Final report

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Manipulation of Wastewater Treatment System to maximize biogas production

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Abstract

The tug of war for the most appropriate organic load for covered anaerobic lagoons (CALs) is a new dilemma in wastewater treatment systems. On the one end, a high organic load is converted to large quantities of the valuable byproduct, biogas. On the other end, however, an excessively high organic load may cause CAL overloading and crust accumulation resulting in treatment failure. This project investigates the balance of these two opposing drivers.

The newly installed wastewater treatment system at Thomas Foods International Murray Bridge facility provided the opportunity to study the effects of dissolved air flotation (DAF) operation on CAL treatment efficiency and biogas production. Three DAF setpoints were investigated, studying the effect of two different polymers against the situation of no polymer addition. DAF performance, CAL effluent quality, biogas production and CAL sludge and crust accumulation were analyzed to determine the best overall operational mode.

Whilst polymer addition aided the DAF performance, it had serious negative effects on the CAL performance and biogas production. The Chemical Oxygen Demand (COD) removals achieved at the CALs during polymer addition were 51% and 62% and average weekly biogas production was between 21,700 m^3 and 23,700 m^3. CAL performance rapidly improved when polymer addition to the DAF ceased with the average COD removal increasing to 82% and the weekly biogas production tripling to 67,100 m^3. This was not due only to the higher feed COD levels for the no addition control.

Murray Bridge has installed a customized biogas fuelled boiler allowing the offset of over $700,000 of natural gas demand each year. With monetary figures of this order, it is inevitable that wastewater treatment efficiency will quickly move from being purely an environmental concern to also being at the scrutiny of company accountants. This project demonstrated that simple changes to the wastewater treatment operation can significantly improve overall treatment effectiveness and increase the economic reward through biogas production.

Executive Summary

This research project investigated the effect of dissolved air flotation (DAF) unit operation on biogas formation in covered anaerobic lagoons (CALs). While the removal of oil and greases in the DAF prevents crust formation in the CAL, it also reduces the potential for valuable biogas formation. This project aimed to find the most acceptable balance of drivers to maximize biogas formation and minimize DAF chemical requirements. The final objective was to calculate the cost benefit analysis of the biogas capture and reuse system in the best case scenario.

Thomas Foods International (TFI) Murray Bridge facility recently upgraded its wastewater treatment facility to include a Krofta DAF and twin 20ML CALs. The system is designed to treat 3.3 ML per day using the assistance of polymer if needed. Offsite ponds complete the wastewater treatment prior to land irrigation.

The wastewater, biogas, crust and sludge were analyzed over a 12 month period using a variety of onsite and offsite techniques of weekly and quarterly sampling by TFI and Johns Environmental (JEPL) personnel. Wastewater and biogas flowrates were also collected by inline meters connected to SCADA.

The DAF was operated in three distinctly different modes:

1. Using polymer 1 to achieve a low COD influent to the CAL,
2. Using polymer 2 to achieve a low COD influent to the CAL,
3. Using no polymer to achieve a moderate COD influent to the CAL.

The addition of polymer produced a large reduction in contaminants to provide a lower strength CAL influent stream. Without polymer addition, COD and total suspended solids (TSS) removal was poor however moderate oil and grease (O&G) removal was achieved.

It is clearly evident that the operation of an upstream DAF without polymer addition is the preferred operating mode. Despite the higher influent COD and O&G concentration in DAF set point 3, the following improvements were noted:

- Effluent COD concentration decreased
- VFA/TA ratio decreased
- Biogas production increased
- Crust thickness decreased

There appeared to be a powerful inhibition of biogas production and treatment efficiency caused by the polymer addition. The mechanism of the inhibition by the polymer addition to the DAF is unknown, but it was very potent and not significantly relieved by reducing the polymer dosage. It is highly recommended to avoid polymer addition upstream of an anaerobic treatment unit.

Further findings indicated the importance of pH and operational control. An overloading event caused stress on the anaerobic process. The impact of this event was masked by incorrect pH readings. The combination of these two events resulted in the CALs quickly losing treatment efficiency which was not recovered for two months. It is advised to ensure regular pH probe calibration to enable accurate pH monitoring so remediation measures can be applied earlier and damage minimized.

Biogas production was reasonably constant over the 7 day week. There was little difference between production and non-production day biogas flowrates. A peaking factor of 1.5 would be reasonable for flare design.

Biogas composition found methane concentrations between 60 and 80 %v/v over the research period. H_2S concentration decreased from ~2,500 ppm (0.25%v/v) to 1,600 ppm as the biogas flowrate increased.

The sludge recirculation system installed at the time of CAL commissioning was tested at the conclusion of DAF setting 3. The pumping mechanism used in the sludge recirculation system proved inadequate largely due to degassing issues on the pump suction side with sludge flowrates quickly decreasing to insignificant levels. Pump specialists are currently contemplating the sludge recirculation system and aim to resolve the pumping challenges

Biogas utilization for onsite boilers appears to be highly desirable from the cost benefit analysis based on the Murray Bridge installation. With the estimated capital expense of the TFI Murray Bridge biogas scrubber and pipeline of $550,000 and estimated reduction in natural gas demand by $730,000 per year, the payback period is less than 1 year. A total saving of nearly $13 million is gained over the estimated 20 year life of the biogas system, a considerable return on investment.

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1.0 Background

1.1 Introduction

Organic loading on covered anaerobic lagoons (CALs) forms valuable biogas but may form undesirable crust and overload the system.

The implementation of the CAL introduces a new dimension to wastewater treatment; through the valuable byproduct, biogas. Biogas is approximately 70% methane. In cases of significant biogas production, it may be economically advantageous to use this fuel source in onsite boilers or co-generators. Economic incentives fuel the desire to maximize biogas formation and provide the first driver in wastewater treatment system operation.

Wastewater pretreatment is recommended upstream of CALs to reduce introduction of oils and grease and thus prevent crust formation under the cover. Crust formation is undesirable as it may reduce treatment volume and block biogas capture systems. The need to protect the CAL from oil and grease provides the second, opposing driver to wastewater treatment system operation.

Is there an acceptable balance between these two drivers?

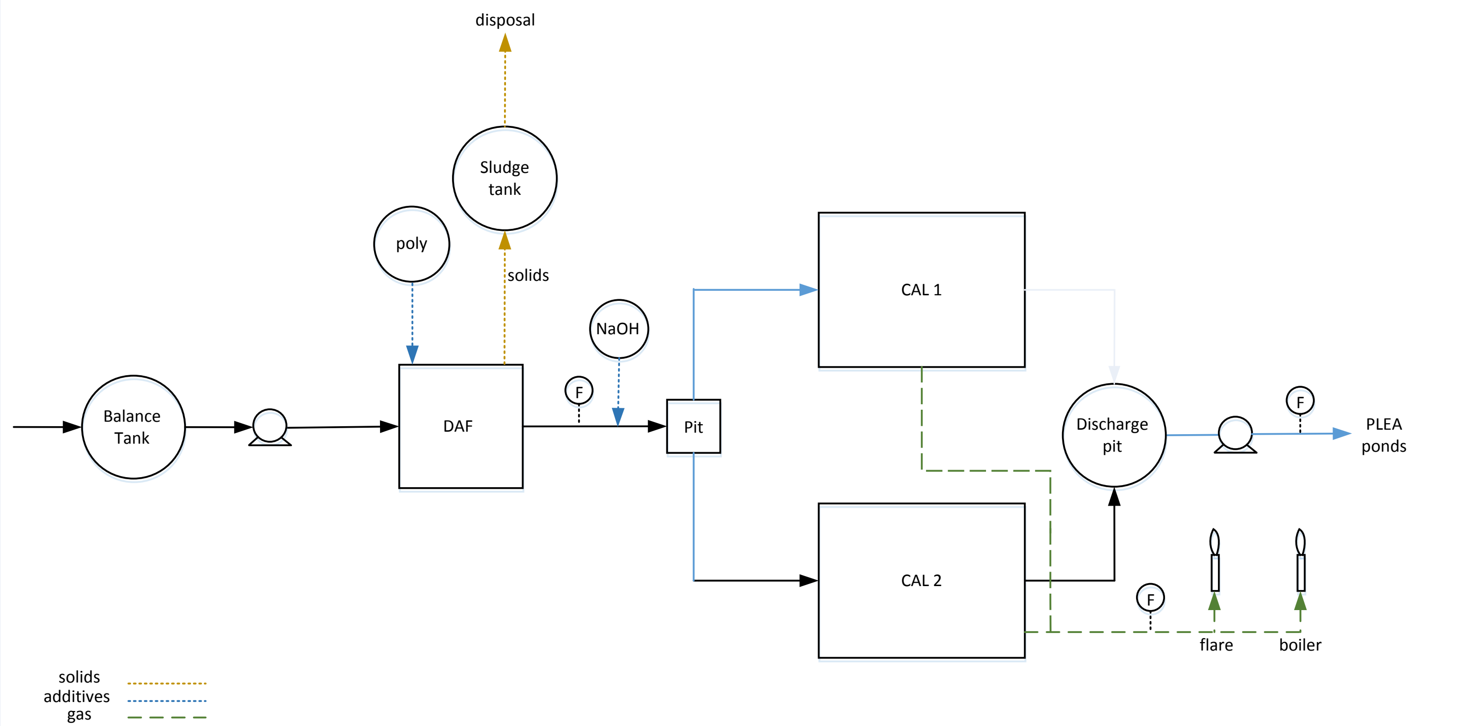
The commissioning of the new wastewater treatment system at TFI's Murray Bridge facility provided a suitable platform to investigate pretreatment operation options to sufficiently protect the CALs while maximizing biogas formation. A dissolved air flotation (DAF) unit with a polymer dosing option and twin 20ML CALs formed part of the new wastewater treatment system.

Past DAF operation may have focused on maximizing removal rates to reduce loading on the downstream treatment units. However, this mode of operation produces significant sludge that requires land disposal and may remove potential biogas creating food. This project investigated the impact of three DAF settings on the overall CAL performance including biogas formation, effluent treatment and crust formation.

1.2 Site Description

Thomas Foods International is a mixed species facility located in Murray Bridge, South Australia. Figure 2 illustrates the site and location of the new WWTP commissioned in late 2012. Figure 1 shows the schematic of the 2012 WWTP upgrade excluding the offsite PLEA ponds. The onsite upgraded units included a dissolved air flotation (DAF) treatment unit and twin covered anaerobic ponds.

The abattoir typically processes 11,000 lamb per day and 880 cattle per day operating on a 5 day/week, 250 day/ year basis. There exists a full range of ancillary operations including rendering (HTR), boning and offal and intestine processing. Hides for the cattle and sheep are dry salted for off-site transport.



TFI **Murray Bridge**	**Johns Environmental Pty Ltd** Ph 07 3863 0051 PO Box 534 Fax 07 3863 0057 ASPLEY Q 4034 This drawing © Johns Environmental 2014	**Murray Bridge WWTP Onsite Upgrade** Date: 4th August 2014 Dwg No: 34-002 Revision : A

Figure 1: Wastewater Treatment Plant Schematic

Figure 2: Thomas Foods International Murray Bridge facility and new WWTP illustrated

The Krofta dissolved air flotation (DAF) treatment unit shown in Photo 1 and Photo 2 was designed to remove O&G and suspended solids from the full wastewater flow of 3.3 ML per day using the assistance of polymer dosing if needed. The floating solids are skimmed from the surface and belt pressed before disposal. The DAF discharge is gravity fed to a split pit at the CAL site.

Photo 1: Elevation of new DAF

Photo 2: Float removal chain on new DAF

The twin CALs shown in Photo 3, each have a 20ML capacity and are fed evenly via the central split pit. Biogas is collected under the covers and feeds the single biogas train to the flare and/or onsite boiler. The effluent spills over a weir at the discharge end of each CAL and flows to the effluent substation before being pumped to the offsite ponds for further treatment before irrigation.

Photo 3: Twin CALs

CAL ancillary equipment includes:

- Emergency vents consisting of weighted flaps calibrated to open under overpressure conditions.
- Pressure transducer to measure gas pressure in the CAL cover. This information is used to control biogas flowrate to the flare and/or boiler.
- Biogas methane and flow analyzers on the biogas train.
- Stormwater weighting.
- Six inspection ports per CAL cover.
- Sludge removal system that allows three modes of operation
    - extraction of sludge to a receiving truck
    - recirculation of extracted sludge to the inlet pit; and
    - recirculation of influent to the sludge pipes

2.0 Project Objectives

The objectives for this project are as follows:

1. Determine the best DAF operation at Murray Bridge to maximize organic load to the CAL system while still providing adequate protection.

2. Determine the wastewater load composition and characteristic that generate maximum amount of biogas.

3. Determine how best to minimize chemical requirements for the DAF.

4. Calculate the cost benefit analysis of the construction of the biogas capture and reuse system.

3.0 Methodology

The covered anaerobic lagoons (CALs) was monitored over the 12 months as the upstream dissolved air flotation (DAF) unit was operated in three distinctly different modes:

1. Using polymer 1 to achieve a low COD influent to the CAL,
2. Using polymer 2 to achieve a low COD influent to the CAL,
3. Using no polymer to achieve a moderate COD influent to the CAL.

Data collected during the investigation period includes;

- Wastewater laboratory and field data from weekly sampling of DAF inlet, CAL inlet and east and west CAL outlet streams. No measurements were collected during shutdowns periods.
- Biogas flowrate and methane content from the SCADA system.
- Effluent flowrate data from the SCADA system.
- Crust and sludge analysis during site visits.

3.1 Wastewater Monitoring

Wastewater monitoring of the DAF influent stream, DAF effluent stream (i.e. CAL influent stream) and east and west CAL effluent streams enabled characterization of individual stream flow and quality entering and leaving the DAF and CALs.

3.1.1 Wastewater Flow

Inline flowmeters connected to the SCADA allowed both instantaneous and totalized flow recording at 15 minute intervals. Two flowmeters monitored the following streams:

- DAF effluent, and
- combined CALs effluent. This flow was assumed to be split evenly between the east and west CAL.

TFI provided JEPL with the daily wastewater flows at each point along with daily production information.

3.1.2 Wastewater Characterization

DAF influent and effluent samples were collected from sampling points on Wednesdays by TFI personnel. An ISCO auto sampler was located at each DAF sampling point and collected hourly samples that were composited into a large bottle. Analysis of samples was conducted onsite and via an external laboratory.

- Onsite measurements by TFI personnel determined pH, temperature, and conductivity using a portable Hach HQ40d device supplied by JEPL.

- Samples were also bottled, chilled and sent to an offsite laboratory for analysis. Weekly analysis measured COD, TSS and O&G in both samples. Additional analysis of BOD_5, total alkalinity (TA), VFA, TN and ammonia was also included in the last weeks of each set point.

CAL influent was characterized by the weekly DAF effluent samples. However, an extra set of individual samples was collected at the conclusion of each DAF mode from the CAL inlet pit. Samples were collected using an ISCO auto sampler set at 2 hour intervals over a 24 hour production day and dispensed into individual bottles. Each individual sample was analyzed as follows:

- Onsite measurement of pH and conductivity by JEPL personnel using a portable Hach HQ40d.

- Each individual samples was also bottled, chilled and sent to an offsite laboratory for COD, TSS and O&G analysis.

CAL discharge samples from each discharge pit were collected weekly on Wednesday by TFI personnel. The samples were also both, field and laboratory analyzed:

- Field measurements of the effluent samples to determine pH, temperature, and conductivity were conducted by TFI personnel using a portable Hach HQ40d.

- Each CAL sample was also bottled individually and sent to an offsite laboratory. Laboratory analyses in the initial 9 weeks adjustment period of each set point determined COD, VFA and TA. Additional analysis in the final 4 weeks steady state period for each DAF set point returned BOD_5, TSS, O&G, TKN and NH_3 results.

Photo 4: CAL Discharge sample

3.2 Biogas Analysis

Biogas monitoring included biogas flowrate, methane concentration and hydrogen sulphide (H_2S) concentration.

3.2.1 Biogas Flow

An inline Drager 400 biogas flowrate meter connected to SCADA provided cumulative biogas flowrate data at 15 minute intervals. This meter measured the total biogas flowrate to the flare and the biogas boiler.

3.2.2 Biogas Characterization

Biogas methane composition was measured using an inline Endress & Hauser Proline 200 biogas methane analyzer situated downstream of the biogas fan. Readings were linked to SCADA and control systems.

Additional biogas analysis was performed at the end of each DAF set point. Samples were collected from the tap point located on the fan discharge during periods of flare operation. Two analytical methods were employed:

- A GEM 2000 Plus portable gas analyzer allowed continuous in-situ monitoring of methane, carbon dioxide and oxygen over many hours.
- Gastec detector tubes measured hydrogen sulphide concentrations during production hours.

3.3 Crust and Sludge Analysis

Crust and sludge analysis was performed at the beginning and end of each DAF setpoint to determine thickness and crust appearance. Measurement required the opening of the sampling ports on the CAL covers that, for OH&S requirements, was only performed if the cover was at water level to minimize biogas escape.

Crust depth was measured using two methods. Both are best approximations only with the accuracy with Method 1 probably ± 25mm, whereas Method 2 accuracy is probably ± 50mm.

1. Thin crust thickness was measured visually using a Perspex tube as shown in Photo 5. This technique was not suitable for thick crusts as the resistance in the tube prevented the full crust thickness from entering.

2. Thick crusts were measured by feeling the depth where resistance of a probe was detected as it was withdrawn from the pond, as shown in Photo 6.

The sludge in each CAL was also measured at the end of each set point. A Royce 711 suspended solids meter was lowered through the water column. TSS readings were recorded at 0.5m intervals and the depth noted where the interface exceeded the maximum 10 g/L recorded.

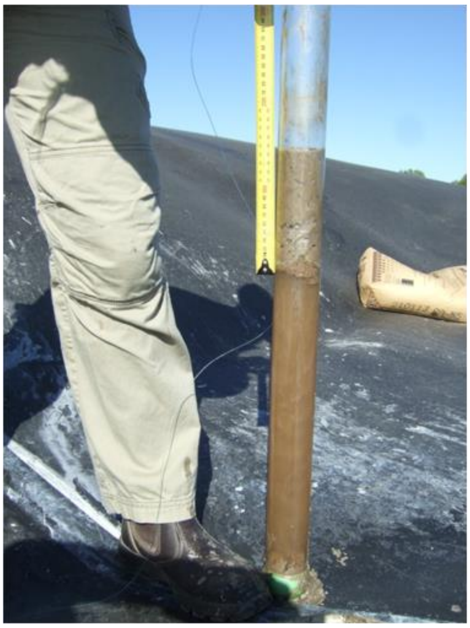


Photo 5: Crust measured with Perspex tube

Photo 6: Crust measured with Royce Probe

4.0 DAF Operation to Maximize Biogas Production

4.1 DAF Contaminant Removal Efficiency

The DAF operation settings, removal rates and CAL loadings for each setpoint are outlined in the following sub-sections.

4.1.1 DAF Setpoint 1

DAF setpoint 1 involved the addition of a cationic polymer 1 (Nalco product) to the DAF feed to achieve a COD concentration suitable as CAL influent. The need for the polymer was driven by the fact that the pre-DAF COD concentrations exceeded the original CAL design value by a factor of approximately two.

Polymer 1 successfully reduced the COD, O&G and TSS concentrations by an average of 60%, 85% and 65% respectively. The average COD in the DAF effluent during DAF setpoint 1 was 5,100 mg/L as illustrated in Figure 3.

The weekly total flowrate to the CALs, as shown in Figure 4, was approximately 17.1 ML/wk during DAF setpoint 1. The lower flowrate values represent the Christmas shutdown.

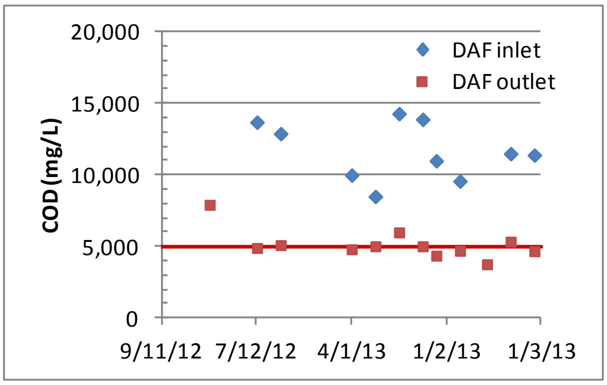


Figure 3: DAF setpoint 1 COD removal

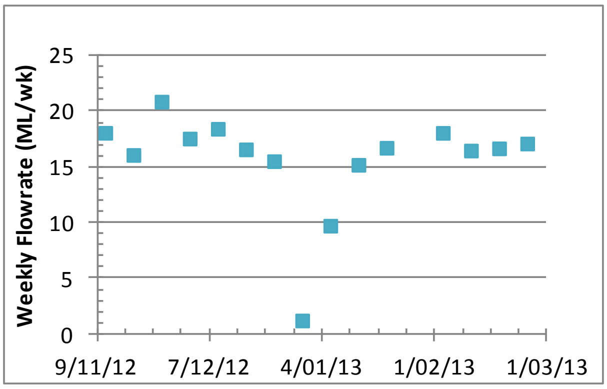


Figure 4: Weekly effluent flow during setpoint 1

4.1.2 DAF Setpoint 2

DAF setpoint 2 involved the substitution of polymer 1 with cationic polymer 2 (Integra product) to achieve a low COD CAL influent. The change in polymer was driven by TFI to reduce operating costs and was introduced in April 2013.

Polymer 2 also successfully reduced the COD, O&G and TSS concentrations by an average of 33%, 55% and 51% respectively. Figure 5 shows that the lower removals rates achieved over the DAF were mainly due to the reduced DAF influent concentrations compared to those during DAF setpoint 1 period. The average COD in the DAF effluent during DAF setpoint 2 was also 5,100 mg/L.

The weekly total flowrate to the CALs, as shown in Figure 6, was approximately 17.3 ML/wk during DAF setpoint 2. The high value on the 9th June 2013 was due to an uncharacteristically large rainfall event.

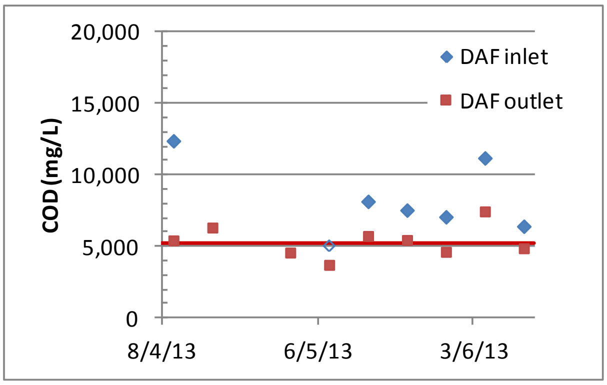


Figure 5: DAF setpoint 2 COD removal

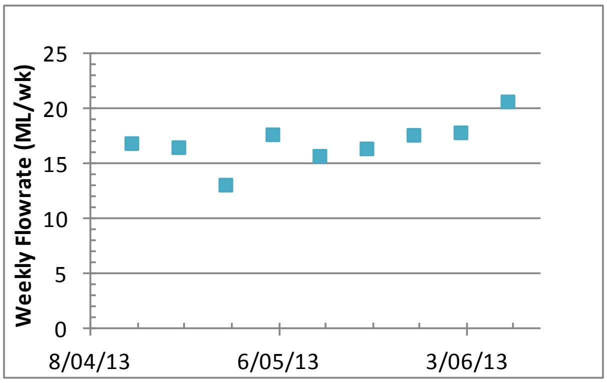


Figure 6: Weekly effluent flow during setpoint 2

4.1.3 DAF Setpoint 3

DAF setpoint 3 was operated with no addition of polymer into the DAF. This achieved a moderate COD concentration in the CAL influent. Polymer addition was no longer necessary due to ongoing efforts by TFI to reduce losses of material to the wastewater system. The rendering plant upgrades also improved wastewater quality significantly.

The DAF was effective in removing an average of 55% O&G with no polymer addition. O&G removal is the fundamental aim of the DAF pretreatment. However, lower COD and TSS removals were lower at 13% and 17% respectively. The average COD entering the CAL during DAF setpoint 3 was 8,000 mg/L – almost 60% higher than for the previous settings.

The weekly total flowrate to the CALs during DAF setpoint 3, as shown in Figure 8, was approximately 16.3 ML/wk. This was reduced from the previous levels by a range of water saving measures across the production site. The three low values in Figure 6 were due to the Christmas and Easter shutdowns.

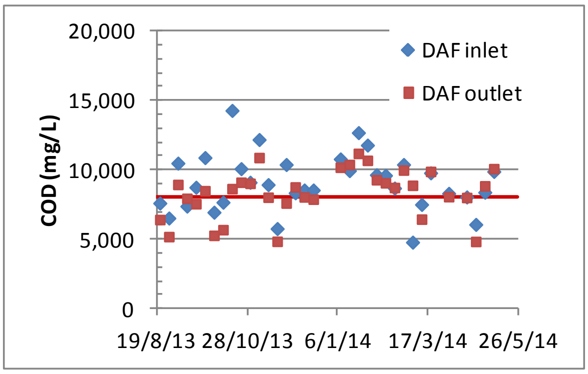


Figure 7: DAF setpoint 3 COD removal

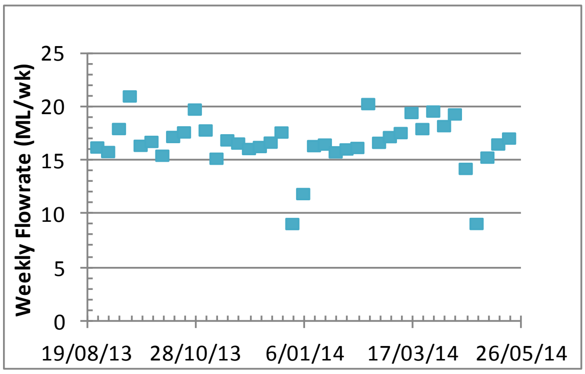


Figure 8: Weekly effluent flow during setpoint 3

4.1.4 DAF Setpoint Summary

Table 1 presents the summary of the conditions at the three DAF setpoints. The addition of polymer provided a large reduction in COD, O&G and TSS, succeeded in producing the lower strength CAL influent stream. Without polymer, COD and TSS removal was poor but moderate O&G removal was achieved.

Table 1: Summary of Average conditions at DAF Setpoints

Parameter	Unit	DAF SP 1	DAF SP 2	DAF SP 3
COD removal	%	60	33	7
O&G removal	%	85	55	46
TSS removal	%	65	51	15
Flowrate	ML/wk	17.1	17.3	16.9
COD in	mg/L	12,200	7,300	8,900
COD out	mg/L	5,100	5,100	8,700
BOD out	mg/L		2,300	4,200
TSS out	mg/L	970	1,500	2,900
O&G out	mg/L	250	140	290
TN out	mg/L	210	320	200

4.2 Load applied to CALs

COD loading is one of the major design criteria as anaerobic bacteria are capable of treating a limited COD within a certain volume and time. While it is obvious that overloading will hinder the removal efficiency, underloading can have the same effect.

Underloading a CAL will limit anaerobic activity, thus limiting biogas release leading to poor natural stirring from the rising bubbles. Natural biogas mixing enhances anaerobic treatment effectiveness through two mechanisms:

1. The natural mixing will continuously lift the sludge into the upper water levels thus exposing the incoming contaminants to a large population of hungry bacteria.
2. The natural mixing will also limit short circuiting through the CAL volume.

In the absence of these two mechanisms, anaerobic effectiveness decreases.

Figure 9 shows that COD load applied affected overall CAL efficiency with a peak at around 0.6 kg COD/m^3/d. The higher loadings applied in DAF setpoint 3 produced the peak COD removal efficiency. Lower COD removal efficiency with the lower COD loadings in DAF setpoint 1 and 2 could be the result of underloading the CAL creating the above undesirable conditions (further discussion in Section 4.7). An overloading event created a step change decrease in the COD removal efficiency. COD overloading can be the result of many variables including uncontrolled spills. Further discussion on this overloading event is presented in Section 5.2.

COD loadings to a CAL should be kept within the design range to ensure reasonable treatment efficiencies.

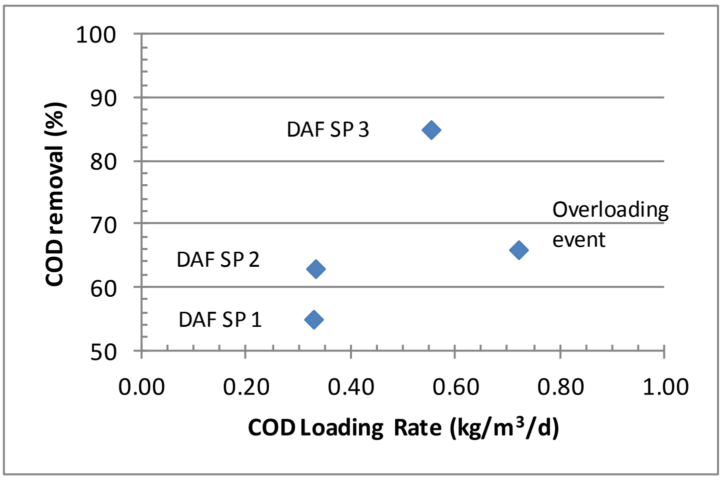


Figure 9: Effect of COD loading on COD removal

4.3 CAL Performance Indicators

CAL performance during each of the three DAF set points has been assessed using the following performance indicators.

- Volatile Fatty Acid (VFA) concentration to Total Alkalinity (TA) ratio. The purpose of this ratio is to indicate the “health” of the anaerobic sludge in the CAL. Healthy sludge consumes VFA while producing total alkalinity thus creating a low ratio. VFA and TA are a direct measure of the anaerobic reaction and are generally not influenced by other factors such as changes in the influent. A typical healthy CAL in the meat industry will operate with a VFA/ TA ratio of less than 0.25.

- Effluent COD concentration. This is a typical measure of CAL performance used in the industry since it is readily measured. However, effluent COD can increase due to significant high COD load events or uncharacteristically high effluent suspended solids concentrations with each event being unrelated to overall CAL performance.

- Biogas production. Biogas production from newly constructed CALs can be measured with inline biogas flowmeters attached to SCADA. Biogas volume will generally reflect COD removal in the CAL. The real time aspect of this measurement is its major advantage. However, biogas measurement can be misleading if there are losses through emergency vents and leaks.

4.4 CAL Performance Indicators Analysis

CAL performance indicators during each DAF setpoint are discussed in the following section.

4.4.1 Influence of DAF Setpoint 1 (Polymer 1) on CAL Performance

Figure 10 to Figure 13 show the CAL performance indicators during the period of polymer 1 addition to the upstream DAF. The period September – December 2012 represents the initial start-up phase. The CALs did not begin to function until early January after intervention by Johns Environmental to reduce the inhibitory VFA/TA ratio. During the setpoint 1 period, the dose of polymer was gradually reduced to attempt to find whether the dose affected performance.

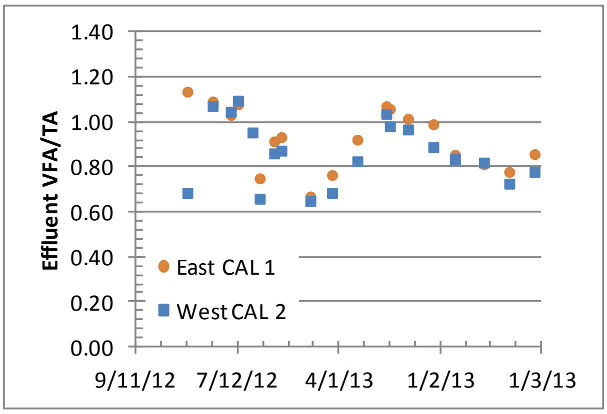


Figure 10: Effluent VFA/TA during DAF setpoint 1

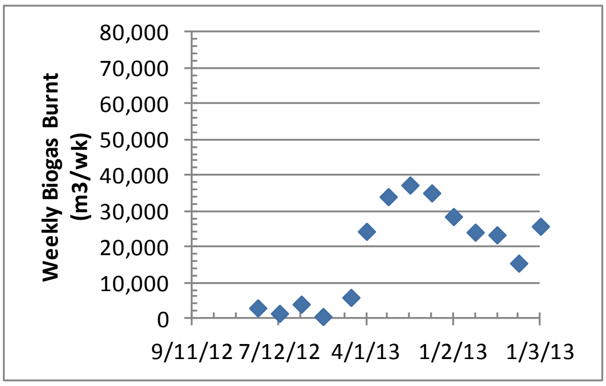


Figure 11: Weekly Biogas during DAF setpoint 1

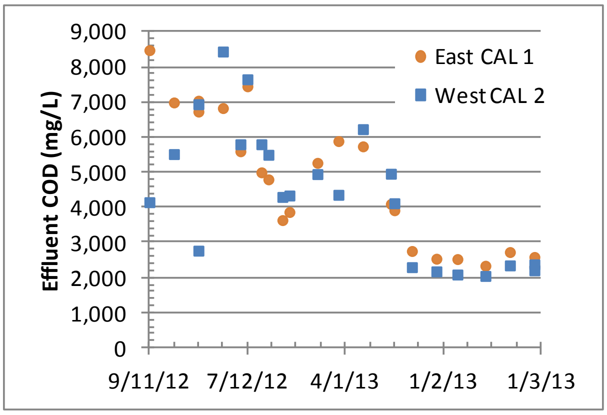


Figure 12: Effluent COD during DAF setpoint 1

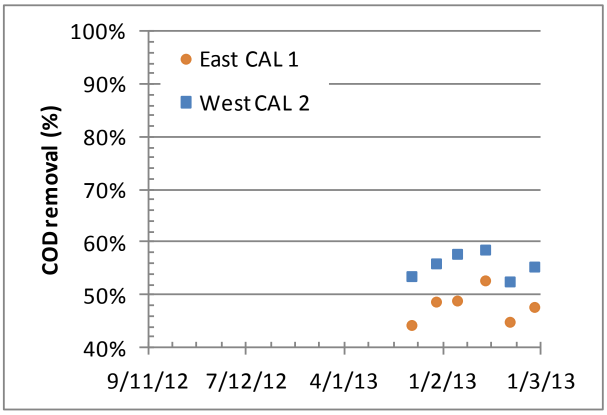


Figure 13: COD removal during DAF setpoint 1

All indicators suggest poor CAL performance during DAF setpoint 1.

- The effluent COD stabilized at 2,600mg/L and 2,200mg/L in the east and west CALs respectively by the end of DAF setpoint 1. The overall COD removal rate was 55%. This was well below the design COD removal of 85%.

- VFA /TA ratio stabilized at a ratio of 0.90 and 0.84 in the east and west CALs respectively. This high ratio suggests that the anaerobic sludge is under severe stress despite achieving some degree of treatment.

- The weekly biogas production stabilized at approximately 23,500 m^3/week.

4.4.2 Influence of DAF Setpoint 2 (Polymer 2) on CAL Performance

In early April, TFI changed from polymer 1 to a new polymer 2. Figure 14 to Figure 17 show CAL performance indicators during the period of Polymer 2 addition to the upstream DAF.

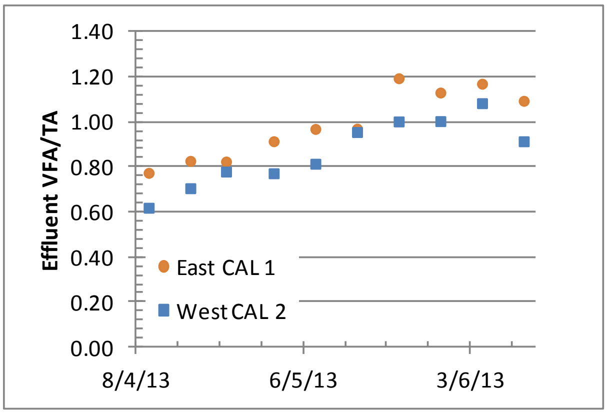


Figure 14: Effluent VFA/TA during DAF setpoint 2

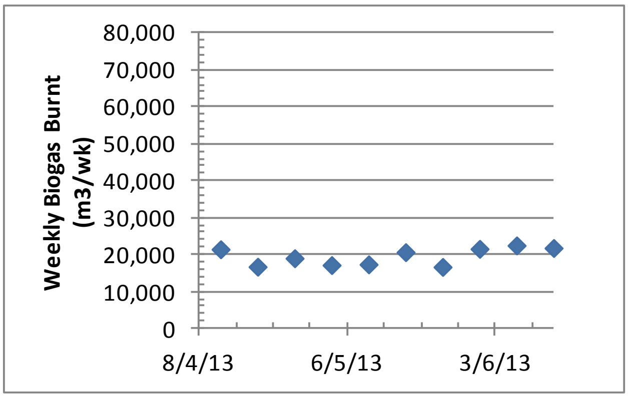


Figure 15: Weekly Biogas during DAF setpoint 2

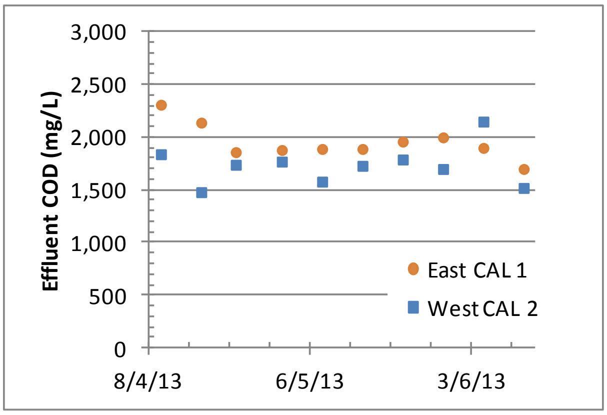


Figure 16: Effluent COD during DAF setpoint 2

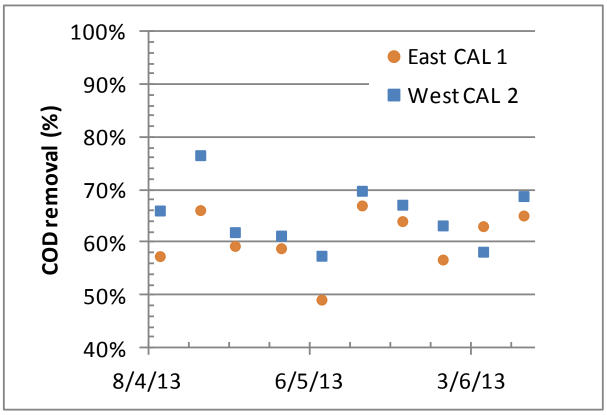


Figure 17: COD removal during DAF setpoint 2

The CAL performance indicators suggest continued poor CAL performance.

- VFA/ TA ratio worsened with ratios increasing to 1.15 and 0.92 in the east and west CALs respectively. This high ratio suggests that the anaerobic sludge was still under severe stress despite the change in polymer.

- The effluent COD were an average of 1,900mg/L and 1,700mg/L in the east and west CALs respectively. This was improved on the previous setpoint, but the overall COD removal rate was still only an average of 63%.

- The weekly biogas production in the second set point was 21,500m^3/week, which was marginally worse than the previous set point.

4.4.3 Influence of DAF Setpoint 3 (no Polymer) on CAL Performance

Work conducted by TFI to reduce the COD concentrations in the raw wastewater (primarily through the render plant upgrade) allowed the project to investigate the operational setpoint of no polymer addition in the DAF. Figure 18 to Figure 21 show CAL performance indicators during the period of no polymer addition to the upstream DAF.

All indicators suggest significant improvement in CAL performance.

- The VFA/ TA ratio declined rapidly once polymer addition ceased (Fig. 17). Unfortunately a large organic load input event during this adjustment period interrupted this trend. It took almost 3 months for both CALs to recover. This illustrates the critical risks associated with operating CALs at elevated VFA/TA ratios. Eventually, the VFA/ TA ratio stabilized below the target ratio of 0.25.

- The effluent COD also decreased in both CALs with an average concentration of 1,350 mg/L and an overall COD removal rate of 84% (Fig. 19). These results also indicate an improved CAL performance with operation within the design specification.

- The weekly biogas production increased significantly stabilizing between 50,000m^3/wk and 75,000m^3/wk depending on the influent concentration with an average value of 66,500m^3/wk (Fig. 18). This is more than double the biogas quantity observed previously.

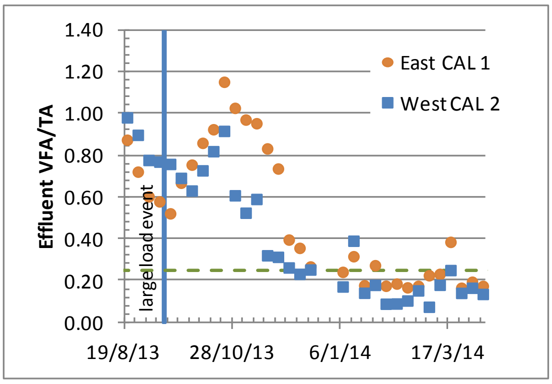


Figure 18: Effluent VFA/TA during DAF setpoint 3

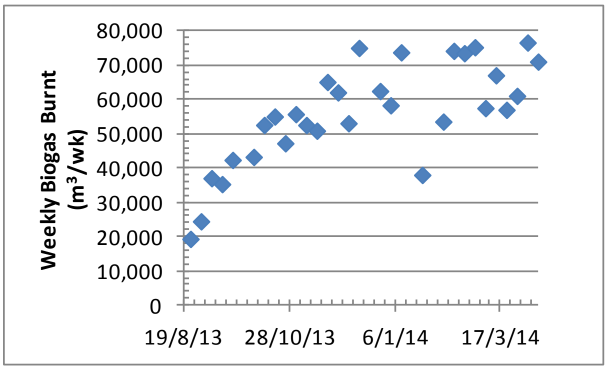


Figure 19: Weekly Biogas during DAF setpoint 3

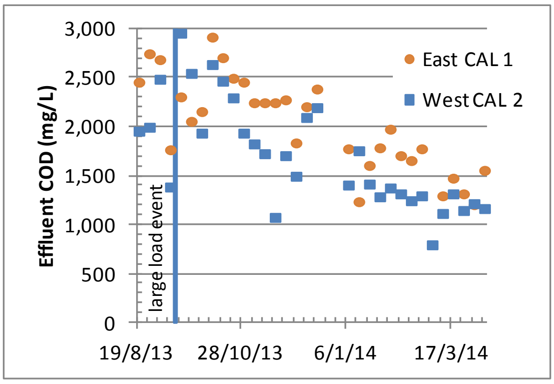


Figure 20: Effluent COD during DAF setpoint 3

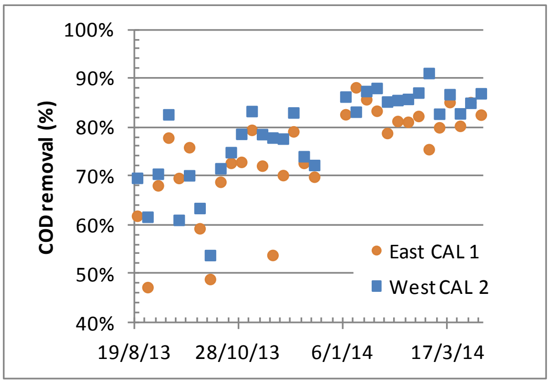


Figure 21: COD removal during DAF setpoint 3

4.4.4 CAL Performance Indicators and Summary

Table 2 presents the summary of the influent and effluent wastewater composition and the CAL performance indicators. The differences between the results in east and west CAL are unexplained.

Table 2: Summary of Performance Indicators and Wastewater Composition at DAF Settings

Parameter	unit	DAF SP 1		DAF SP 2		DAF SP 3	
		East	West	East	West	East	West
Influent							
COD in	mg/L	5,100		5,100		8,700	
BOD in	mg/L			2,300		4,200	
Performance Indicators							
Biogas Flowrate	m^3/wk	23,500		21,500		66,500	
VFA/TA		0.9	0.84	1.15	0.92	0.24	0.15
COD removal	%	51	58	62	64	83	85
COD out	mg/L	2,600	2,200	1,900	1,700	1,300	1,200
Effluent							
BOD out	mg/L	1,100	940	880	760	380	260
VFA out	mg/L	770	750	800	720	280	180
TA out	mg/L	870	910	700	790	1,200	1,200
TKN out	mg/L	260	220	250	260	280	250
NH3 out	mg/L	160	160	160	160	200	210
TSS out	mg/L	320	240	320	240	450	360
O&G out	mg/L	73	44	38	31	62	77

4.5 Crust Analysis

Figure 22 presents the results for crust thickness over the entire research period to date. The results for the crust thickness at the end of setpoint 2 have been omitted as they were only measured by method 1 which was later found to be significantly inaccurate for thick, firm crusts. Crust thickness at the end of setpoint 2 was approximately the same as those measured in October 2013.

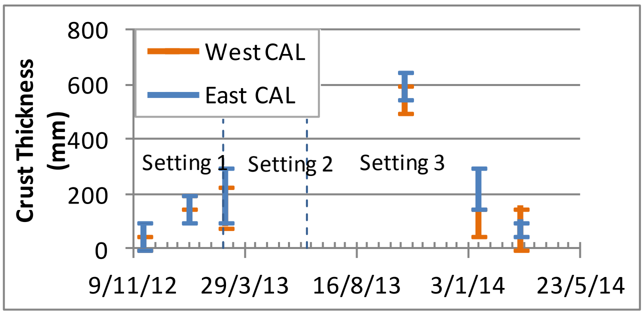


Figure 22: Crust thickness over research period

The crust thickness increased during DAF setpoint 1 and 2 despite being during periods of lower influent oil and grease concentrations. By mid 2013, at the end of DAF setpoint 2, the crust under the cover was almost 600mm thick and dark brown in colour with a firm and sticky consistency.

A significant decrease in crust thickness occurred between mid October 2013 and mid January 2014 during DAF setpoint 3 despite the higher applied organic loads. The crust remaining by March 2014 was dark brown in colour with a soft and frothy consistency.

4.6 Sludge Analysis

Sludge measurement using the Royce meter produced two values to define the sludge:

- Suspended solids measurement in the upper volume of the CAL water column as shown in Figure 23. The value indicated on the plot is the average of the values found through the upper water column at the three inspection ports across each CAL. The values were consistent across each CAL.

- The sludge depth at the base of the CAL where the suspended solids exceeded 10 g/L is shown in Figure 24. The sludge interface was sharp - occurring over a 5 cm depth interval. The bar indicates the range of sludge depths measured in three inspection ports across each CAL.

Prior to DAF setting 1, the CALs were operated with highly concentrated effluent from a polymer-free DAF. During this period, sludge accumulated in the CALs as reflected in the November 2012 values showing high TSS in the upper water layer and > 2.0 m settled sludge depth.

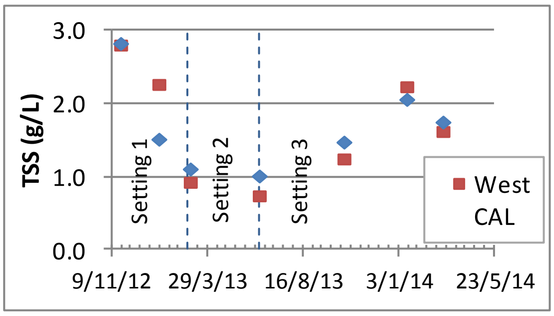


Figure 23: CAL upper layer suspended solids over research period

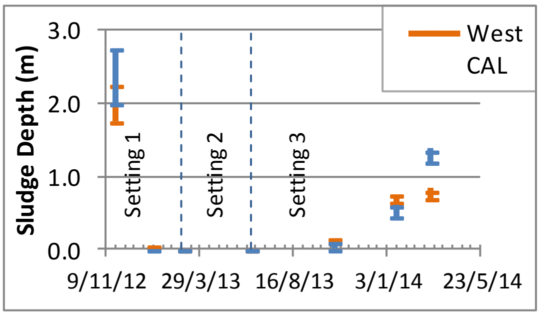


Figure 24: Sludge interface over research period

Sludge content in the CALs decreased during DAF setpoint 1 as shown by the decrease in the upper layer TSS concentration and the sludge depth. The sludge depth was effectively zero with the total solids measurement only exceeding 10g/L when the probe touched the CAL base.

Sludge conditions remained constant through DAF setpoint 2 with the low TSS concentration in the upper water volume and effectively zero sludge depth. The sludge did not accumulate during this period.

Results indicate that sludge did accumulate in the CAL during DAF setpoint 3. The TSS concentrations in the water column increased and then stabilized over the investigation period. The sludge depth also continued to increase with each measurement. Sludge presence appears to correlate with good CAL performance.

4.7 Summary of DAF Setting that Maximizes Biogas Production

It is clearly evident that the operation of an upstream DAF without polymer addition is the preferred operating mode. A COD loading of 150t/wk during DAF setpoint 3 produced 66,500m^3/wk of biogas with a methane concentration of 70v/v%.

Maximum biogas was produced during the period of healthy CAL operational conditions as indicated by the following parameters:

- NH_3/TKN ratio > 80%
- VFA/TA ratio < 0.25
- COD removal > 80%
- pH >6.5

The ammonia conversion rate indicates the degree of completion of the first stage of anaerobic treatment; namely hydrolysis and acidogenesis. The VFA/TA ratio indicates the completion of the second and most tenuous stage of the anaerobic treatment; methanogenesis. COD removal is achieved through the overall anaerobic process with the conversion of complex organic molecules to methane and carbon dioxide. Ideal pH conditions are further discussed in Section 5.1.

Figure 25 provides summary plots of the crucial parameters at the three DAF setpoints. While the influent COD increased significantly in DAF setpoint 3, the effluent COD decreased and the biomass health improved (as evidenced by VFA/TA ratio). In addition, despite the influent O&G being the greatest at DAF setpoint 3, the crust accumulation was negative. Sludge accumulation only occurred during DAF setpoint 3.

DAF operation without chemical addition removes sufficient O&G to prevent crust accumulation in the CAL. As seen in Figure 25, the crust thickness actually decreased during the period of zero polymer addition. Polymer addition is known to aid the removal of colloidal particles. This process is not be beneficial to the overall CAL performance as colloidal oils and greases are unlikely to float to the CAL surface and form crusts while their small size provides relatively easily biodegradable organic content that will form valuable biogas.

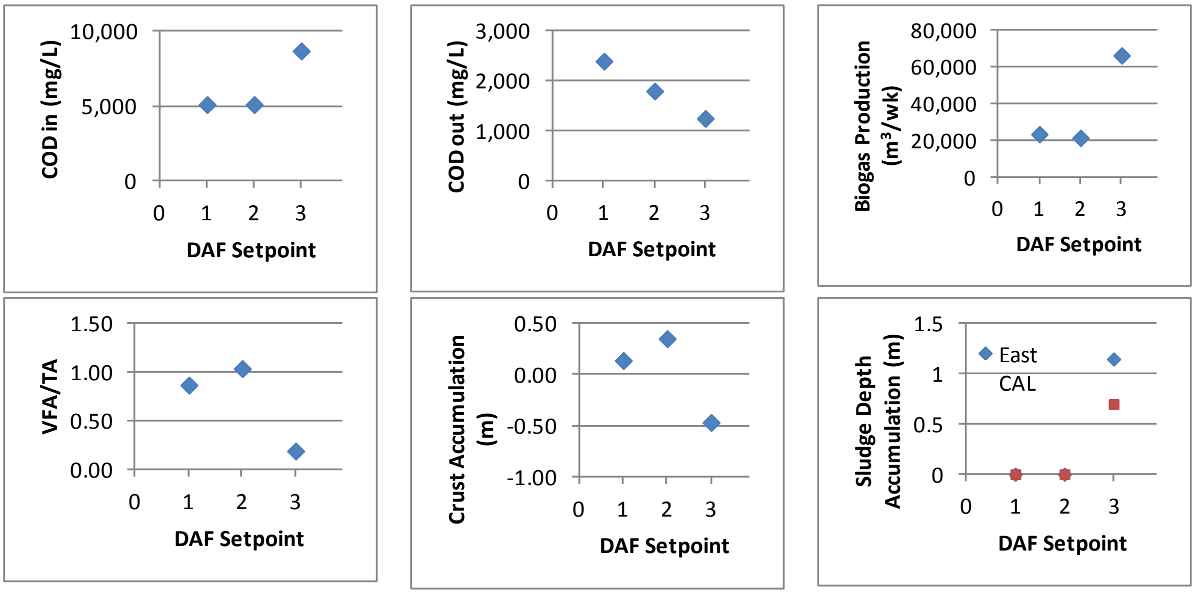


Figure 25: Comparison of CAL performance at the DAF Setpoint 1 to 3

The cause of the significant reduction in anaerobic treatment by polymer addition to the upstream DAF upstream is unknown. However a number of theories are proposed:

- The poor removal is due to underloading the CAL as discussed in Section 4.2. This is unlikely though due to the BOD loading being within the design range.
- The remaining small concentration of polymer causes the anaerobic sludge to float to the pond surface. This theory was inferred from the thick layer of crust forming within the periods of polymer addition.
- The polymer inhibits methanogenic performance. Methanogenesis is the second step in the anaerobic process that converts the VFAs to methane and carbon dioxide. This theory was inferred by the high VFA/TA ratio.
- The polymer flocs the enzymes secreted outside the bacterial cells in the acidogenic phase to hydrolyse the large complex molecules into smaller molecules that can be taken into the cell. Hydrolytic enzyme action releases ammonia from proteins and small alcohols and organic acids (such as VFAs). This theory is supported by the poor conversion of organic nitrogen to ammonia while polymer was used.

Irrespective of the reason for the poor performance, polymer addition to a DAF upstream of the CAL should be avoided especially if treating the full raw wastewater flow.

5.0 CAL Operational Learning's

This section discusses additional operational learning's from the CAL investigation at Murray Bridge.

5.1 pH

Anaerobic treatment prefers the system pH to be greater than 6.5. Below pH 6.5 the overall anaerobic process efficiency is affected with the pH controlling methanogenesis step being the most fragile. As the system degenerates, the pH reduces at an accelerating rate.

pH reduction can occur during periods where the anaerobic population is under stress. Stress may be caused during commissioning or a result of a shock COD load or rapid change in physical conditions. In a well established pond, the large volume of anaerobic sludge will provide sufficient capacity to adjust and return the system to ideal conditions. Occasionally the stress is so profound that the pH continues to fall and below approximately pH 6.5, anaerobic systems appear to exhaust their capacity to adapt.

Urgent remedial action is required if the pH falls below 6.5. If left untended, remediation becomes more difficult and could ultimately result in complete system failure.

Figure 26 shows an example of a pH drop experienced during the CAL investigation period at TFI Murray Bridge. In this case, there were two contributing factors;

1. A large load event on the 14th September 2013 depicted by the solid line,
2. The uncalibrated pH probe measurements, depicted by the unfilled marker points, returned pH values >0.5 higher than actual values.

While the load event caused an immediate 0.1 pH drop, the uncalibrated pH probe delayed action. The eventual decrease in total alkalinity, shown in Figure 27, indicated worsening anaerobic activity. The east CAL generally underperformed the west CAL for unknown reasons.

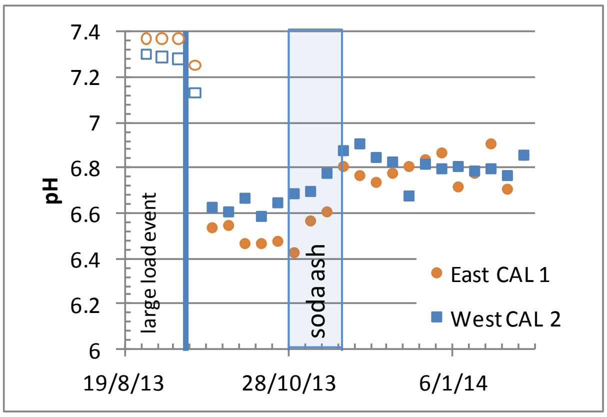


Figure 26: pH after shock load

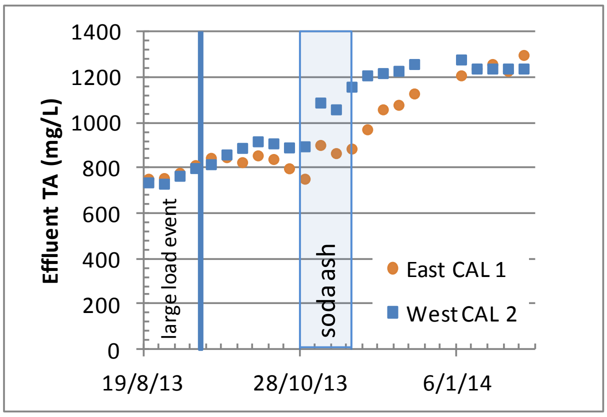


Figure 27: Total alkalinity after shock load

TFI Murray Bridge followed JEPL recommendations of soda ash addition into the CAL as a remediation measure. The impact was immediate, with pH and total alkalinity increasing to desirable levels, and subsequently promoted the CAL's recovery.

TFI Murray Bridge also required continuous addition of NaOH to the CAL feed due to the low influent pH experienced at commissioning. This is an unusual situation in Australian abattoirs as influent pH is usually greater than 7.0 and CALs are usually capable of processing slightly acidic influent. This chemical dosing remains an open issue that requires further attention.

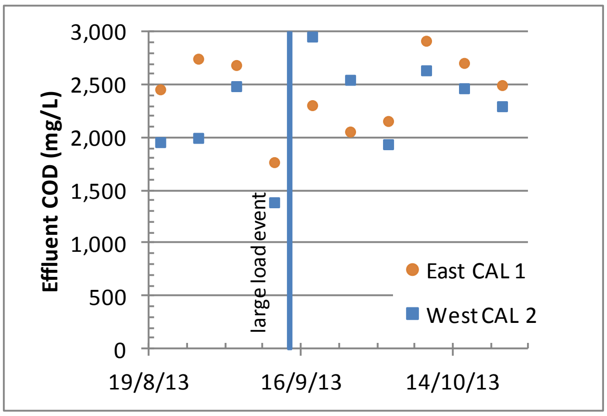
Reliable pH monitoring is crucial to sound CAL operation. The dirty nature of the wastewater environment can cause rapid fouling of the pH probe. Regular pH probe calibration is thus necessary. TFI Murray Bridge now calibrate the pH probe weekly.

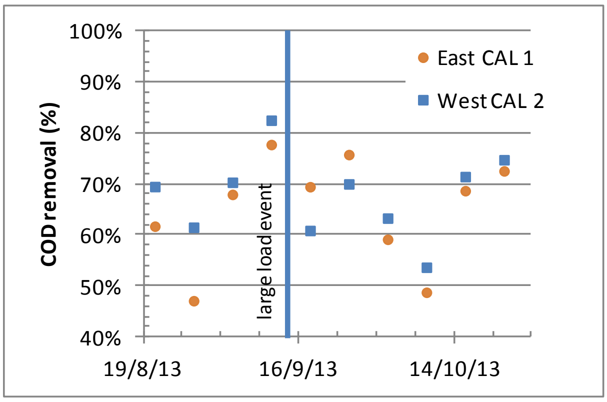
5.2 Organic Loadings

Organic loading should be maintained within the design range to ensure reasonable COD removal rates. Shock COD overloading can start a series of events that leads to the overall reduction in CAL performance. There was an overloading event experienced during the investigation period at Murray Bridge.

The cause of the shock load in September 2014 was the accidental pumping of the emergency dam into the CALs over a weekend. The impacts are shown in Section 5.1 above and Figure 28 below. When reviewing data it must be highlighted that the overloading event occurred as the CAL was adjusting towards favourable operating conditions. The results immediately prior to the large load event should be used for comparison.

All effluent parameters were affected by the large load event. Immediate impacts include; 0.1 pH unit decrease, increased effluent COD and the decreased COD removal. A slower, but profound, impact to VFA concentration and total alkalinity occurred over the following weeks. The improving weekly biogas production also plateaued. If the CAL had been operating at steady state, an event such as this would have been expected to cause a significant and sudden decrease in biogas production.





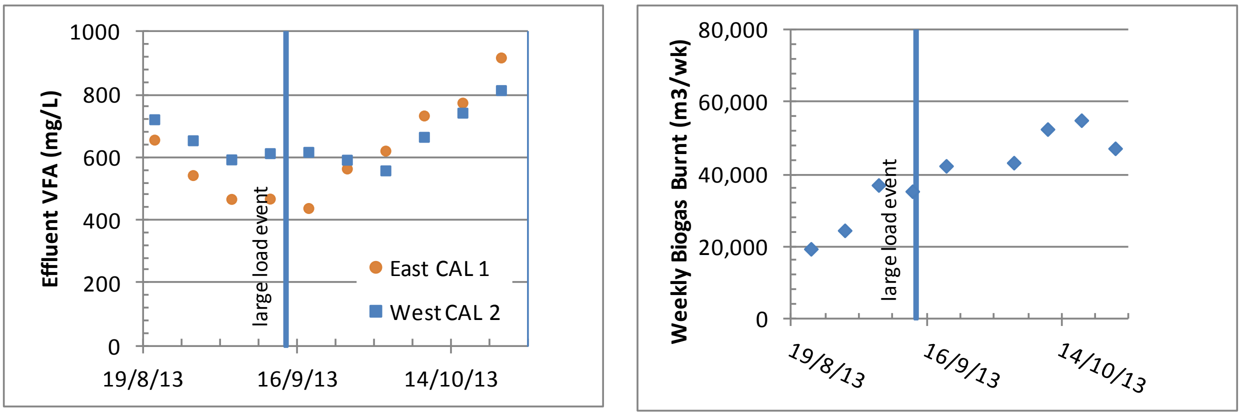


Figure 28: Effects of COD shock loading

6.0 Outcomes of Biogas Monitoring

6.1 Biogas Flow Stability and Peaking Factor

Figure 29 shows the daily biogas flowrate measured from late February 2014 after pond performance stabilized. Biogas flowrates measured during the shutdown period in April and the subsequent 2 weeks are not included as they do not represent normal operation. The average biogas daily flow during DAF setpoint 3, indicated by the dashed line, was 8,600m^3/day. The daily flowrates were less variable after the shutdown.

Biogas production was reasonably constant over the 7 day week despite the 5 day operation as shown in Figure 29. Non production day gas production (red markers) is of the same order as production days (blue markers). This highlights the need to continue controlled flaring over the weekend in order to avoid excessive biogas accumulation under the CAL covers.

Flare design requires prediction of peak biogas flow which dictates the overall flare size and thus cost. The 90th percentile of biogas flow of 12,200m^3/wk during the period illustrated in Figure 29 is equivalent to a peaking factor of 1.5. This value would be considerably lower if the CAL continues to operate in post shutdown mode.

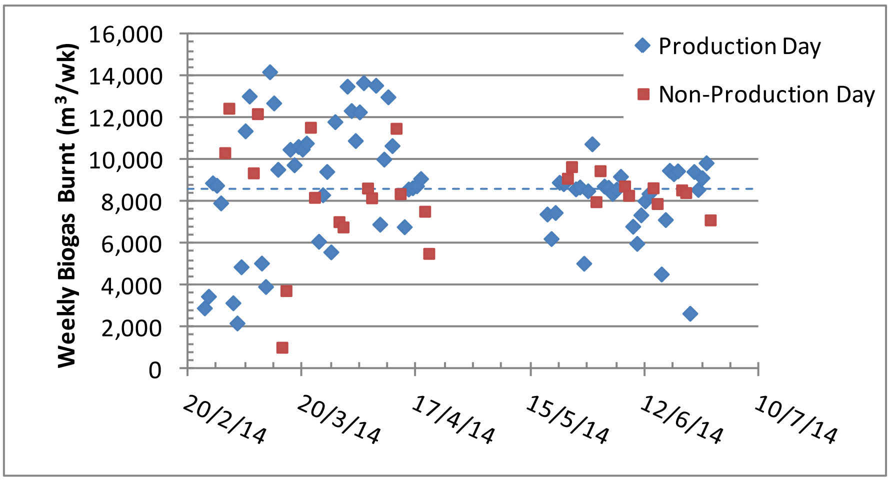


Figure 29: Daily Biogas Flowrate

6.2 Biogas Composition

Biogas methane concentration, shown in Figure 31, varied between 60 and 80 %v/v over the research period. Measurements recorded by the portable meter were 74 +/- 3 %v/v over the entire monitoring period. 70%v/v is considered t typical methane composition of anaerobic lagoon biogas and is confirmed by these results.

Figure 30 shows the measured H_2S concentrations over the research period. H_2S concentration decreased from ~2,500ppm to 1,600ppm as the biogas flowrate increased. The highest H_2S concentration of 2,800ppm on the 24th January 2013 occurred when the CAL performance was poor with high VFA/TA ratio and low biogas production. The lowest H_2S concentration of 1,600 (3 separate measurements) occurred when the CAL performance was excellent with healthy

VFA/TA ratio, good COD removal and high biogas production. This could be explained by the higher biogas volume diluting a constant quantity of H_2S release.

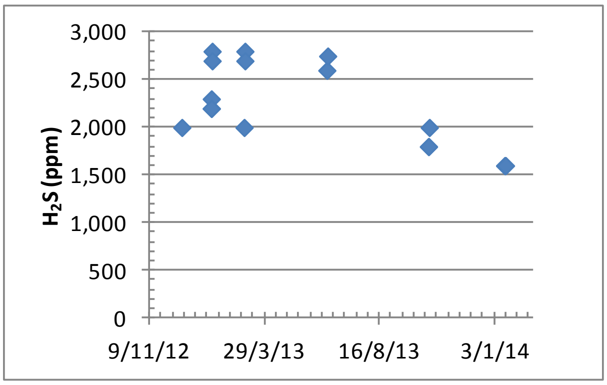


Figure 30: Biogas H_2S over research period

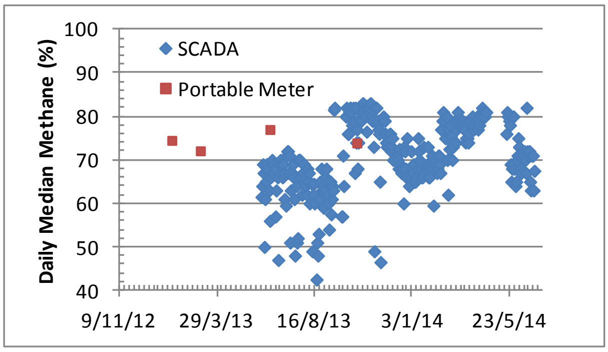


Figure 31: Biogas CH_4 over research period

7.0 Testing of Sludge Recirculation System

The sludge recirculation system installed at the time of CAL commissioning was tested at the conclusion of DAF setting 3. By this time, there was sufficient sludge in the base of the CAL. The testing was to determine how to best operate the system and to assess if sludge concentration decreased after a long pumping period due to sludge concentration decreasing in the immediate vicinity of removal site.

The pumping mechanism used in the sludge recirculation system proved inadequate with sludge flowrates quickly decreasing to insignificant levels. The degassing of the biogas-saturated sludge under low suction pressure and typical shear thickening rheological behavior of dense sludge probably caused pump cavitation. Flowrates continued to be poor even with continuous addition of water to the system. The installed centrifugal pumps were inadequate to cope with the unique sludge properties.

Pump specialists are currently contemplating the sludge recirculation system and aim to resolve the pumping challenges.

The total solids content of the sludge withdrawn from the sludge pumping trials varied between 1.4 and 4.4%. It is, however, difficult to assess the true value of the pure sludge total solids as the sludge was diluted with an unknown ratio of water.

8.0 Cost Benefit Analysis of Biogas Utilization

Biogas is a valuable energy source that is potentially wasted if simply flared. To utilize this resource, the biogas must be cleaned and transported to an onsite boiler or cogeneration unit.

The capital expense of installing a system to allow for the utilization of the biogas includes the biogas scrubber and pipeline. While the CAL and the boiler are necessary for the production and utilization of the biogas, they are primarily for the purposes of wastewater treatment and onsite heating respectively.

The estimated capital expense of the TFI Murray Bridge biogas scrubber and pipeline is $550,000. Murray Bridge installed an iron adsorption scrubber (Photo 7) and HDPE piping (Photo 8) to a newly installed boiler in order to utilize the 66,500m^3 of biogas per wk (as per DAF setpoint 3). The capital costs to install this system, as summarized in Table 3, include the initial installation expense of the biogas scrubber and biogas pipeline to the boiler room of $150,000. However, the existing scrubber is insufficient to treat the high H_2S concentrations in the biogas and will require upgrading at the expense of approximately $400,000. The biogas system is assumed to have a 20 year life.

Photo 7: Current biogas scrubbers that require upgrade

Photo 8: Biogas pipeline leaving CAL site

Table 3: Capital Expense Items required for Biogas Utilization

Item	Capital Expense
Biogas Pipeline & Initial Scrubber	$150,000
Scrubber upgrade	~$400,000
Total Capital Expense	**~$550,000**

The estimated operating expense of the biogas system will include the replacement of scrubber material and miscellaneous maintenance expenses. Operating labour expense will be minimal. The operating expense will be estimated at 10% of the capital cost equating to $55,000 per year. A more accurate figure for operating expense will be possible after a number of years of operation.

The biogas produced at TFI Murray Bridge facility has an estimated value of $730,000 per year. This assumes that the continued biogas production of 66,500m^3/wk with a methane content of 70%. Table 4 summarizes the assumptions and values used to calculate this value.

Table 4: Biogas Value Calculation

Parameter	Unit	Value
Biogas Flowrate	m^3/wk	66,500
Methane Composition	%	70
Methane Energy Content	MJ/m^3	33.81
Natural Gas Price	$/GJ	9.65
Production Weeks	wk/yr	48
Natural Gas Saving	$/yr	730,000

A simple assessment presented in Table 5 highlights the significant benefit of installing infrastructure to enable biogas utilization. A total saving of nearly $13 million is gained over the estimated 20 year life of the biogas system. The natural gas offset also repays the capital expense of the biogas pipeline and scrubber in less than one year. Biogas utilization for onsite boilers appears to highly desirable at this level of analysis.

Table 5: Cost Benefit Analysis

	Yearly Expense	No. Years	Total
Biogas System CAPEX			$550,000
Biogas System OPEX	$55,000	20	$1,100,000
Natural Gas Saving	-$730,000	20	-$14,600,000
Overall			**-$12,950,000**

9.0 Recommendations

1. Avoid polymer addition to DAF units located immediately upstream of an anaerobic wastewater treatment unit and treating a substantial fraction of the wastewater as it was shown to have severely negative impacts on CAL treatment efficiency irrespective of dosage.

2. Monitor pH accurately to detect system disturbances and enable implementation of remediation measures prior to serious and/or irretrievable system failure. The protein and fat-rich wastewater in the feed to CALs in meat processing plants makes regular cleaning and calibration of pH probes essential to avoid false results.

3. Investigate the benefits of increase sludge/wastewater mixing on biogas production and wastewater treatment efficiency. The significant biogas monetary value may warrant further attention to increase its production.

4. Install infrastructure to enable biogas utilization. Biogas is a valuable resource that can potentially save a facility millions of dollars over the lifetime of the biogas system.

10.0 Conclusions

The main conclusions drawn from this report are as follows.

- Addition of polymer to a DAF upstream of an anaerobic system significantly hinders its wastewater treatment ability especially when it is treating a high proportion of the total flow. The reason for the negative polymer effect is unknown.

- DAF operation without chemical addition removes sufficient O&G to prevent crust accumulation in the subsequent CAL provided a modern and effective DAF is installed.

- A COD loading of 150 tonne/wk produced 66,500m^3/wk of biogas with a typical methane concentration of 70v/v%.

- Healthy CALs operate at
  - VFA/TA ratio < 0.25
  - COD removal > 80%
  - NH_3/TKN ratio > 80%
  - pH >6.5

- CAL performance is severely affected at pH levels below 6.5 with immediate intervention required.

- pH monitoring is crucial to the sound CAL operation. Regular pH probe calibration is recommended as the dirty nature of the wastewater environment can cause rapid fouling.

- COD loading rates should be maintained within the design range to ensure reasonable COD removal rates. In addition, shock COD overloading can start a series of events that leads to the overall reduction in CAL performance.

- Biogas production was reasonably constant over the 7 day week despite the 5 day production week. Peaking factors of 1.5 were experienced once the CAL operation stabilized.

- Biogas methane concentration was relatively constant over the entire monitoring period with the exception of a peak seen at the installation of a new meter. In contrast, the H_2S concentration decreased from 2,500ppm to 1,600ppm as the flowrate per unit liquid volume increased.

- The sludge recirculation system installed at the time of CAL commissioning was not adequate to pump anaerobic sludge. Pumping rates rapidly declined as the unique sludge characteristics of shear thickening rheology and degassing caused significant pump cavitation.

- Installation of a scrubber and biogas pipeline to enable the use of the biogas in an onsite boiler is economically feasible with an approximate payback period of less than one year.

Abbreviations

BOD_5	=	Biochemical Oxygen Demand (after 5 days at 20°C) (mg/ℓ).
CAL	=	Covered Anaerobic Lagoon
CH_4	=	Methane
COD	=	Chemical Oxygen Demand (mg/ℓ)
DAF	=	Dissolved Air Flotation
EC	=	Electrical conductivity
JEPL	=	Johns Environmental Pty Ltd
HTR	=	High Temperature Rendering
H_2S	=	Hydrogen Sulphide
NH_3-N	=	ammonia-nitrogen concentration (mg/ℓ)
NO_2-N	=	nitrite-nitrogen concentration (mg/ℓ)
NO_3-N	=	nitrate-nitrogen concentration (mg/ℓ)
O&G	=	Oil and Grease
PLEA	=	Probiotic Low Energy Aeration
SP	=	Setpoint
SS	=	suspended solids concentration (mg/ℓ)
TA	=	Total Alkalinity (mg/ℓ)
TFI	=	Thomas Foods International
TKN	=	Total Kjeldahl nitrogen (mg/ℓ)
TN	=	Total Nitrogen concentration (mg/ℓ)
TP	=	Total Phosphorus concentration (mg/ℓ)
TSS	=	Total Suspended Solids (mg/ℓ)
VFA	=	Volatile Fatty Acids (mg/ℓ)
WWTP	=	Wastewater Treatment Plant

LIST of UNITS

kg	=	kilogram
kL/d	=	kilolitres (cubic metres) per day
L	=	litre
m	=	metre
mg/L	=	milligrams per litre = ppm.
ML	=	Megalitres (1,000 kL)
ML/wk	=	megalitres per week

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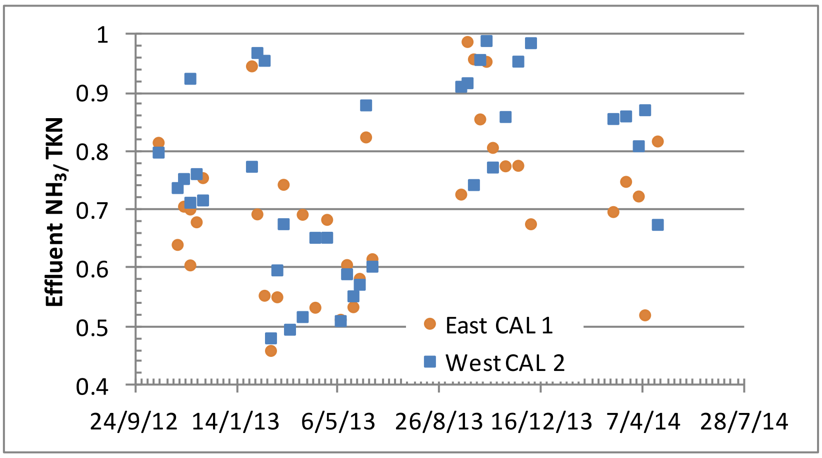
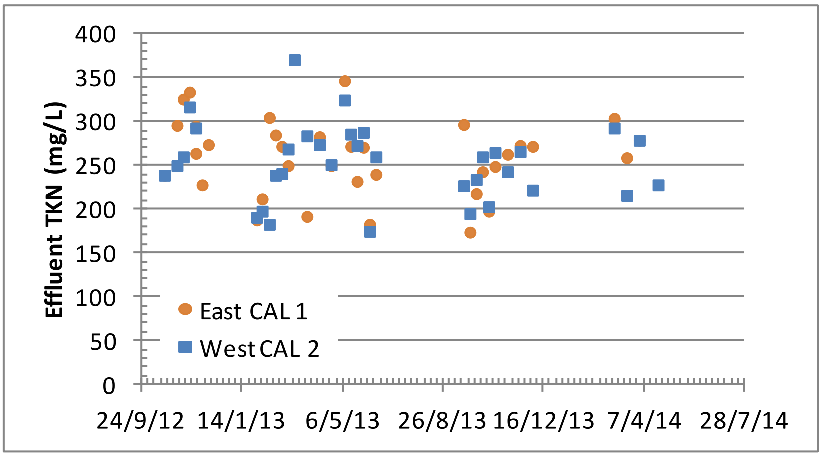
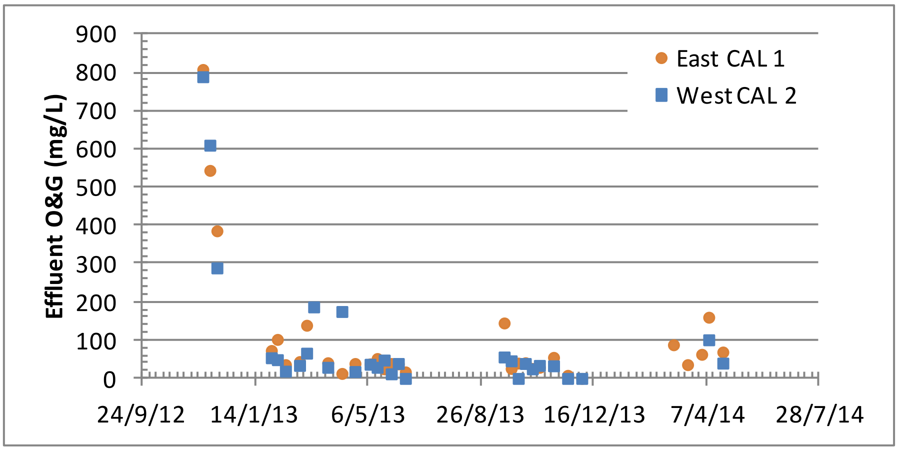
Date Issued:	14 Aug 2014
QA:	Paula Janetski & Dr Mike Johns
Client input finalised:	Yes
Sub-consultant	None

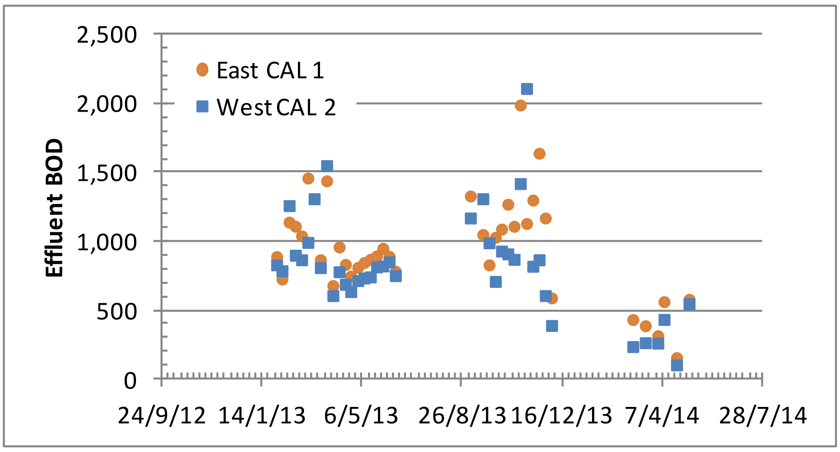
Appendix A: Full Data Set

Data from Entire Research Period





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1,500
1,000
500
0
Effluent BOD
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West CAL 2
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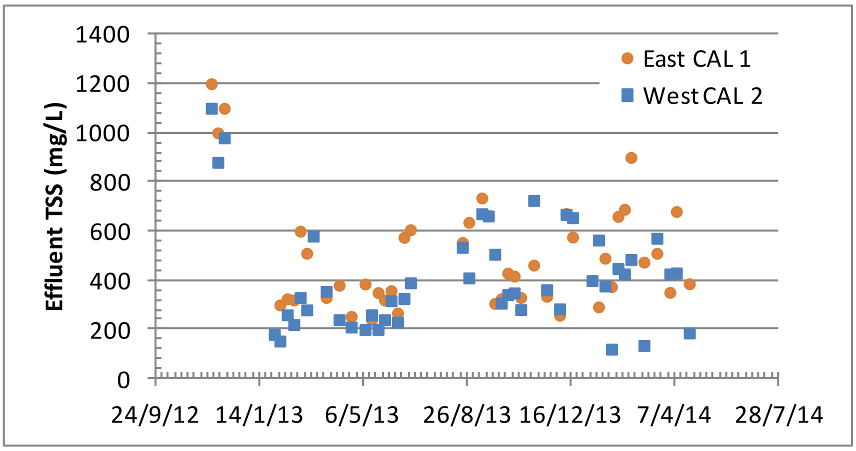
6/5/13
26/8/13
16/12/13
7/4/14
28/7/14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1200
1000
800
600
400
200
0
Effluent TSS (mg/L)
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West CAL 2
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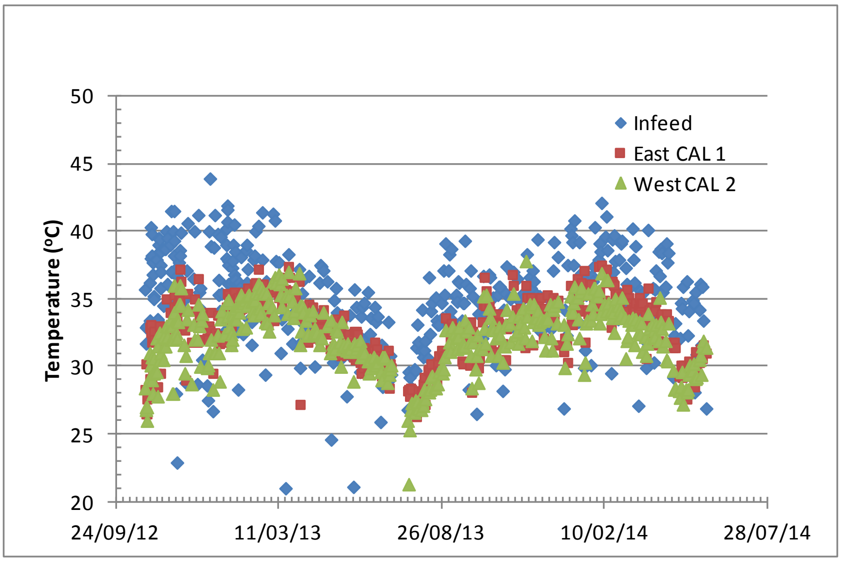
16/12/13
7/4/14
28/7/14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35
30
25
20
Temperature (ºC)
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West CAL 2
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11/03/13
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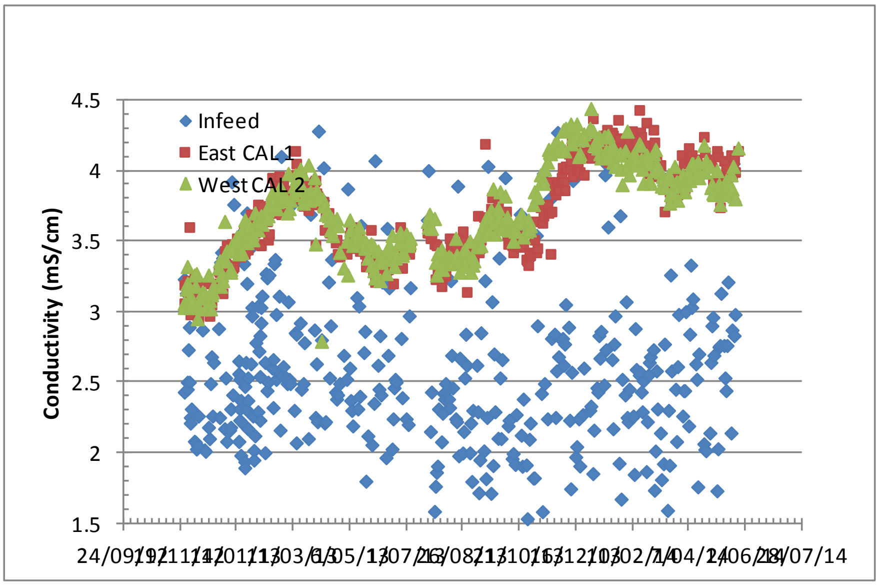
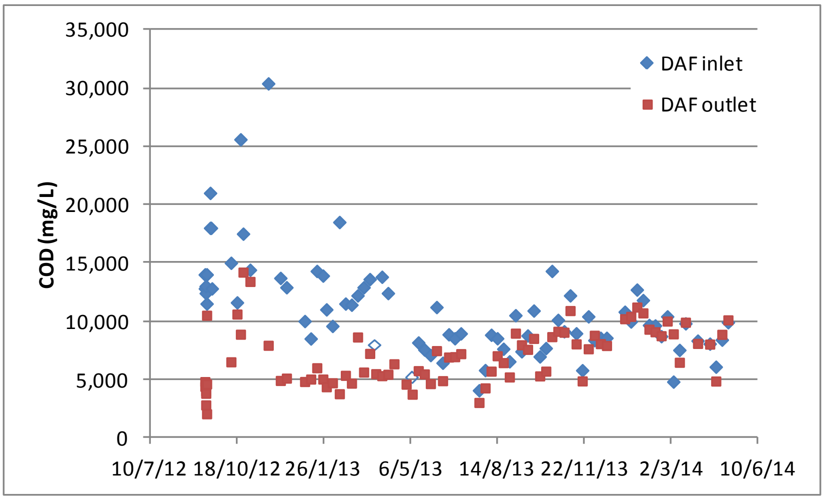
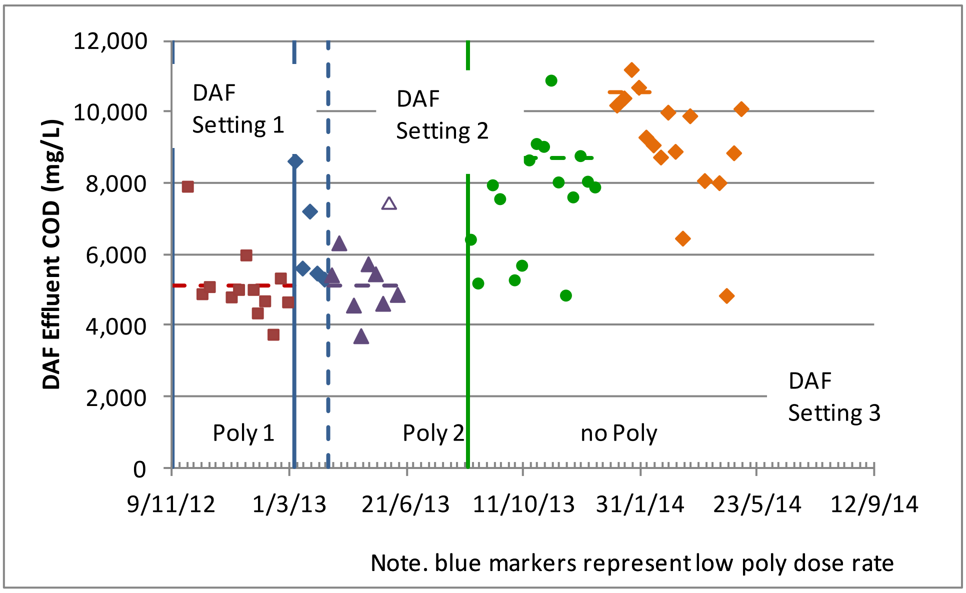
10/02/14
28/07/14



Infeed
East CAL 1
West CAL 2
Conductivity (mS/cm)
4.5
4
3.5
3
2.5
2
1.5



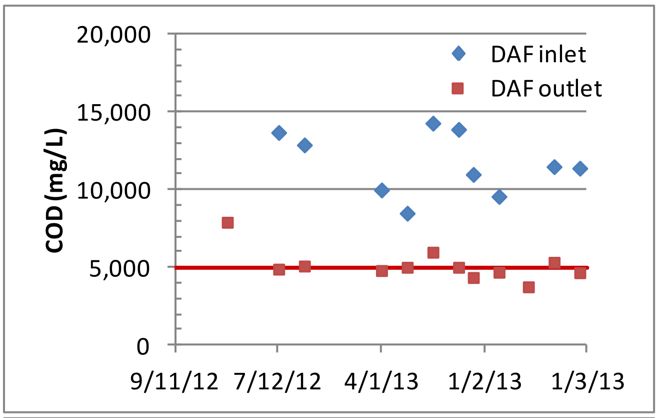
DAF inlet
DAF outlet
COD (mg/L)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
10/7/12 18/10/12 26/1/13 6/5/13 14/8/13 22/11/13 2/3/14 10/6/14

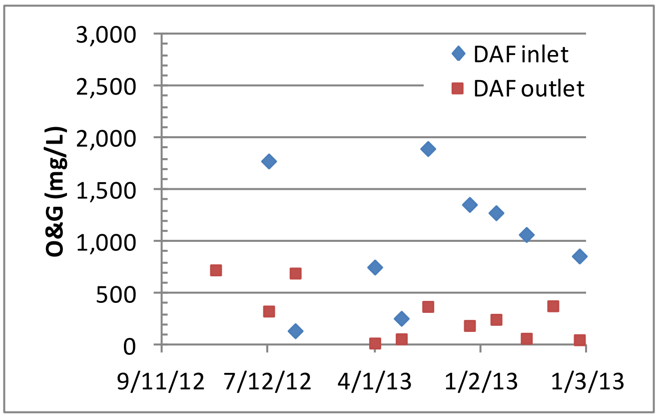


DAF Effluent COD (mg/L)
12,000
10,000
8,000
6,000
4,000
2,000
0
DAF Setting 1
DAF Setting 2
DAF Setting 3
Poly 1
Poly 2
no Poly
9/11/12 1/3/13 21/6/13 11/10/13 31/1/14 23/5/14 12/9/14
Note. blue markers represent low poly dose rate

DAF Set Point 1

DAF Setpoint 1 - DAF Effluent





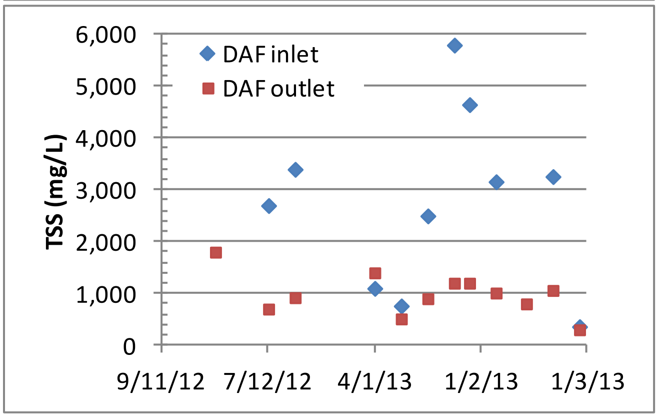
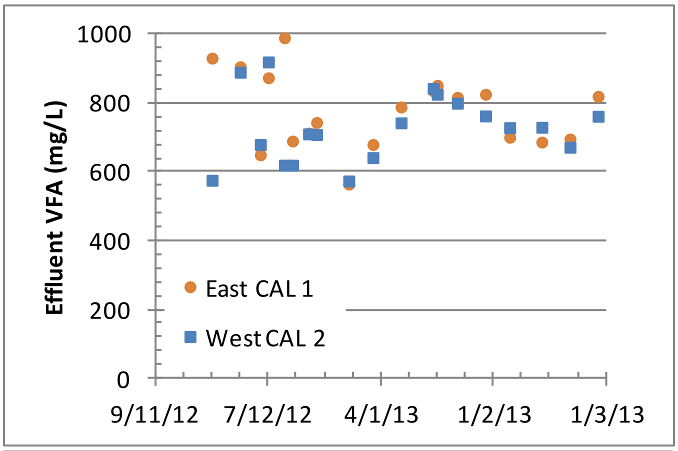
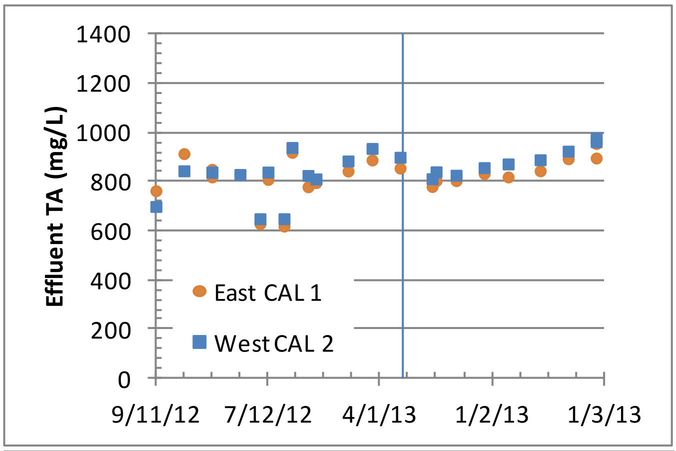


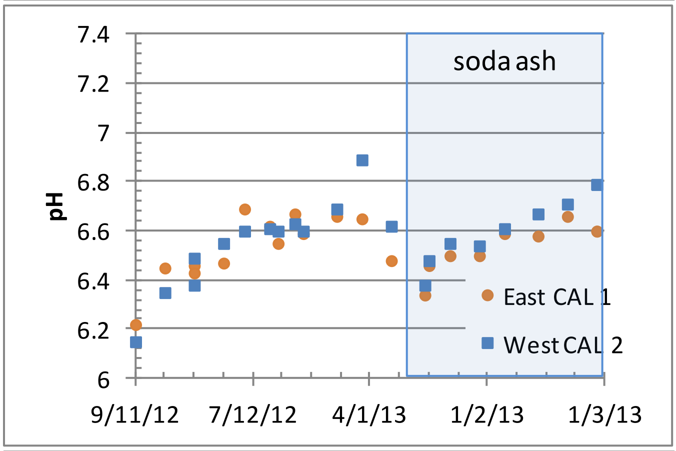
Table A1: DAF Setting 1 Effluent over Production Day

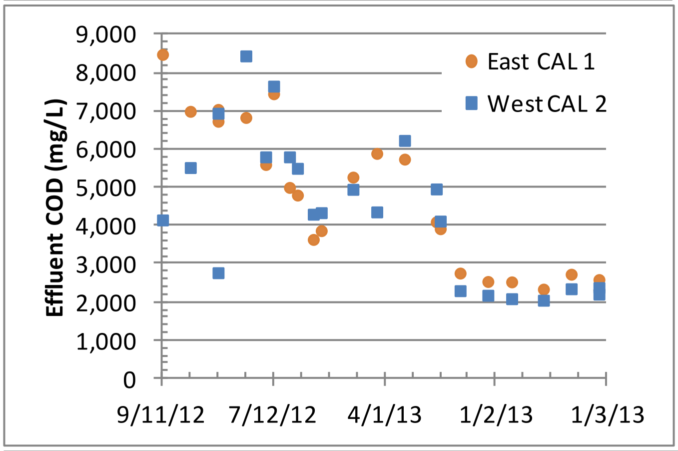
Time	DAF Setting	COD	TSS	O&G
5/03/2013 13:00	1	6,860	1,790	540
5/03/2013 15:00	1	8,440	2,160	863
5/03/2013 17:00	1	4,760	1,060	475
5/03/2013 19:00	1	5,440	1,160	499
5/03/2013 21:00	1	6,700	1,540	638
5/03/2013 23:00	1	7,100	1,400	376
Set 1 Median		6,780	1,470	520

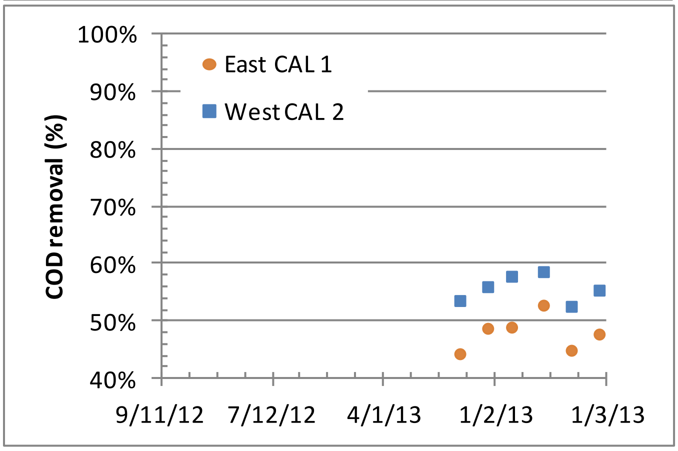
DAF Setpoint 1 - CAL Effluent

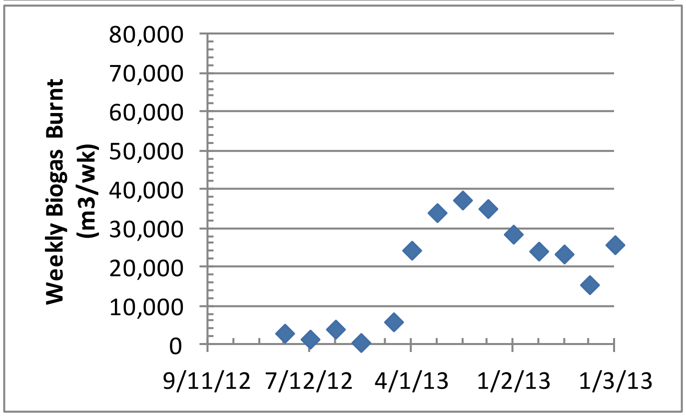






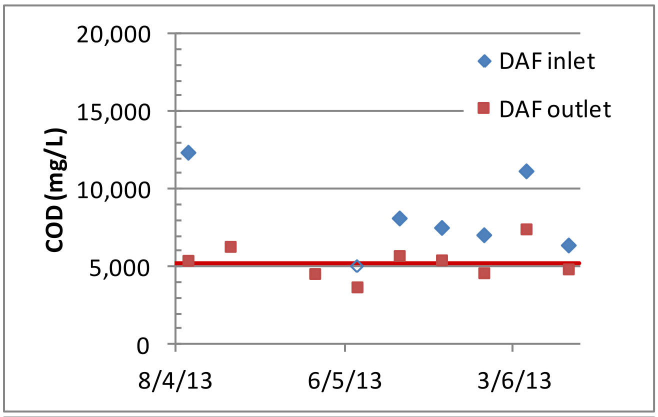


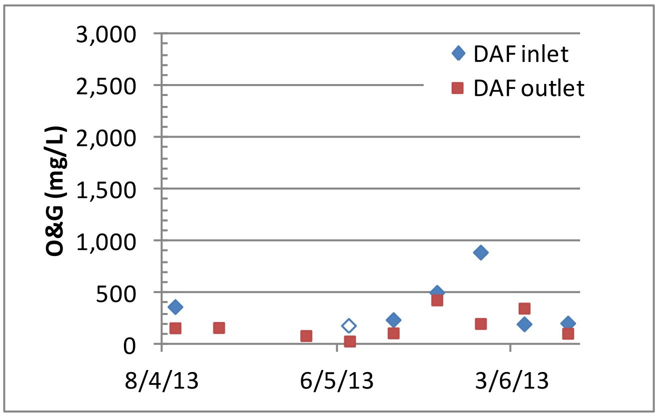




DAF Setpoint 2

DAF Setpoint 2 - DAF Effluent





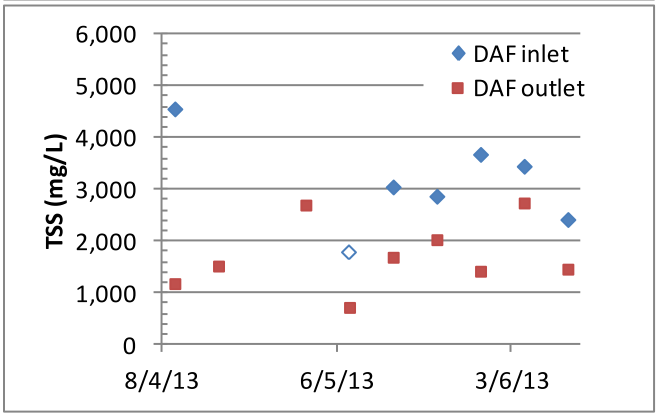
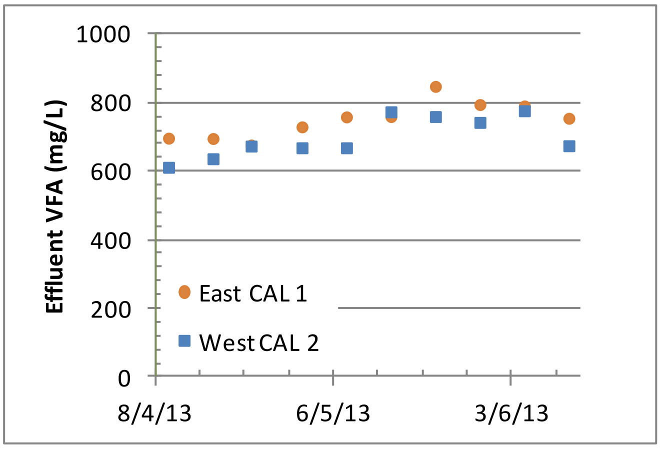
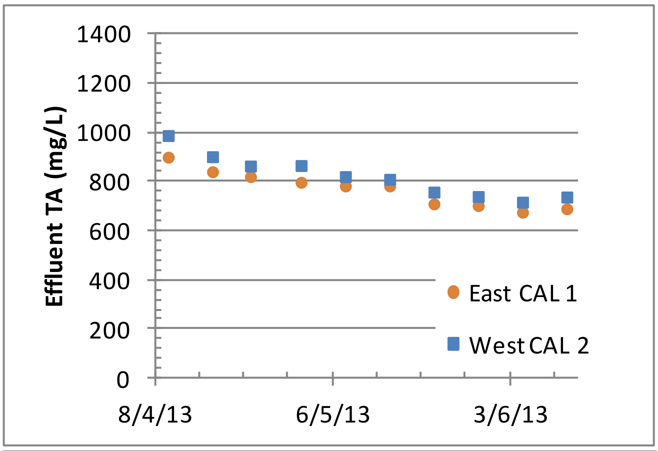


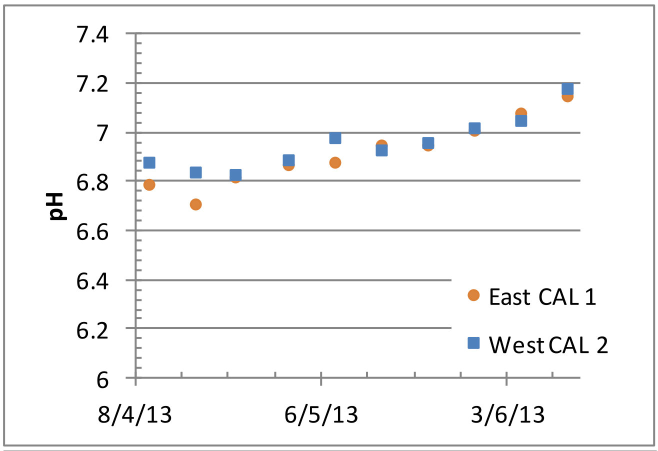
Table A2: DAF Setting 2 Effluent over Production Day

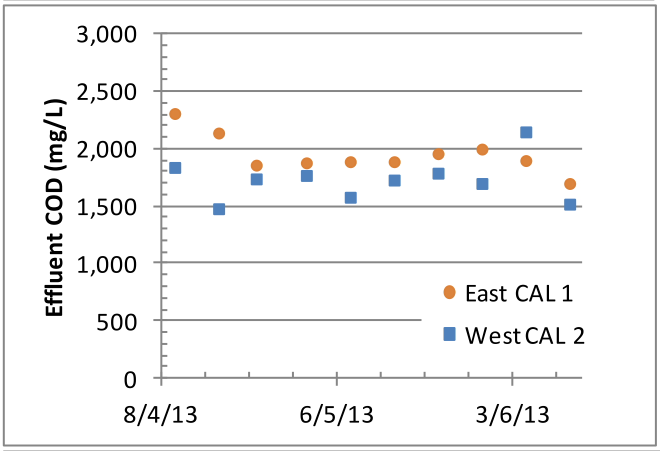
Time	DAF Setting	pH	EC	COD	TSS	O&G
13/06/2013 11:00	2	7.71	2440	3,680	1,320	103
13/06/2013 13:00	2	7.64	2260	4,360	1,680	134
13/06/2013 15:00	2	7.64	2290	5,000	1,830	185
13/06/2013 17:00	2	7.67	2520	5,320	1,700	199
13/06/2013 19:00	2	7.68	2820	5,200	2,040	147
13/06/2013 21:00	2	7.65	2860	6,140	2,230	119
13/06/2013 23:00	2	7.63	2690	6,720	2,050	167
14/06/2013 1:00	2	7.64	2790	6,020	1,840	243
14/06/2013 3:00	2	7.71	3000	4,610	1,980	153
14/06/2013 5:00	2	7.66	3420	5,400	1,820	301
14/06/2013 7:00	2	7.88	3810	3,850	1,200	142
14/06/2013 9:00	2	7.8	3330	5,080	1,450	205
Set 2 Median		7.665	2805	5,140	1,825	160

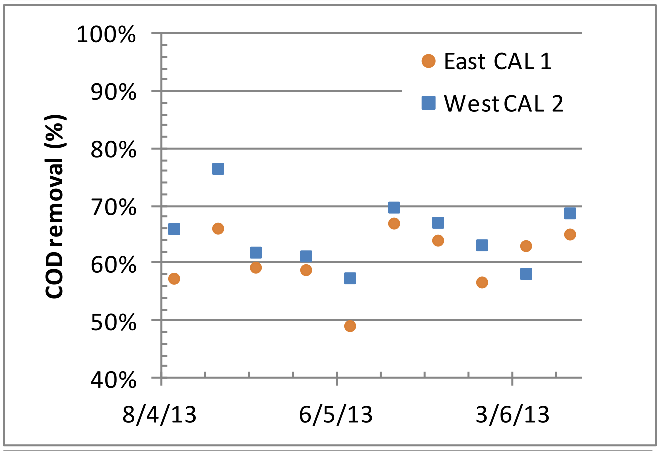
DAF Setpoint 2 - CAL Effluent

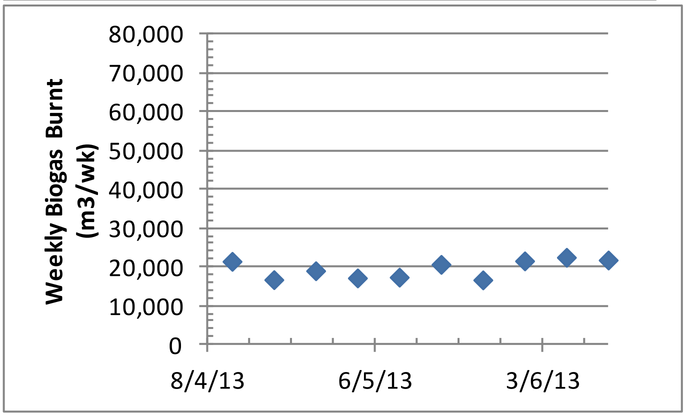


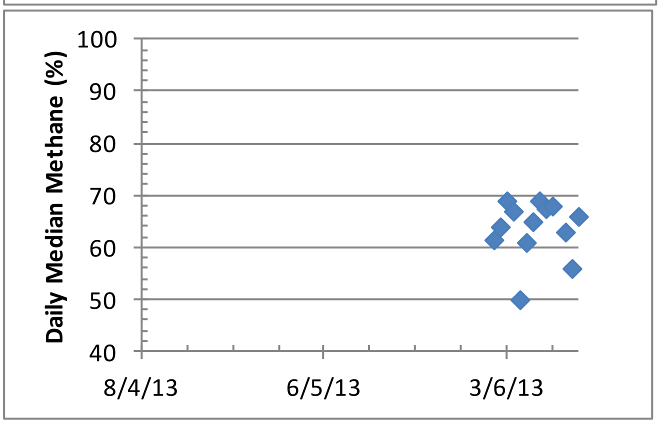






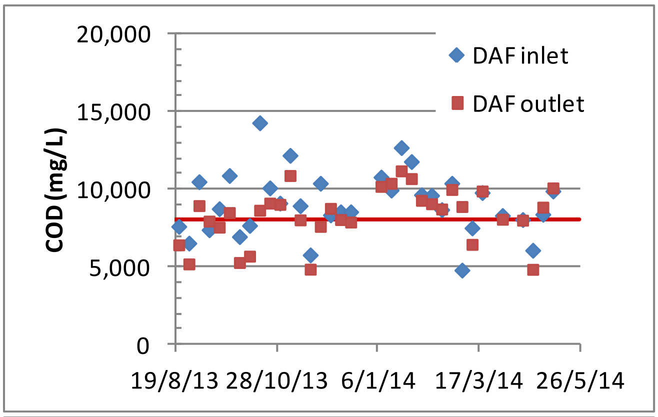


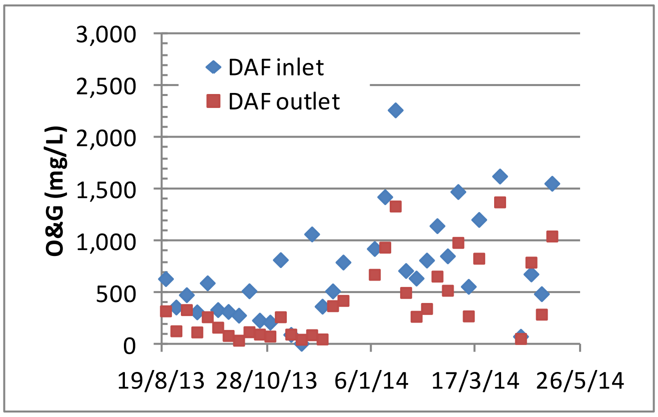




DAF Setpoint 3

DAF Setpoint 3 - DAF Effluent





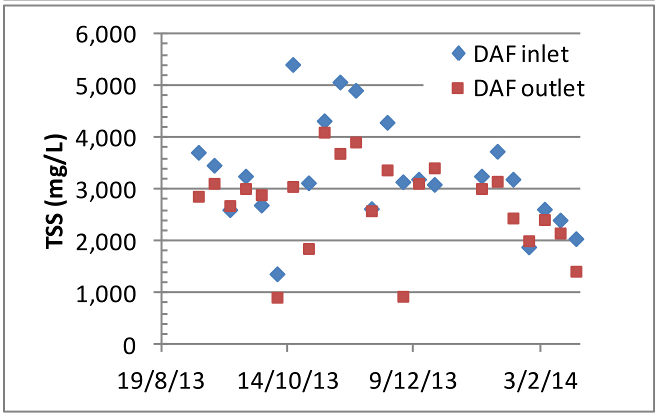


Table A3: DAF Setting 3 Effluent over Production Day

Time	DAF Setting	pH	EC	COD	TSS	O&G (mg/L
16/01/2014 8:00	3	7.1	1.99	7,560	1,960	1,010
16/01/2014 10:00	3	6.96	2.03	8,080	1,610	721
16/01/2014 12:00	3	6.89	2.3	8,720	3,490	891
16/01/2014 14:00	3	6.9	2.28	9,180	3,540	943
16/01/2014 16:00	3	6.9	2.26	11,600	4,010	897
16/01/2014 18:00	3	6.91	2.28	12,700	4,360	1,010
16/01/2014 20:00	3	6.95	2.43	12,300	4,170	1,080
16/01/2014 22:00	3	6.96	3.85	10,400	2,740	983
17/01/2014 0:00	3	7.06	3.19	10,400	2,800	1,120
17/01/2014 2:00	3	7.08	2.6	7,810	3,100	1,620
17/01/2014 4:00	3	6.62	3.84	2,670	1,240	493
17/01/2014 6:00	3	7.15	2.11	7,400	2,700	1,180
Set 3				9,068		996

DAF Setpoint 2 - CAL Effluent