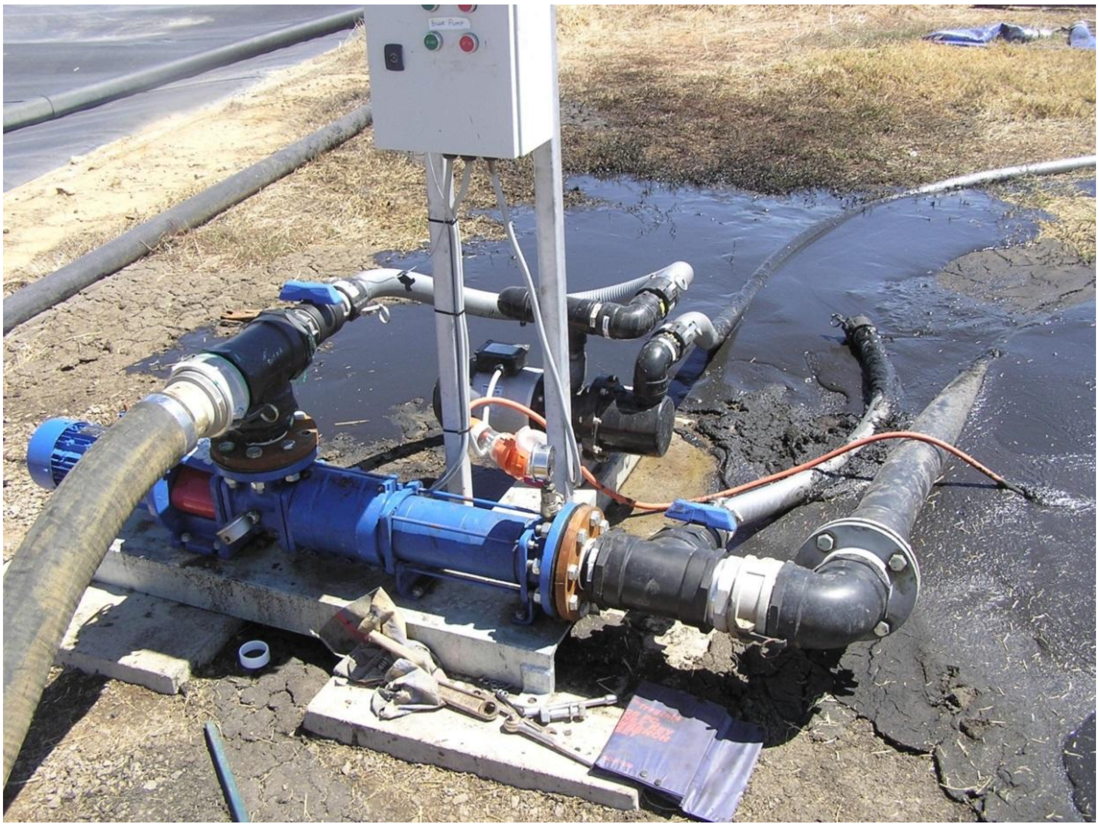

Figure 10: Replacement desludge and backflush pumps, February 2012

There were a number of problems with the replacement pump. The motor driving the desludge pump was initially under-powered and while it was subsequently replaced with more powerful unit, that unit was still prone to overheating. More critically, it was not able to move sludge at sufficient velocity to keep the solids in suspension. It is thought that the low velocity achieved (0.85 m s^{-1}) may have been allowing solids to settle in the 430m of largely horizontal discharge pipe, creating excessive back pressure which the single stage pump was unable to overcome.

There was some indication that the low flow may also have allowed methane gas to be released accumulating in the pipework at the pump. A release of gas under pressure was evident when the valve at the pump was opened.

In an effort to make some progress on reducing the volume of accumulated solids, a new 500mm (nominal) inclined access sleeve was installed that allowed a 100mm suction line (separate to the previously used manifold and in-situ inlet ports) to be progressively lowered down the internal batter so avoiding the highest TS concentration solids found at the bottom. An additional delivery line from the green water pump was attached to the desludge pump suction pipe so that cleaner effluent from the winter storage could be used to agitate and dilute the settled solids. This arrangement was an improvement and would have reduced the suction head but the helical rotor pump was inherently not able to deliver the higher solids content material from the lower depths at an adequate flowrate.

Bears Lagoon management then hired a trailer mounted, diesel-driven centrifugal dewatering pump (Allight CD100MSA) to attempt to extract sludge from the CAP (Figure 11). This arrangement was more successful and the drying bays were filled for the first time in late October 2012. It is noted that the TS content was variable and not representative of in-situ material due to the need to use effluent to dilute the recovered sludge and that no material was recovered from deeper than mid-depth.

Figure 11: Hire pump operating from the inclined access sleeve, February 2013

Figure 12: Filling the drying bays, October 2012

It must also be noted here that subsequent trial work completed using this pump as part of Australian Pork Limited Project No. 2012/1029 found that the pump was limited to a maximum head of around 25 m (Appendix B) and would therefore not be able to deliver sludge with a solids concentration exceeding approximately 7% given the friction losses in 430 m of delivery pipe. The report on APL project no. 2012/1029 is expected to provide further discussion of these issues.

12. Characteristics of recovered solids

The filled drying bays were left undisturbed for 15 weeks. At the end of that 15 week period, a survey of the undisturbed solids was completed (12/2/2013) and samples taken for analysis.

While the farm does not record rainfall, over that 15 week period the surrounding Bureau of Meteorology recording stations received little rainfall (between 6 and 27 mm) – typical of the area during summer months. Pan evaporation is typically 5 to 7 mm per day over the summer period or potentially 670 mm over the 15 week period.

Generally, the initial charge depth of 560 to 640 mm (representing a sludge volume of approximately 1200 m^3 in the south and middle bays) had been reduced to between 230 and 150 mm of residual solids. The exception to that was the first 15 m at the inlet end where a crystalline material (assumed to be struvite) was deposited and, together with the residual organic solids, remained up to 460 mm deep.

Over the remaining length of each drying bed, the top 150 mm were reasonably consistent; light, dry (76% dry matter) organic solids that had undergone significant shrinkage leaving a columnar structure (Figure 14). Underneath that top 150 mm, any material was moist (31% dry matter). The depth of solids decreased with distance from the inlet.

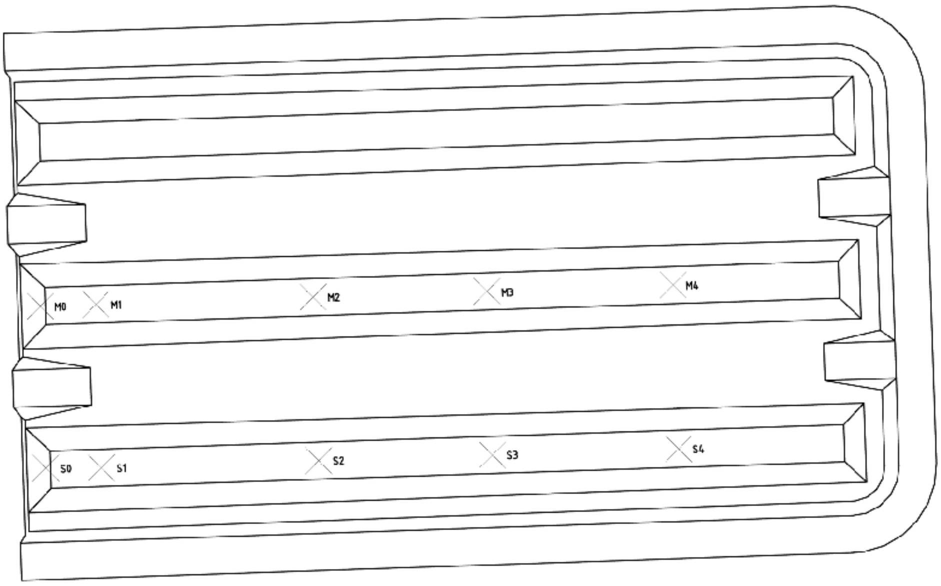

Figure 13: Layout of drying bays showing sampling locations

Figure 14: 150 mm of dry manure solids over 100 mm of moist material (test location M2)

Table 3 contains the results of the analysis of the sampled dried solids. Samples identified as 'SM' are a composite of samples taken at the same distance from the inlet in the South and Middle bays, whereas M relates to the middle bay only. The differing distance from bay inlet to the sampling point is designated by the suffix '0' to '4' (Figure 13).

Figures 15a to 15e show graphically any differences in deposition pattern after the recovered solids leave the discharge pipe. It is apparent that there are differences in deposition patterns, and that the more soluble species, such as zinc (Figure 15d) and chloride (Figure 15e) are carried further along the drying bed compared to those such as phosphorus and calcium (Figure 15b) that are bound with material that settles more readily. This behaviour will have implications for reuse of the recovered material as the variable concentrations complicate the process of nutrient budgeting.

Nitrogen deposition (and presumably subsequent loss) patterns are complex; Figure 15d shows that nitrate-N and ammonium-N behave very differently with the nitrate-N level high at the inlet end and then tapering off thereafter, whereas the ammonium-N level increases to a peak mid-way down the bay. It is expected that the freshly recovered sludge has little if any nitrate-N and that it can only form as nitrification commences with increasing levels of oxygen available upon dehydration. Research completed as part of APL project no. 2130 (Payne *et al* 2008) confirmed that nitrate levels in SEPS were low at moisture contents greater than approximately 75-80%. Reasons for the difference in nitrate level at inlet compared to further down the bay are not clear.

With the exception of lower nitrate levels, the average nutrient concentrations in the recovered solids were in general agreement with Payne *et al* 2008.

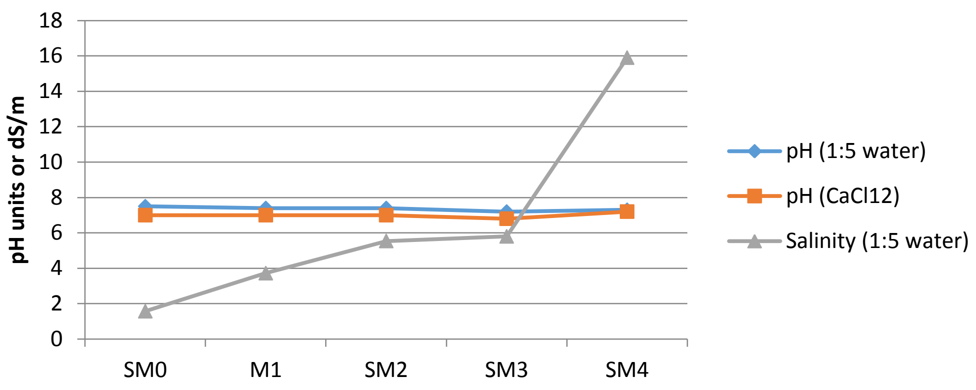

Figure 15a.

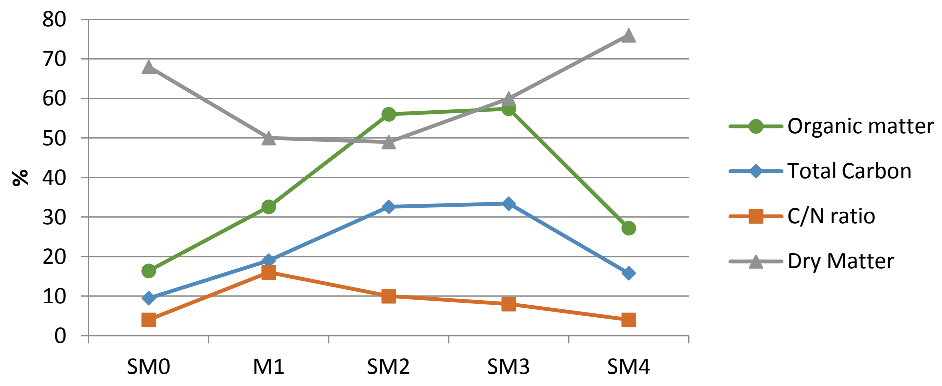

Figure 15b.

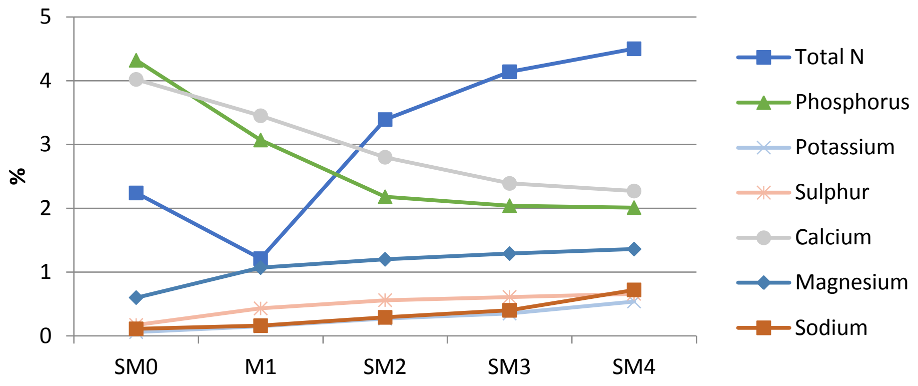

Figure 15c.

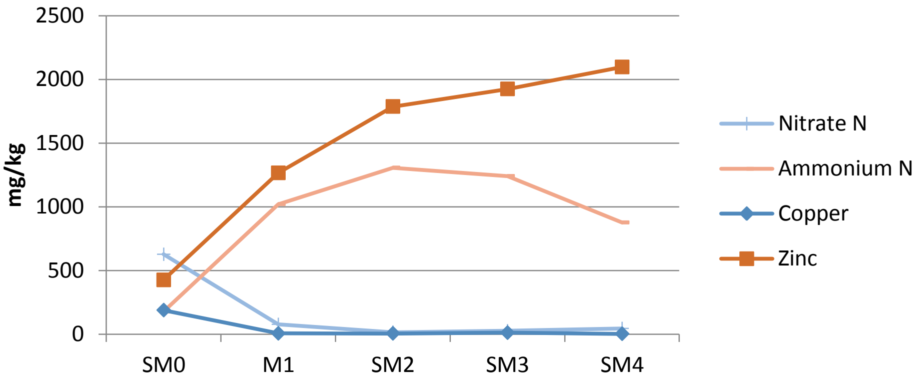

Figure 15d.

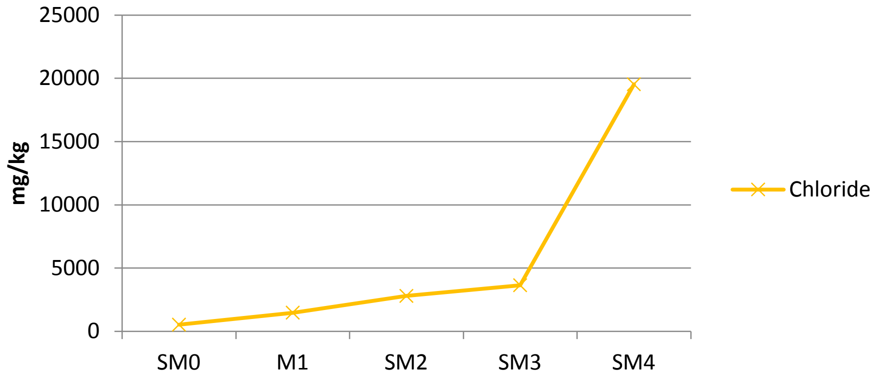

Figure 15e.

With current fertiliser prices (June 2013, delivered to site, GST inclusive) at $590/t urea, $367/t superphosphate, and $700/t muriate of potash, each tonne of as-recovered solids (59% dry matter) would be worth $85. Assuming a density of 800 kg/m³, this would suggest a value of $68/m³.
The farm manager estimated that 120 m³ of solids were recovered from the south and middle drying bays and spread on paddocks a rate of 3m³/Ha. At this rate, the sludge could be expected to supply approximately 47 kg N/Ha, 33 kg P/Ha & 5 kg K/Ha however some of the nutrients will need to be mineralised before becoming plant available.

After one 'turn' of the drying bays, both the farm manager and excavator operator were generally satisfied with the design of the drying bays. The only suggestion made that could improve the design was to increase the side batter slope so that the operator could fill the bucket against it. Currently, the side batters are 3:1 and cleaning is a two-step process; the excavator (located on the berm between bays) pulls the solids across to the berm, up the batter and leaves them in a windrow on top of the berm. With every 6 to 8m of progress, the excavator has to rotate a quarter-turn and fill the bucket from the windrow to load the truck. With a steeper batter, the operator suggested that he could fill the bucket in one-step against the batter saving time and cost. However, it must be pointed out that maximum batter slopes of 2.5:1 to 3:1 are needed for conventional compaction methods so unless additional time and effort is put into constructing the bays (for example "stair-step" compaction may be used to allow a steeper trimmed batter) then this may not be achievable.

Table 3. Analysis of solids recovered from the drying bays

Parameter	Units	Test ID no. Dist. from inlet				
		SM0* 2m from inlet	M1 12m from inlet	SM2 47m from inlet	SM3 75m from inlet	SM4 105m from inlet
pH (1:5 water)		7.5	7.4	7.4	7.2	7.3
pH (CaCl12)		7.0	7.0	7.0	6.8	7.2
Salinity (1:5 water)	dS/m	1.57	3.72	5.54	5.8	15.9
Chloride	mg/kg	523	1472	2796	3638	19525
Organic matter**	%	16.4	32.6	56	57.4	27.2
Total Carbon	%	9.5	19	32.6	33.4	15.8
Nitrate Nitrogen	mg/kg	627	77	16	27	45
Ammonium Nitrogen	mg/kg	178	1021	1307	1241	877
Dry Matter	%	68	50	49	60	76
Carbon/Nitrogen ratio		4	16	10	8	4
Total Nitrogen	%	2.24	1.21	3.39	4.14	4.5
Phosphorus	%	4.32	3.07	2.18	2.04	2.01
Potassium	%	0.06	0.15	0.27	0.35	0.54
Sulphur	%	0.17	0.43	0.56	0.61	0.66
Calcium	%	4.02	3.45	2.8	2.39	2.27
Magnesium	%	0.6	1.07	1.2	1.29	1.36
Sodium	%	0.11	0.16	0.29	0.4	0.72
Copper	mg/kg	189	6.5	6.2	11.9	3.2
Zinc	mg/kg	426	1266	1787	1925	2097
Manganese	mg/kg	1036	803	516	466	443
Boron	mg/kg	7.4	15.1	16.2	19	20
Iron	mg/kg	4480	2549	3386	3348	3837

* S = south bay, M = middle bay. SM = composite sample from south and middle bays.
** Loss on ignition method

13. Conclusions

13.1 Quantity and fate of solids partitioned to sludge

The sludge surveys completed at Bears Lagoon piggery identified that a significant amount of VS resides in the sludge in this CAP having not been desludged since being commissioned. However, compared to the influent load, the estimated accumulation rate was a relatively small proportion at just over 3% for unscreened wastewater. Further investigation into how much gas production potential the sludge represents would be beneficial.

13.2 Management of the sludge extraction system

The project's stated objective to "document procedures for managing the in-situ sludge removal system to optimise performance" was not achieved as a robust sludge extraction system was not established during the life of the project. While more information has now been documented on what doesn't work, the challenges in handling potentially abrasive, high solids content material remain to be overcome at this site and for the industry in general. Two conclusions that can be drawn from the work performed are that:

- Pump duties need to be clearly defined for selection of appropriate pumps. Better information on the velocity required to keep solids in suspension and the resulting pipe friction losses when pumping high solids content material are key pieces of information when designing a sludge extraction system. Some preliminary information was collected from this site under APL project no. 2012/1029.
- Fixed suction pipes can become blocked with inactivity and are difficult to rehabilitate. Small radius bends in the submerged pipework at this site prevented suction pipes from being unblocked except by backflushing. Installing access sleeves for retractable suction pipes through the embankment or cover allow more control over the depth of the suction inlet and provide more flexibility for trouble shooting and pump choices. The sleeve diameter should be large enough to accommodate the largest anticipated suction pipe and a pipe providing a pressurised supply of water or effluent for agitation and/or dilution.

With the difficulties encountered during desludging – particularly the stop/start nature and use of diluting effluent, wet sludge samples were not considered representative of the in-situ material. Nor was it possible to survey to identify the zone over which the extraction pump could recover sludge as desludging efforts were interrupted and did not extend below mid-depth.

13.3 The design of the drying bays

After one 'turn' of the drying bays, both the farm manager and excavator operator were generally satisfied with the design of the drying bays. The design criteria presented in the SEPS guidelines were suitable for the task.

13.4 Sharing data with the University of Queensland AWMC

Analysis of the in-situ solids recovered during the sludge surveys was performed by Preethi Gopalan (industry funded PhD student) at the Advanced Water Management Centre at the University of Queensland.

14. References

Birchall, S. 2010. 'Biogas production from covered lagoons; performance data from Bears Lagoon', RIRDC Research Publication No. 10/023, Canberra.

Kruger, I., H. Payne, K. Moore & J. Morgan 2008. 'Sedimentation and evaporation pond systems', draft Primefact, NSW DPI.

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15. Appendix

Appendix A – Drying bay tender drawings
Appendix B – Pump curve for hire pump