"INNOVATIVE SUSTAINABLE SYSTEMS UTILIZING ECONOMICAL SOLUTIONS (ISSUES)"

A Three-Component Program

FINAL REPORT

For the NC Attorney General-Smithfield Foods/Premium Standard Farms/Frontline Farmers Agreements

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Project Title:

Innovative Sustainable Systems Utilizing Economical Solutions (ISSUES).

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EXECUTIVE SUMMARY

Innovative Sustainable Systems Utilizing Economical Solutions (ISSUES) consists of three separate approaches to swine waste management building upon the existing lagoon and sprayfield technology. In addressing performance requirements set forth and outlined in the NCAG/SF/PSF/FF Initiative (Agreement) for consideration as "Environmentally Superior Technologies" (EST) the goal became to utilize, incorporate, and maximize the existing infrastructure. This goal also included efforts to provide an EST that would become both operationally and economically feasible for the swine industry.

The following is a summary of the three ISSUES technologies and the performance of those sites relative to nutrient management and operational feasibility, consistent with the terms of the Agreements.

Aerobic Blanket Technology (ABS)

Installed on a site with 9 finishing houses (6480 animals), the ABS technology incorporated the use of aerated lagoon liquid (IESS system) for potential nitrification and the creation of an aerobic "blanket" (ABS) by misting the nitrified liquid over a portion of the primary anaerobic treatment lagoon. The objective of the ABS was to reduce odor and ammonia emissions from the lagoon. In addition, IESS treated liquid was used to recharge 2 of the finishing houses in efforts to offer further impact on emissions especially in the animal housing area.

Assuming the ABS technology operated under steady state conditions, the total system resulted in a reduction of nitrogen (N) fractions of 27-33 percent (total N and NH_4-N) with an increase of 59 percent in nitrate (NO_3). It is assumed the N reduction is the result of emissions of both ammonia (NH_3) and/or dinitrogen gas (N_2) and retention in organic forms associated with sludge biomass accumulation. This phase of the overall project did not address these partitions. A dramatic temperature/seasonal effect was noted in respect to the IESS component resulting in a substantial NH4-N reduction and NO_3-N increase with 54 and 66 percent reductions taking place in total N and NH_4-N respectively and a 286 percent increase in NO_3-N (input vs. output). It should also be noted repairs to the IESS component coincided with the seasonal changes referenced previously.

A 40 percent solids reduction was observed across the complete system. The retention of minerals phosphorus (P), zinc (Zn) and copper (Cu) occurred at rates of 50 percent (P), 64 percent (Zn) and 35 percent (Cu) respectively. It is assumed these retentions are associated with the accumulation of biomass as sludge as noted above and indicate containment and management by this retention. However, these retentions would need to be considered in the nutrient management practices if the sludge was to be ultimately land applied.

Based on the nutrient data the ABS system (misting of IESS (nitrified) liquid) did not appear to be effective. If mechanical difficulties encountered for continual operation of the aeration equipment can be managed, the use of the IESS system in conjunction with the primary lagoon and the use of IESS-treated liquid as flush water for all of the houses (only 2 of 9 houses were recharged with treated water) substantial treatment of N could potentially be provided. Operation requirements (labor) were considered to be minimal in regards to day to day operation but would require daily monitoring. Subsequent data on ammonia and odor emissions, as well as, pathogen analysis would provide additional data needed for consideration as an EST.

Permeable Cover System (PCS)

The Permeable Cover System (PCS) site consisted of 5 finishing barns with a combined capacity of 6120 animals with two barns providing waste to the PCS. The system components included an anaerobic treatment lagoon with a permeable cover (PC) to aid in management of nitrogen (N) and nutrients and reduction of emissions of ammonia and odor; and an aerobic digester (AED) to enhance nitrification. Recharge liquid for the two test houses was provided from the AED. Excess liquid from the AED was held in a storage basin for subsequent land application.

Assuming steady state operating conditions, the PCS resulted in a 51% reduction of total N across the entire system and 46 percent for NH_4-N. Nitrate (NO_3-N) increased 16 percent indicating nitrification activity. Quantitatively the PC lagoon component resulted in the greatest changes. A reduction of 37 percent in total nitrogen and 25 percent in NH4-N was observed in the PC lagoon with a small (6 percent) gain in NO_3-N. The AED reduced total N by 17 percent and NH_4-N by 22 percent with an increase in NO_3-N of 15 percent. The storage basin impacts are less reliable due to irregular removals of the stored treated water for land application (and later for the evaporation system) with smaller quantities of N being processed in earlier stages of the system. A reduction of 62 percent in total N, 71 percent for NH_4-N, and a 33 percent increase in NO_3-N (all of these changes based on small quantities) was observed. The partition of the N cannot be made in this study but would include the same possible fates, as also noted in the ABS section listed above. As indicated in the ABS evaluation, a seasonal effect (temperature) on NH_4-N was recorded in the AED with lower values observed in warmer seasons.

The retention of minerals (P, Zn and Cu) was significant with the majority taking place in the PC lagoon (P, 67 percent; Zn, 88 percent; Cu, 84 percent). Overall, the percentage retention by the system was 81 (P), 94 (Zn) and 86 (Cu) indicating confinement and removal from release to the environment. Solids removal was 81 percent by the system with the PC lagoon being most effective. As noted in the ABS section, the retention of the nutrients in the sludge/biomass would have to be addressed in the farm nutrient management plan if land application is eventually the final destination of these biosolids.

Operationally, as reported in the ABS section, the aeration equipment required the most attention with labor requirements being minimal in regards to operation of the components of the system as evaluated. The build up of solids in the lift station transferring waste water to the PC lagoon created challenges periodically.

Based on the data, the PCS was effective in managing N and retaining other non-volatile nutrients doing so with minimum labor. Improvements in the reliability of the aeration system are needed. Data on emissions of odors, pathogens and NH3 could impact the effectiveness of the system in meeting the requirements as a candidate EST.

Recycling of Existing Nutrients, Energy and Water (RENEW)

The RENEW system was installed on two farm sites with each site having four naturally ventilated, flush-style finishing houses and a total combined capacity of 9792 animals. Both facilities were incorporated into the RENEW technology. Waste was transferred daily from the houses to a lift station, pumped to an equalization tank and subsequently to a gravity thickener with thickened solids transferred to an in-ground mesophilic anaerobic digester (MD) for biogas production. Biogas was intended to be processed in a microturbine with recovery of electrical energy. Thickener liquid (supernanant) was transferred to a storage basin (SB) as was effluent from the digester. Liquid from the SB was fed to an aerobic digester (AED) for further nitrification. Treated liquid from the AED was used to flush the houses and to provide influent into the water reuse module (R) with the potential of creating potable drinking water for the animals.

Due to delays in executing agreements for electricity distribution to the local utility company, the microturbine element of this project was not evaluated. The biogas produced by the MD was either flared or used to generate heat for the MD. Due to operational difficulties with the R, data on animal performance, health and other production aspects were not collected. For this report, performance will primarily focus on the nutrients and mass balance with some biogas production data and preliminary system data on the water reuse module.

In addition to the 15 months of scheduled "grab-sampling" data, hourly samples were composited at each point in the system during a one day trial in order to evaluate the variability associated with the daily cycle. Those data are reported and while not used for the basic system evaluation, the data provide some extremely valuable insights into sampling protocol and possible modifications for future projects.

A 70 % and 85% reduction in total N and NH_4-N across the RENEW system was observed respectively with a gain of NO_3-N of 280 percent. Based on the nutrient data the mesophilic digester influent had lower concentrations of NH_4-N than the effluent resulting in the overall increase of NH_4-N. As with the other ISSUES technologies, NO_3-N concentrations in samples collected from the aerobic digester during the warm season were significantly higher than those collected during the cool season. This nitrate increase was accompanied by a reduction in NH_4-N concentrations in the AED during the warm season indicating more effective nitrification within the system during warm weather. These data are based on the assumption that steady-state operating conditions were achieved. It should also be noted the flow for the waste stream within the entire RENEW system was not a direct flow. In order to manage flows through each of the technology components the total volume of the waste stream was split and/or transferred to another treatment component with several components receiving more than one waste stream.

The SB was the most effective site of reduction in total N and NH_4-N both percentage and quantitatively. Solids settling in the EQ tank and lines delivering waste water to the thickener presented numerous challenges. The performance of the thickener was significantly below what was expected. This resulted in substantially more of the potential degradable solids being transferred to the SB in the liquid fraction than was anticipated. This also resulted in the SB operating as an anaerobic treatment lagoon to a greater extent than was planned. Nitrate production was greatest, as expected, in the AED (over 485 percent of input).

As noted in previous sections of this Summary, it is assumed the N reduction is the result of a combination of emissions of both ammonia (NH_3) and/or dinitrogen gas (N_2) and retention in organic forms associated with sludge biomass accumulation. Sludge depth measurements indicated sludge levels were increasing in the MD, SB and AED. This "buildup" of solids in the MD was greater than anticipated. Phosphorous, copper, and zinc show reductions of 45-50 percent over the complete RENEW system indicating their association with solids retention. The greatest retention of these elements (62-76 percent) was observed in the storage basin. It should also be noted as with the previously listed technologies, the nutrients retained in the solids/sludge would need to be addressed if land application is the fate of the sludge.

Despite the disappointing performance of the thickener, biogas production was as high as 47,000 SCFD (standard cubic feet per day) during one month of measurement. When the yield was calculated against disappearance of volatile solids, the result was exactly what would be predicted for swine waste based on literature values (ASAE, 2003). Data on solids reduction are consistent with expectations, with over 60 percent reduction overall and over 77 percent (based on house effluent) of the solids entering the MD being eliminated. The SB also was effective in solids reduction consistent with the statements about its role as an anaerobic treatment lagoon.

The RENEW system could benefit with the use of an alternative solid separation system for the transfer of solids to the MD. This could potentially be accomplished with the current technology and a flocculation agent or with the replacement of the settling system currently used. With modifications, the SB would function more as a true storage basin by receiving lower nutrient loads and less as an anaerobic treatment lagoon.

While no data on animal performance or related issues from the R component are available, the analytical data suggest that the process could provide water of drinking quality and provided a base for subsequent work.

Based on the data evaluated in this component of the performance review, RENEW appears to have potential as a candidate EST pending results from the emission, pathogen reduction and economic analysis components. Completion of the agreements for the generation of electricity is required for the microturbine portion of the RENEW system to be evaluated. Improvement in the continual operation of the R component will also provide the consistency required for the water reuse module evaluation.

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Carroll's site – Aerobic Blanket System (ABS) technology

Farm and Technology description:

The Aerobic Blanket System (ABS) technology was installed on the Carroll's 2529 farm site located in Duplin County in 2003. The site was originally a "Farrow to Finish" farm with 6480 finishing head (720 head per house) and with a 1067 sow capacity which was later converted to all finishing houses. Each house was flush style and was mechanically ventilated. During the technology evaluation, nine houses were flushed daily into a primary lagoon. The ABS system was installed on the south end of the primary lagoon (1/2 of the lagoon surface) to provide a light mist or "blanket" over the primary lagoon in efforts to reduce emissions (NH_3 and Odor) from the existing primary lagoon. The ABS consisted of a floating 12 port PVC line with 24 spray nozzles which sprayed treated (aerated - nitrified) waste water above the surface of the primary lagoon every 15 minutes for approximately 1.27 minutes which delivered approximately 2400 gallons of mist per day. No spraying occurred if wind speed was greater than 10 mph. Approximately 50,000 gallons of liquid was pumped daily from the primary lagoon to an existing aeration cell (IESS) from a previous evaluation sponsored by NCDENR. Due to repairs required for the continued operation of the IESS cell, two 3000 gallon tanks were installed to provide similar aeration treatment to approximately 3000 gallons of liquid per day (from the IESS cell) which was used in the ABS over the primary lagoon. Houses 12 and 13 were recharged with liquid from the aeration cell (IESS system) and Houses 5 - 11 were recharged with liquid from the primary lagoon. During the evaluation the blower which provided aeration to the IESS cell was repaired (May 04), therefore 3000 gallons of waste water being aerated in the aeration tanks was also being treated (aeration) in the IESS cell. All liquid used for land application was delivered from the primary lagoon (shown as Lagoon "A" on farm schematic – Figure 2).

Figure 1. Flow process diagram for the ISSUES – ABS technology located on the Carroll's 2529 farm site.

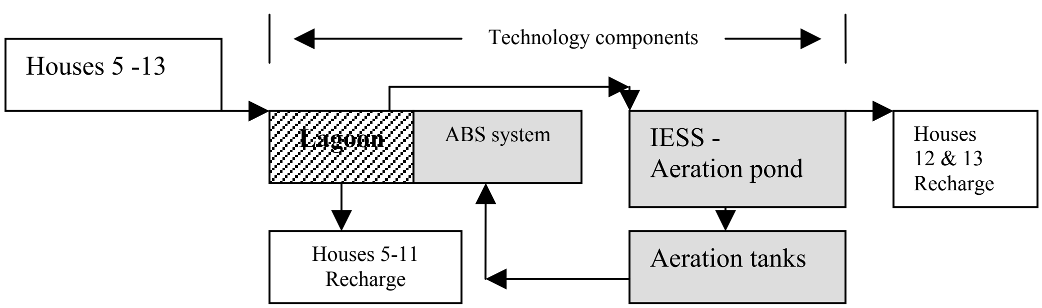


Figure 2. Schematic of ISSUES – Aerobic Blanket System (ABS).

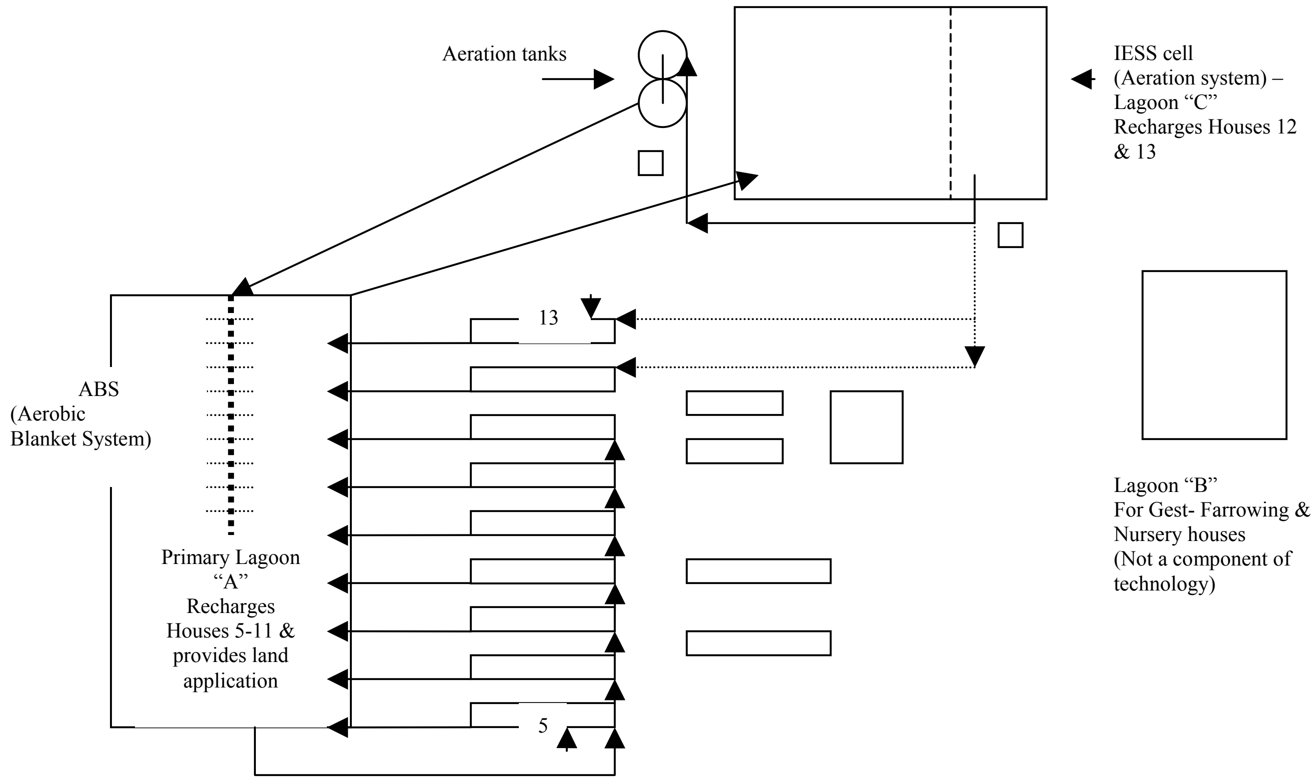


Figure 3. Aerial image of Carroll's Farm site.

Figure 4. Images of the ABS system.

Sample Collections and Nutrient Analysis:

The ABS evaluation began in February 2004 and concluded in October 2004. Grab samples from various technology components / sampling points were collected biweekly until steady state was established and then monthly thereafter for a total of 9 sampling events. All samples were analyzed at the North Carolina Department of Agriculture and Consumer Services (NCDA & CS) Agronomic Division analytical lab located in Raleigh, NC. Emissions monitoring by the OPEN (Odor, Pathogens, and Emission of Nitrogen) team occurred during March 04 and June 04.

The results of all of analyses for all sampling events and each sampling point are included in Appendix A for reference. Only mean values are shown in Tables 1 and 2 for ease of reading.

Table 1. The following table summarizes the sampling points, nutrient analyses (ppm), pH, and %DM for all sampling events. Mean values (STDev) are listed below:

Sample	N (total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM%
House effluent	718 (103)	707 (103)	514 (164)	12 (5)	132 (134)	6.6 (9.7)	1.6 (1.7)	7.6 (.30)	0.45 (.31)
Lagoon	590 (174)	579 (175)	466 (128)	11 (4)	85 (58)	2.9 (3.7)	1.2 (1.9)	7.6 (.10)	0.32 (.14)
Lagoon ABS	598 (136)	587 (136)	466 (119)	11 (4)	79 (31)	2.6 (1.7)	1.1 (.97)	7.6 (.10)	0.32 (.07)
IESS cell	333 (122)	274 (188)	195 (149)	60 (74)	38 (9)	0.94 (.53)	0.23 (.09)	8.2 (.45)	0.20 (.11)
ABS mist	327 (143)	279 (191)	190 (139)	48 (59)	37 (11)	1.1 (.95)	0.21 (.07)	7.8 (.39)	0.18 (.08)

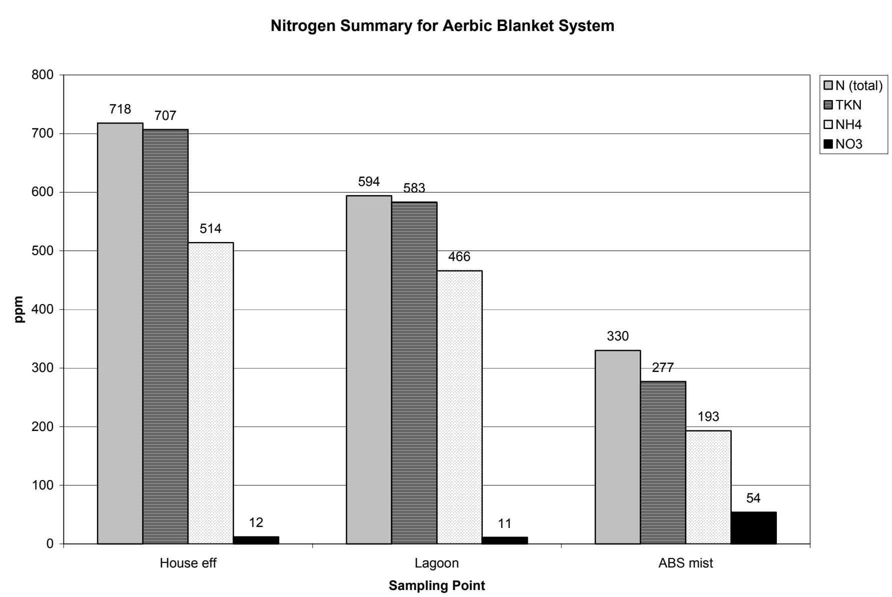
Based on these data, samples collected from each end of the lagoon were similar, as expected, but verified herein, since the ABS is being misted over the primary and not directly into the existing lagoon. Also as expected but verified, the liquid in the IESS cell and aeration tanks also exhibited similar composition. The aeration tanks were installed to reproduce the treatment effects of the IESS (aeration) cell. Nitrate (NO_3-N) levels increased in both the IESS cell and the aeration tanks during the latter sampling period (August 04 – October 04) which is suspected to be due blower operation and increased environmental temperature. Based on the observations documented above, the analytical data were consolidated as shown in Table 2 in preparation for conducting recoveries and balances of nutrients.

Table 2. The following table combines and averages both lagoon sampling points (Lagoon and ABS Lagoon) and samples collected from the aeration treatment (ABS mist and IESS cell) due to results showed in Table 1.

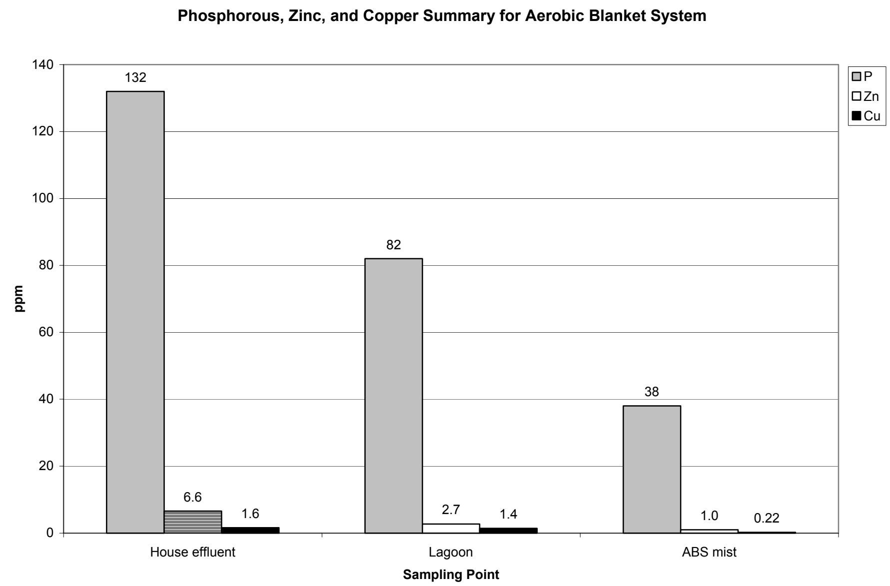
Sample	N (total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM%
House effluent	718	707	514	12	132	6.6	1.6	7.6	.45
Lagoon	594	583	466	11	82	2.7	1.4	7.6	.32
ABS mist	330	277	192.5	54	38	1.0	.22	8.0	.19

Figures 5a -5d. Nutrient Analysis charts and comparisons.

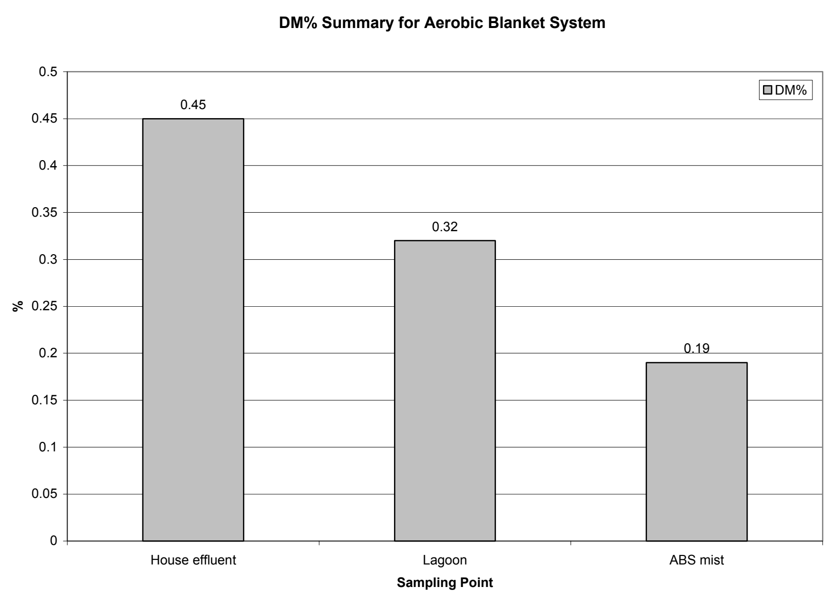
5a.



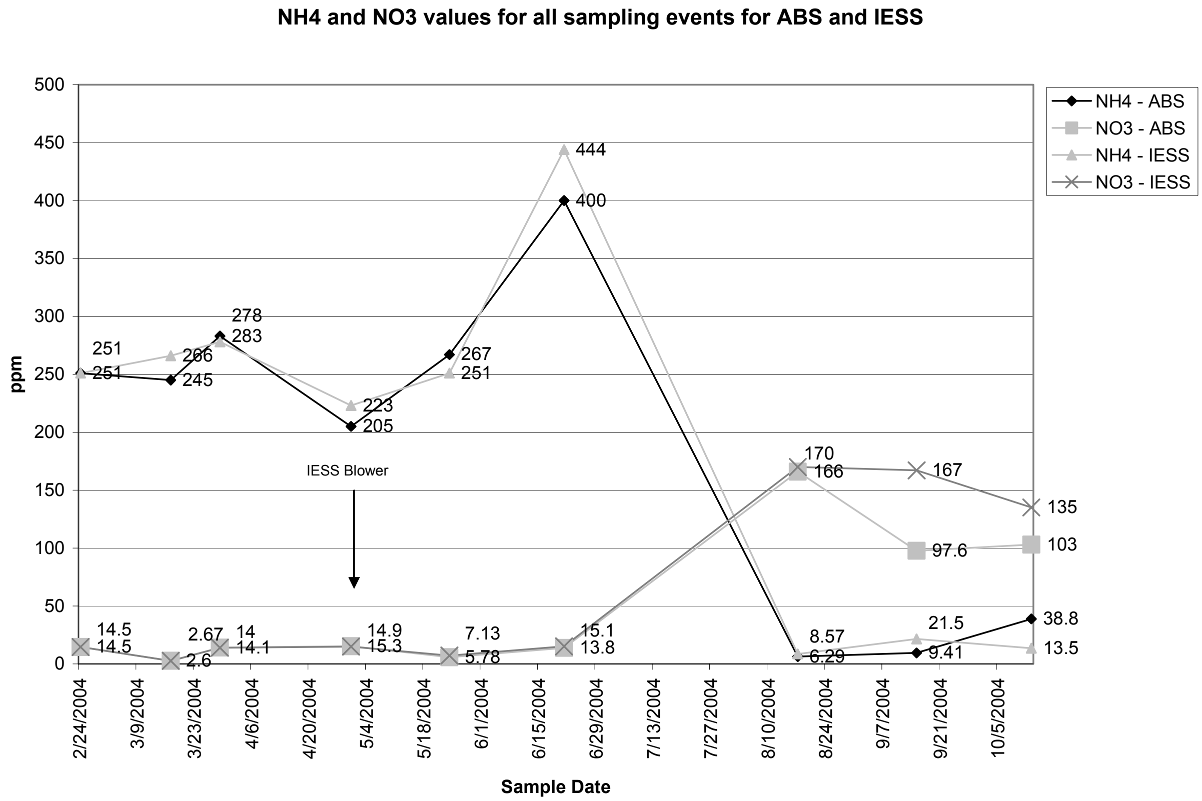
5b.


Phosphorous, Zinc, and Copper Summary for Aerobic Blanket System
140
120
100
80
60
40
20
0
ppm
132
6.6
1.6
82
2.7
1.4
38
1.0
0.22
P
Zn
Cu
House effluent
Lagoon
ABS mist
Sampling Point

5c.


DM% Summary for Aerobic Blanket System
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
%
0.45
0.32
0.19
DM%
House effluent
Lagoon
ABS mist
Sampling Point

5d.



The data in the figure above suggest treatment effects due to the installation of the blower system, as well as, (and confounded with) the increased environmental temperature on the fate of nitrogen compounds. The striking reduction in ammonia concentration in both the ABS and IESS samples, along with the increased nitrate concentrations, suggest that there was much more active biological treatment during the warm season samplings than in earlier, cooler periods. Although the blower installation coincides with the seasonal changes, other data collected on other ISSUES project sites (RENEW) support the seasonal/temperature effects as the primary cause. It was also noted in the previous evaluation of the IESS system located on the Carroll's 2529 site (Westerman and Arogo, 2003).

Flow rates and Volumes:

All 9 finishing houses were flushed (approximately 2.5 complete times/house average; 2 – 800 gallon tanks/house with 10-12 flushes per tank) daily into the 12.1 M gallon (total volume capacity) primary lagoon for a total volume of 187,700 GPD (includes feces, urine, and wasted water). Approximately 50,000 gallons of liquid were pumped from the primary lagoon into the 5 M gal (total volume capacity) IESS cell per day and 134,400 gallons were returned to 7 of the finishing houses as recharge water for the flush tanks daily. Three thousand gallons from the IESS cell were pumped to the aeration tanks with 2400 gallons being misted over the primary lagoon each day with the remaining 600 gallons being returned to the IESS cell. Approximately

40,000 gallons were pumped from the IESS cell to recharge the flush tanks at 2 of the finishing houses. Liquid flow through the technology components are outlined in Table 3. All volumes were estimated based on pump ratings and operation period. A more detailed description of the Aerobic Blanket System is outlined in the ABS Permit Application submitted to NCDENR is listed in the Appendix C.

Table 3. The following table outlines estimated flows and volumes (Gallons / day (GPD) through the ABS technology site:

Flow gal/day	**Houses (12 flushes/day)**	**Lagoon**	**IESS cell**	**Aeration tanks**	**ABS mist**
IN (12 -13)	38,400 (IESS)	41,700		3,000	
OUT	**41,700***		**38,400**	**2400 + 600**	
IN (5 -11)	134,400 (lagoon)	146,000			
OUT	**146,000***	**134,400**			
Other (in)		2400	50000 + 600		2400
Other (out)		**50,000**	**3000**		**2400**
TOTAL (in)	172,800	190,100	50,600	3000	2400
TOTAL (out)	**187,700***	**184,400**	**41,400**	**3000**	**2400**
Difference**	**+14,900**	**+5,700*****	**+9200**	0	0

*Assumes 2.3 gallons of waste water (manure, urine, wasted water) produced per head (720/hse) per day (g/h/d).
** Difference does not include precipitation or natural evaporation.
***Land application – Total lagoon liquid land applied from April 26 to September 23, 2004 was 3,188,745 gallons.

Mass Balance of Nutrients:

A number of calculations were made using flow and composition data (shown in the above tables) to determine the quantities and balances of nutrients throughout the system. The following tables contain those data, in each case assuming that steady-state conditions had been achieved. A description of mass balance calculations and reductions and/or increases in nutrients is outlined in Appendix B.

Table 4a & 4b. The following tables describe the mass balance of nutrients and nutrient reduction observed for the Aerobic Blanket System.

4a.

Kg/day	House (In)	House (Out)	Lagoon (In)	Lagoon (Out)	IESS (In)	IESS (Out)
N(Total)	350.1	510.0	513	414	113.0	51.7
TKN	336.8	502.1	505	407	110.9	43.4
NH4	265.0	365.1	367	325	88.6	30.2
NO3	13.5	8.5	9.0	7.7	2.2	8.5
P	47.2	93.8	94.1	57.2	15.6	5.9
Zn	1.52	4.26	4.27	1.88	0.51	0.16
Cu	0.74	1.13	1.14	0.98	0.27	0.035
Solids	1903	3196	3213.4	2232.9	609	298

4b.

% Reduction	House (In - Out)	Lagoon (In - Out)	IESS/ABS (In –Out)	Total System Reduction %
N(Total)	45.7+	19.3	54.2	31.4
TKN	49.0+	19.4	60.9	33.0
NH4	37.8+	11.4	66.4	27.5
NO3	37.0	14.4	+286.4	58.8 gain
P	98.7+	39.2	62.2	49.7
Zn	180.3+	56.0	68.6	64.3
Cu	52.7+	14.0	87.0	35.0
Solids	67.9+	30.5	51.1	40.4

The data in Tables 4a & b represent the difference between the quantities of the nutrients added to the primary anaerobic treatment lagoon and those removed on a daily basis. Included in the addition is the nutrient contribution of the ABS mist. The differences noted in the input and output of nitrogen (total, Kjeldahl, ammonium, and nitrate) could be contributed to a combination of fates including: 1) retention in biomass generated by the active microorganisms involved in treatment (accumulation in sludge; 2) interconversion among these and potentially other forms; 3) volatilization as ammonia or dinitrogen gas; 4) cumulative errors in flow measurement, sampling and analysis. Due to an 11-19 percent reduction of the nitrogen inflow it is assumed that all of the biological and physical processes were active. The pH of the all of the samples was greater than 7.0, indicating that volatilization is possible. However, the fact that the unrecovered fractions of non-ammonia nitrogen are greater than those for ammonia (i.e., less ammonia than non-ammonia nitrogen appears to have been lost), suggests that the contribution of microbial incorporation into cellular proteins and nucleic acids, as well as some conversion to dinitrogen gas is plausible.

Mineral elements (P, Zn and Cu) were also retained in the primary lagoon to the extent of 14-56 percent. Since these nutrients are not lost to volatilization, it is assumed that incorporation into biomass and accumulation as sludge or settled material explains the differences. Recent work in our laboratories indicates that the concentration of nutrients in normal lagoon sludge may be in excess of 10x that of the liquid fraction that is normally land applied or transferred to other sites. From a system performance standpoint, the fact that these mineral nutrients are confined to the lagoon sludge is important and indicates that they are not released to the environment unless, of course, the sludge is land applied.

Data shown in the above tables reflect the impact of aeration treatment (IESS) on shifts in nitrogen content and form. Although the original design using the aeration cell as the primary treatment was modified to accommodate equipment problems (installation of aeration tanks), a treatment effect was observed. All forms of nitrogen except nitrate were drastically reduced during treatment in the IESS cell/tanks. Reductions in total, Kjeldahl and ammonia forms of nitrogen ranged from 54 to 66 percent. While quantitatively less than the reductions, the increase in nitrate is indicative of aeration effects. It is concluded from the results that nitrogen volatilization took place to a significant extent. Species of nitrogen volatilized is not known but should include dinitrogen gas as well as ammonia. In regard to the mineral nutrients (P, Zn and

Cu), it is assumed these nutrients were both retained and incorporated into biomass produced as a result of aeration with accumulation in sludge as discussed above.

The data in tables shown above can be used to indicate the magnitude and site within the system where recovery is most affected. As expected, the primary lagoon shows the largest quantitative component of the total reduction of nutrients with the exceptions of NH_4-N and copper noted the IESS cell. The largest percentage change in nitrogen also occurs across the IESS cell.

It is apparent in terms of "reduction" of nitrogen and solids the IESS cell is significantly more effective than the primary lagoon. The ABS mist appears to be relatively ineffective as a treatment to the primary lagoon. As a consideration, it might be appropriate to remove the misting system and process all recycled or water used for house flush through an IESS system. The results suggest that significant treatment effects would occur in regard to nitrogen.

Table 5. Calculated average nutrient excretion per animal based on 6480 animals and data from nutrient inflow and outflow from houses.

Total N	TKN	NH4	NO3	P	Zn	Cu	Solids
(g/animal/day)							
25.0	25.0	15.4	<1	7.2	0.4	0.06	200

The data in Table 5 are shown as a reference and to reflect on the validity of the entire process. For example, recently summarized data (ASAE, 2003) indicate that finished swine excrete (daily) 466g. total solids, 39g. total N and 6g. P. While the above data do not agree in total, the period of sampling shown include more than one finishing cycle (the ASAE, 2003 values are based on 120-day cycles) and could be weighted inappropriately for direct comparison with a single cycle. The fact that the values shown are within reason (based on flow and analysis data across several houses) is encouraging.

Conclusions:

The ABS mist system is not considered an effective tool for nutrient management. Data on odor reduction and ammonia emissions may provide additional insights on the value of the ABS mist. The problems encountered with pump maintenance are further evidence that these systems require regular attention to remain functional; however, labor involved for day to day system operation was indicated to be minimal by farm management.

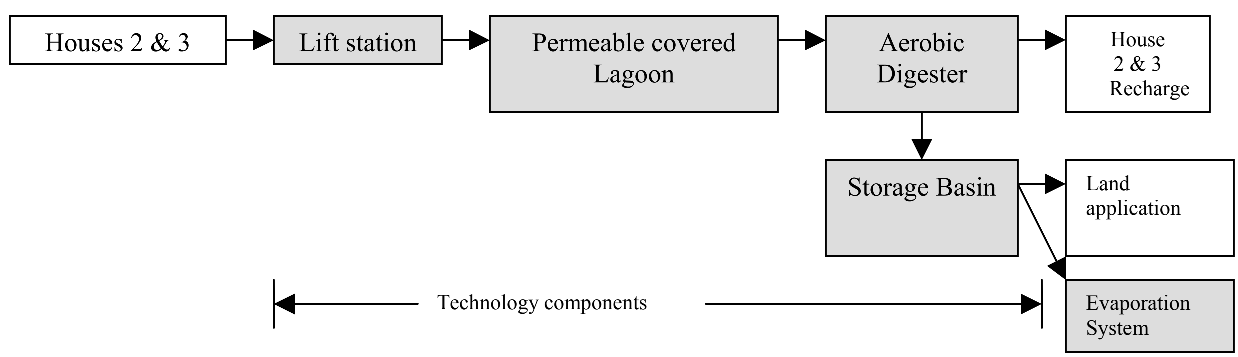
Based on the data, the performance of the IESS system resulted in a treatment effect (reduction of nitrogen and solids in the IESS cell) especially during the warm season. A reduction was also noted in the primary lagoon. It is not possible to determine whether the reductions in nitrogen observed are a result of emission of ammonia, dinitrogen gas or accumulation in sludge of organic nitrogen as a result of biological activity. In addition to the conversion to nitrate as shown, it is probable that all of those routes are involved. Further experimentation is needed to quantify those non-nitrate partitions. In the case of solids, it is expected that actual reduction occurred, with carbon released as carbon dioxide or methane or both. In the case of the minerals quantities reflect accumulations within the treatment cells in association with solids and settling. Performance in warm vs. cool seasons should be considered in any economic evaluation of these systems.

Harrell's Site – Permeable Cover System (PCS)

Farm and Technology description:

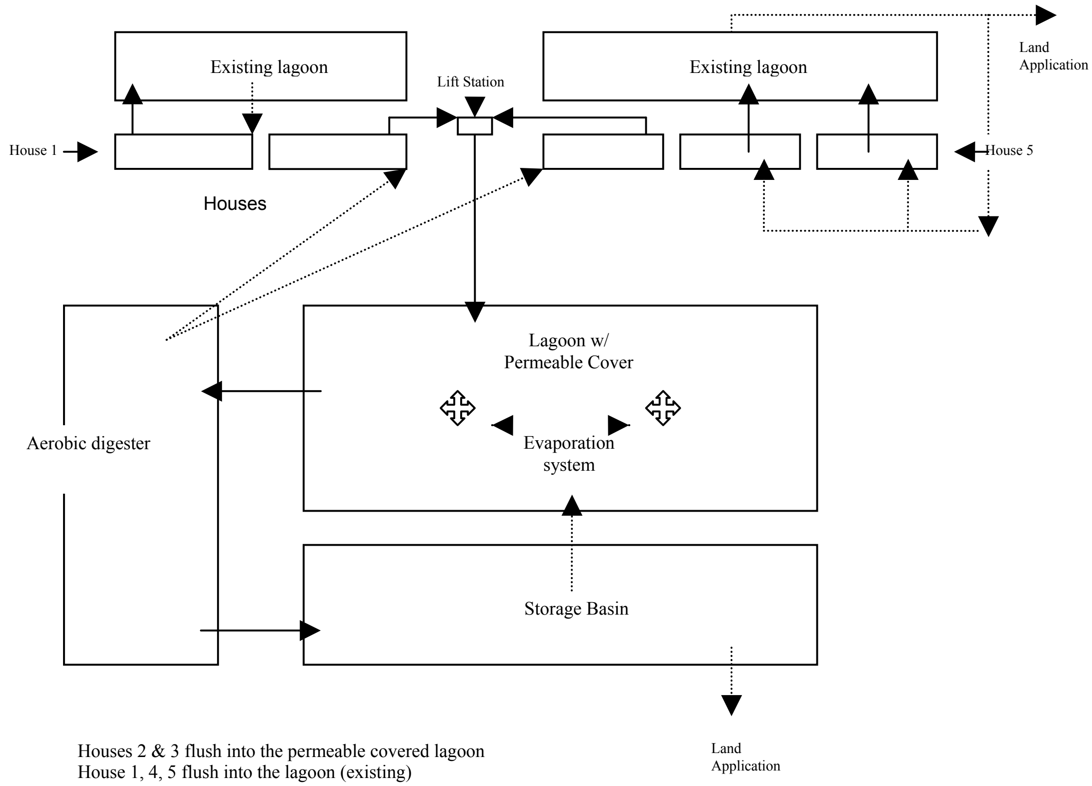
The Permeable Cover System (PCS) was installed on the Harrell's farm located in Sampson County in 2003. The floating woven polypropylene BioCap^{ML} permeable cover was designed with input from the technology supplier and developed by Baumgartner Environics Inc. (BEI). The farm had 5 naturally ventilated finishing houses with approximately 6120 total head (1224 head / house) with 2448 head providing waste to the ISSUES technology. Waste from two of the houses (#2 & #3) were flushed daily into a lift station and then pumped into an in-ground permeable covered (PC) lagoon for anaerobic digestion. The permeable cover was designed to act both as a barrier and as a biofiter and/or matrix for aerobic bacteria in efforts to reduce lagoon emissions (odor and NH3) through mass transfer (lagoon to ambient air) and biofiltration respectively. Liquid was pumped from the PC lagoon into an in-ground 40 mil HDPE lined aerobic digester (AED) for nitrification. The treated (nitrified) liquid was then pumped daily as tank recharge to 2 – 580 gallon (4 total) flush tanks for two of the houses (2 & 3). A portion of the aerated effluent was also pumped into a 40 mil HDPE lined storage basin for tertiary treatment - denitrification and to be stored for land application. The remaining 3 houses (1, 4, & 5) were flushed daily into the existing lagoon. Lagoon liquid from the existing lagoon was used for flush tank recharge for houses 1, 4, & 5.

Figure 1. Process flow chart of the ISSUES – PCS technology located on the Harrell's farm site.



*Existing lagoons receive waste from houses 1, 4, 5 and recharges houses 1, 4, 5

Figure 2. Schematic of Permeable Cover System (PCS) technology located at the Harrell's farm site.



Houses 2 & 3 flush into the permeable covered lagoon
House 1, 4, 5 flush into the lagoon (existing)
Houses 2 & 3 are recharged with Aerobic Digester treated liquid
Houses 1, 4, 5 are recharged with the (existing) lagoon liquid
Storage Basin and Existing Lagoons are used for land application
Storage Basin effluent is used for the Evaporation System also

Figure 3. Aerial image of Harrell's farm site.

Figure 4. Images of the Permeable Cover System (PCS) – Permeable covered lagoon and aerobic digester.

Sample Collections and Nutrient Analysis:

The ISSUES Permeable Cover System technology evaluation began in July 2003 and concluded in May 2004. Grab samples from various technology components / sampling points were collected biweekly until steady state was established and then monthly thereafter for a total of 15 sampling events. Sample collections were extended into September 2004 with the addition of an Evaporation system over the PC lagoon. All samples were analyzed at the North Carolina Department of Agriculture and Consumer Services (NCDA & CS) Agronomic Division analytical lab located in Raleigh, NC. Emissions monitoring by the OPEN (Odor, Pathogens, and Emission of Nitrogen) team occurred during January/February 04 and June 04.

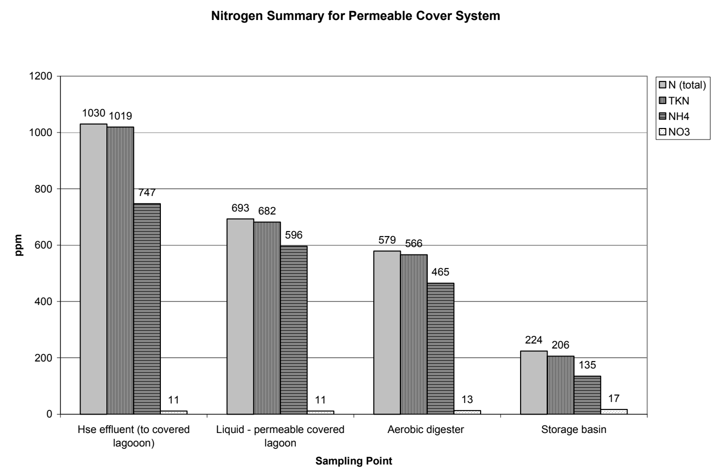
Table 1. The following table summarizes the sampling points, nutrient analyses (ppm), pH, and %DM for all sampling events (July 03 – Sept 04). Mean values (STDev) are listed below:

Sample	N (Total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM %
House effluent (to covered lagoon)*	1030 (291)	1019 (289)	747 (279)	11 (10)	240 (248)	10 (11)	1.49 (1.79)	7.6 (.67)	1.00 (1.10)
Liquid - permeable covered lagoon	693 (96)	682 (95)	596 (86)	11 (9)	85 (11)	1.3 (.74)	0.22 (.22)	7.3 (.11)	0.25 (.09)
Aerobic digester	579 (116)	566 (117)	465 (121)	13 (10)	51 (8)	0.92 (.41)	0.15 (.07)	7.9 (.25)	0.21 (.12)
Storage basin	224 (84)	206 (85)	135 (75)	17 (12)	31 (11)	0.74 (.36)	0.14 (.18)	8.1 (.35)	0.12 (.08)

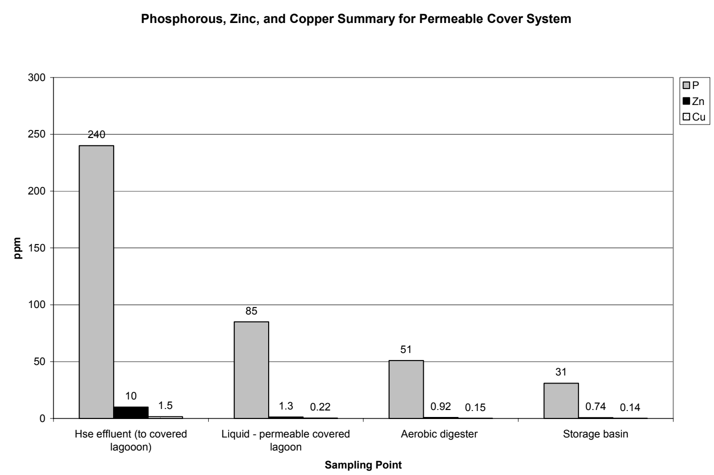
* 7/31/03; 9/10/03; 11/17/03; & 8/13/04 not included in summary due to lift station pump failures.

Figure 5a - 5d. Nutrient Analysis charts and comparisons.

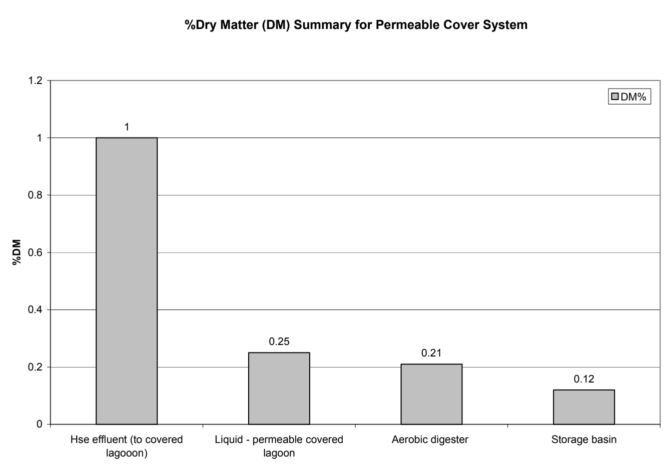
5a.



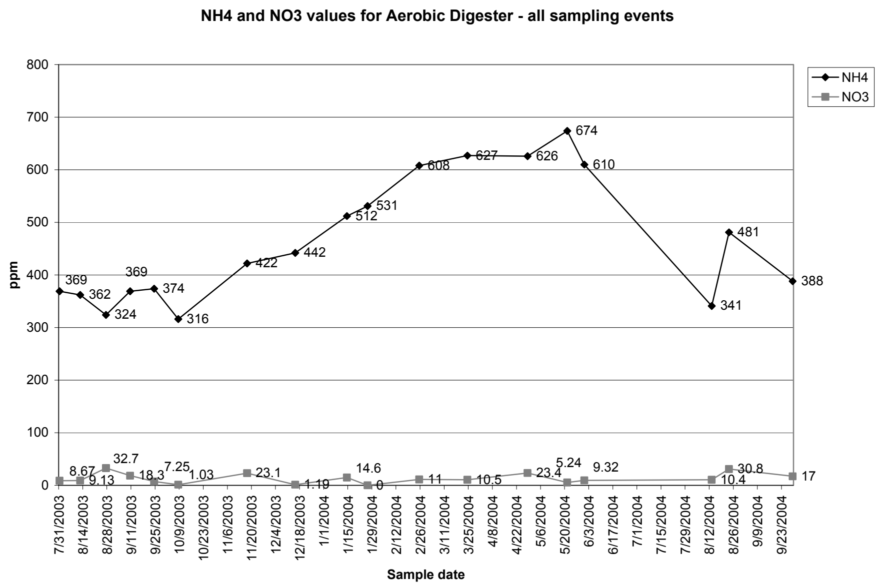
5b.



5c.



5d.



During the performance evaluation the aeration in the aerobic digester was difficult to maintain due to overheating of the 10 hp motor installed to provide the fine bubble diffusion in the AED (which needed 3 phase power). As a result of the inconsistent air flow through the submerged air lines in the AED, sediment plugged the air diffusion lines also contributing to aeration challenges. During the final (August) OPEN team (evaporation system monitoring) evaluation the 10 hp motor was placed on a timer with 40 minutes of operation and 20 minutes of downtime to allow the motor to cool and prevent overheating. Based on monitored NO_3 levels in the aerobic digester on this site there was no treatment effect measured in the aerated waste water primarily due to the inconsistent aeration provided to the AED treatment cell. However, as noted in the discussion of the ABS a seasonal effect on ammonia concentration (although confounded with aeration) was observed indicating that warm season reduction may be more effective and efficient on this and other systems adding support for a seasonal effect in aeration systems.

Flow rates and Volumes:

Two of the 5 flush style houses located on the farm site were flushed into a 4000 gallon lift station located between the 2 test houses. Approximately 33,700 gallons of wastewater (flushed manure slurry) was pumped from the lift station (2 – 5hp submersible pumps installed in parallel configuration) to the 4.2 million gallon PC lagoon daily. Initially, 18,850 gallons of liquid were pumped from the PC lagoon to the 1 million gallon aerobic digester (AED) daily. Modifications in flows (float installation) were made during the evaluation in order maintain permitted freeboard on all the treatment cells resulting in an out flow similar to output of the AED. Approximately 28,000 gallons of treated water from the AED were pumped to flush tanks recharging the test houses (Houses 2 & 3). Approximately 3700 gallons were pumped into the 1.4 million gallon storage basin daily which was stored for land application and later for the evaporation system installed over the PC lagoon in July 2004.

Original design provided a 220 day hydraulic retention (HRT) time in the PC lagoon. It was later estimated that the actual HRT was approximately 180 days. HRT in the aerobic digester was 30 days by design but estimated to be approximately 36 days based on actual flow. The storage basin was designed for an 81 – 171 day HRT. Initially volumes were estimated based on pump ratings and operation period, however, during the evaluation actual volume was measured during system operation (volumetric container and timer) to insure accuracy and to make adjustments to prevent freeboard concerns. A more detailed description of the Permeable Cover System is outlined in the PCS Permit Application to NCDENR shown in the Appendix C.

Table 2. The following table summarizes the approximate flow rates and volume of waste water being treated with the PC lagoon; aerobic digester; and storage basin technologies.

Volume (GPD)	**Houses (Hses) (2 & 3)**	**Lift station (LIS)**	**PC lagoon[2] (PCL)**	**Aerobic Digester[4] (AED)**	**Storage Basin (SB)**
In	28000	33700	33700	31700	3700
Out	33700	33700	31700	28000 hses + 3700[3] SB	Irrigation
Difference	5700[1]	0	2000+	0	-

[1]Assumes 2.3 gallons of waste water (manure, urine, wasted water) produced per head (1224/hse) per day (g/h/d) x 2 houses.
[2]Pump volumes - 20.83 minutes / 4 hrs in a 24 hour period @ 150 gal/min = 18850 gal/day but was later adjusted to maintain permitted freeboard.
[3]Original Pump volumes - 6.26 minutes/ 4 hrs in a 24 hour period @150 gal/min (pumps 1 hour on / 1hour off) = 5634 gal/day; measured volume = 3687 gal/day.

Mass Balance of Nutrients:

Table 3a and 3b. The following tables describe the mass balance of nutrients and nutrient reduction observed for the Permeable Cover System. A description of mass balance calculations and reductions and/or increases in nutrients is outlined in Appendix B.

3a.

Kg/day	House (In)	House (Out)	PC Lagoon (In)	PC Lagoon (Out)	AED (In)	AED (Out)	Storage Basin (In)	Storage Basin (Out)*
N(Total)	61.3	131.3	131.3	83.1	83.1	69.4	8.1	3.1
TKN	60.0	129.9	129.9	81.8	81.8	67.8	7.8	2.9
NH4	49.3	95.3	95.3	71.5	71.5	55.8	6.5	1.9
NO3	1.38	1.40	1.40	1.32	1.32	1.56	0.18	0.24
P	5.4	30.6	30.6	10.20	10.20	6.11	0.71	0.43
Zn	0.10	1.28	1.28	0.16	0.16	0.113	0.013	0.010
Cu	0.02	0.19	0.19	0.026	0.026	0.022	0.002	0.002
Solids	222	1275	1275	300	300	251.4	29.4	16.8

*Calculation based on storage basin input only as does not reflect land application.

3b.

% Reduction	House (In -Out)	PC Lagoon (In -Out)	AED (In - Out)	Storage Basin (In - Out)	Total System Reduction %
N(Total)	114+	36.7	16.5	61.7	51.0
TKN	116.5+	37.0	17.1	62.8	51.5
NH4	93.3+	24.9	22.0	70.8	46.3
NO3	1.4+	5.7+	15.4+	33.3+	15.7+
P	46.7+	66.7	40.1	39.4	81.0
Zn	1180+	87.5	29.4	23.0	93.7
Cu	850+	84.2	15.4	0	86.3
Solids	474+	76.5	16.2	42.9	81.3

+ indicates gain

The data listed above suggest treatment of nitrogen occurred in all components of the system (PC Lagoon, AED, and Storage Basin). Reduction in nitrogen fractions between the houses (house effluent) and the storage basin shows a 46-52 percent reduction in total N, TKN and NH_4-N. NO_3-N values were low and the percentage changes are not indicative of significant impact. Nitrogen reduction as emissions of ammonia and dinitrogen gas, and accumulations in organic forms within sludge biomass are all possible routes, requiring further investigation to accurately partition. Solids reduction based on measured flows was substantial with 81 percent reduction observed. The mineral nutrients indicate accumulation in solids or other forms within the PC Lagoon or AED, probably within accumulating sludge.

The daily house flow data were used to compute the daily per-animal contributions in nutrients, as an internal check (see similar data in ABS section). The daily outputs of nutrients were very close to those observed in ABS, with 28g N, 19g NH_4-N, 0g NO_3-N, 10g P, 0.5g Zn, 0.7g Cu, and 430g solids, based on building capacity average animal numbers.

Evaporation System

In July 2004 after the initial evaluation of the ISSUES technology, an evaporation system was installed over the PC lagoon. Water being stored in the storage basin (post treatment) was pumped through the 2 spray irrigation nozzles over the permeable cover at a combined flow of 140 gal / min. Due to the transfer of water from one cell to another the evaporation system was operated every other day to maintain permitted freeboard. The tables listed in Appendix B – Calculations, pages 69-70, outline the waste water flow through the technology site and the water balance for the Evaporation System. Table Appendix B – 2 was provided by Murphy Brown, LLC. It should also be noted both the MB nutrient management and engineer teams had concerns regarding accuracy of the water balance data provided. Should additional evaluations be conducted at this site and a detailed protocol and daily monitoring of freeboard, water use, and time logs should be utilized since most recordings are weekly.

Figure 6. Image of the Permeable Cover System (PCS) with Evaporation system.

Table 4. The following table summarizes the sampling points, nutrient analyses (ppm), pH, and %DM for August 2004 evaporation sampling events (Means):

Sample	N (total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM %
Storage Basin liquid 8/04	186	151	89.1	35	28.2	0.52	0.04	8.12	0.06
Liquid on PC lagoon 8/04	168	139	53.7	29	37.4	1.05	0.09	8.33	0.07

Conclusions:

Based on the data the Permeable Cover System was effective in removing nitrogen from swine waste. Based on concept and design, the removal of nitrogen should have been through accumulation of organic forms in the retained sludge in the lagoon or as dinitrogen gas. The system is designed to contain and allow treatment (reduction) of ammonia. Emission data in the OPEN (Odor, Pathogen, and the Emissions of Nitrogen) report will address this component. The addition of the aeration system to enhance nitrification was less effective with lower nitrogen removal, however, improvements to the aeration system (continual operation) may provide the desired nitrification outlined in the original design.

Vestal site – Recycling of Existing Nutrients, Energy and Water (RENEW)

Farm and Technology description:

The Recycling of Existing Nutrients, Energy, and Water (RENEW) system was installed on the Vestal farm site located in Duplin County in 2003. The technology components included an equalization (EQ) tank; solids concentrator or thickener; mesophilic digester (MD); micro-turbine electric generator; and aerobic digester (AED). A water reuse component was also installed in 2004 to provide further treatment to the aerobic digester effluent to serve as animal drinking water, however, was not a component of the original project funded through the NCAG/SF/PSF/FF Initiative. The technology received waste from 2 farm sites, Vestal 1 and Vestal 2, housing 9792 (1224 head / house) finishing head total. Each farm had 4 naturally ventilated flush style houses. Eight houses were flushed daily into 2 lift stations (4 houses with one 820 gallon tank - 1 lift station on each farm) and pumped to a centrally located 10,000 gallon equalization tank. The system was designed to deliver waste from the EQ tank to a 10,000 gallon solids concentrator which would thicken (settle) the wastewater into 2 components, sludge and supernatant (liquid). The sludge was pumped into an in-ground mesophilic digester both lined and covered with a 40 mil HDPE synthetic liner. The supernatant was fed into a central storage basin. The mesophilic digester was maintained at a temperature of $95^{o}F \pm 3$ by heated re-circulated digester effluent through a 4,000 gallon heat exchanger designed by Smithfield Foods engineers and Robert (Bob) Hoffland of Hoffland Environmental Inc. All biogas produced by the MD was either flared or used to generate heat for the heat exchanger. The biogas was also designated to power the Capstone micro-turbine which was to be used to generate electricity for the farm. The micro- turbine was not evaluated during the performance evaluation due negotiations between the technology supplier (SF) and the local power supplier. Effluent from the MD flowed daily into the storage basin. Liquid from the storage basin was pumped into the aerobic digester (AED) which was aerated by fine bubble aeration and an Air-Jammer^{TM} (aerator and mixer) promoting nitrification. Effluent from the aerobic digester was used to recharge each of the 820 gallon tanks used to flush each of the houses. Once installed, 10,000 gallons of the AED effluent were sent through the water reuse component.

Figure 1. Process flow chart of the ISSUES – RENEW technology located on the Vestal farm site.

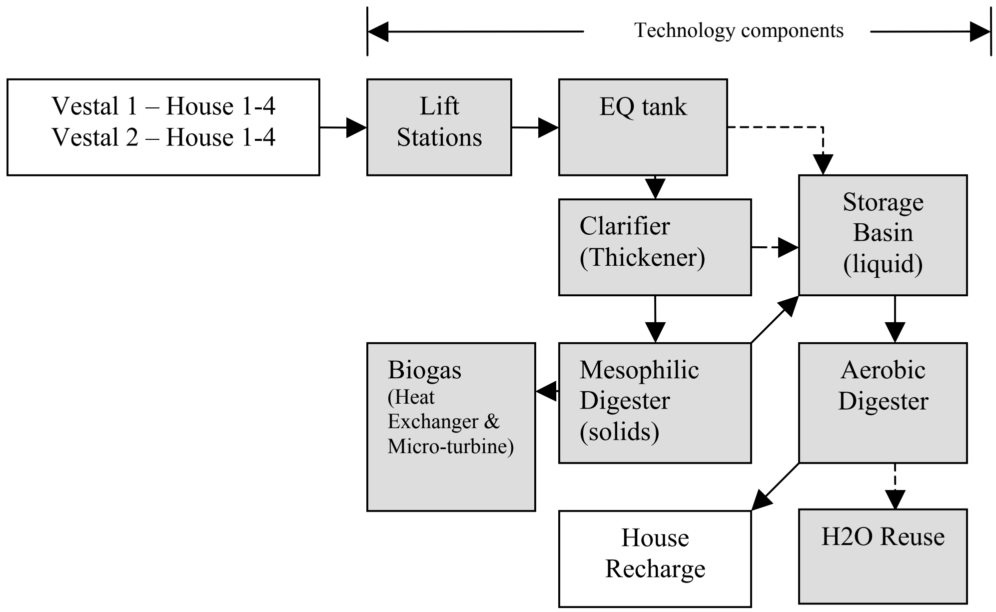


Figure 2. Schematic of ISSUES – RENEW technology located at the Vestal farm site.

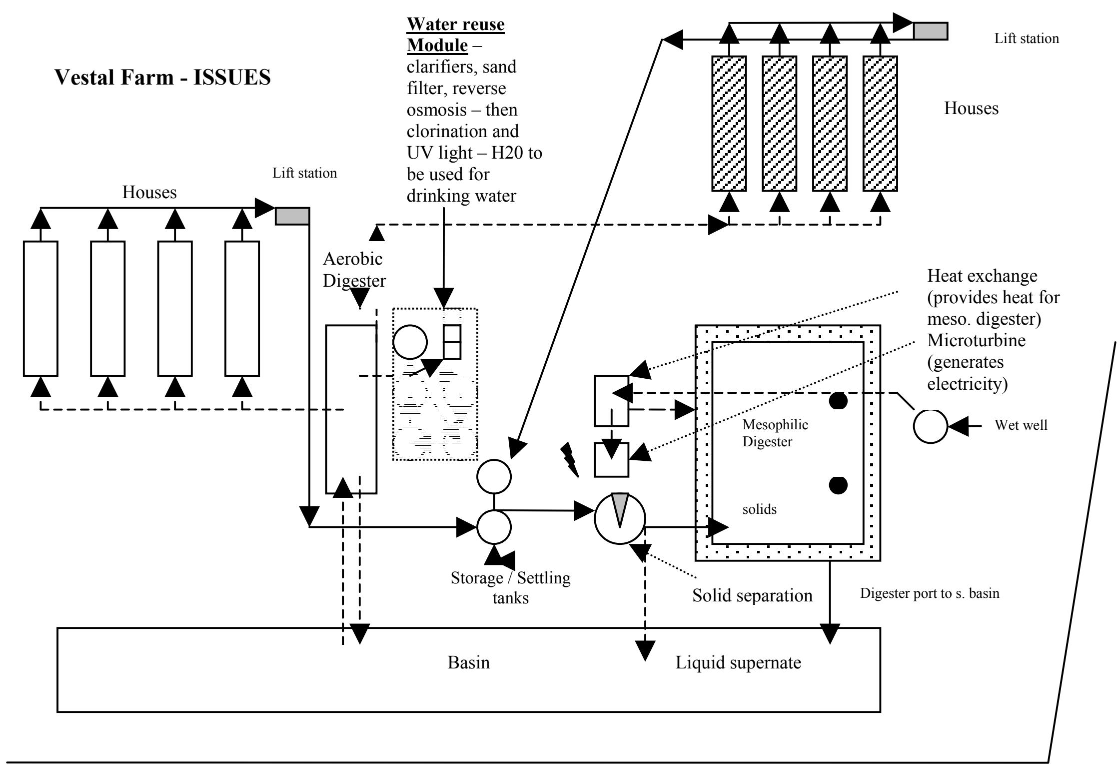


Figure 3. Aerial image of Vestal farm site.

Figure 4. Images of the RENEW technology.

Clarifier (thickener), Mesophilic Digester, Heat Exchanger, Micro-turbine

Storage basin

Aerobic Digester and Water Reuse

Sample Collections and Nutrient Analysis:

The ISSUES – RENEW Vestal site evaluation began in August 2003 and concluded in November 2004. Grab samples from the various technology components / sampling points were collected biweekly until steady state was established and then monthly thereafter for a total of 15 sampling events. Sample collections were extended into February 2005 with emphasis on monitoring flows through the system. Composite sample collection began at system "start up" and concluded at "shut down" (6AM to 4PM) during the February sampling event. All samples were analyzed at the North Carolina Department of Agriculture and Consumer Services (NCDA & CS) Agronomic Division analytical lab located in Raleigh, NC. Samples collected during the February 2005 sample collections were also analyzed at NCSU BAE service lab to determine % TS and % VS. Emissions monitoring by the OPEN (Odor, Pathogens, and Emission of Nitrogen) team occurred during March 04 and August 04.

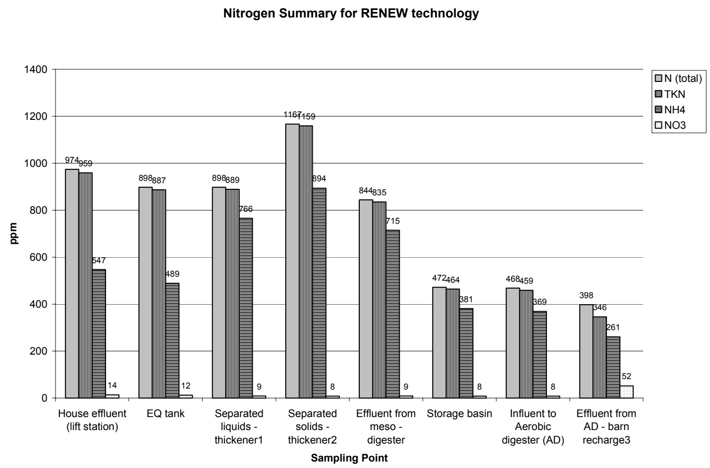
Table 1. The following table summarizes the sampling points, nutrient analyses (ppm), pH, and %DM for all sampling events. Means values (STDev) are listed below:

Sample	N (Total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM %
House effluent (Lift station)	974 (393)	959 (397)	547 (193)	14 (12)	244 (178)	14 (11)	2.0 (1.8)	7.4 (.73)	1.4 (.99)
EQ tank influent	898 (380)	887 (377)	489 (130)	12 (4.5)	128 (75)	7.3 (4.6)	1.1 (.61)	7.6 (.40)	.81 (.49)
Thickener (liquid)*	898 (74)	889 (76)	766 (91)	9 (3)	53 (66)	1.7 (2)	.29 (.32)	7.6 (.24)	.58 (.04)
Thickener (solid)*	1167 (249)	1159 (251)	894 (227)	8 (2)	158 (116)	4.9 (5)	.76 (.68)	6.9 (.42)	.82 (.23)
Mesophilic Digester effluent	844 (238)	835 (238)	715 (238)	9 (4)	120 (59)	5.4 (5)	.84 (.74)	7.3 (.14)	.31 (.14)
Storage basin**	472 (126)	464 (126)	381 (99)	8 (4)	52 (17)	1.1 (.52)	.22 (.21)	7.7 (.18)	.2 (.12)
Aerobic Digester influent**	468 (111)	459 (110)	369 (89	9 (5)	47 (15)	1.3 (.96)	.20 (.19)	7.7 (.17)	.16 (.08)
Aerobic Digester Effluent***	398 (115)	346 (130)	261 (113)	**52** (47)	46 (16)	1.0 (.59)	.16 (.12)	7.8 (.13)	.15 (.09)

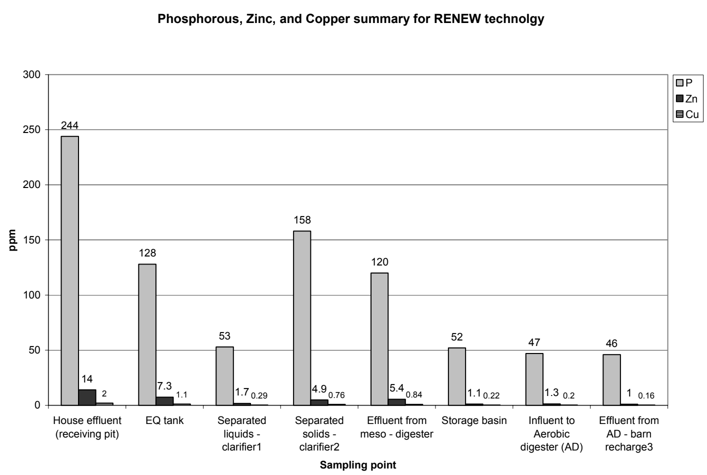
*Reflects 2 & 3 sampling events respectively.
** Storage basin and AED influent were collected at different sampling points however are virtually the same based on the data
***An increase in NO3 was noted during the last 6 sampling events (May 04 – Nov 04). See appendix.

Figure 5a – 5d. Nutrient Analysis charts and comparisons.

5a.



5b.



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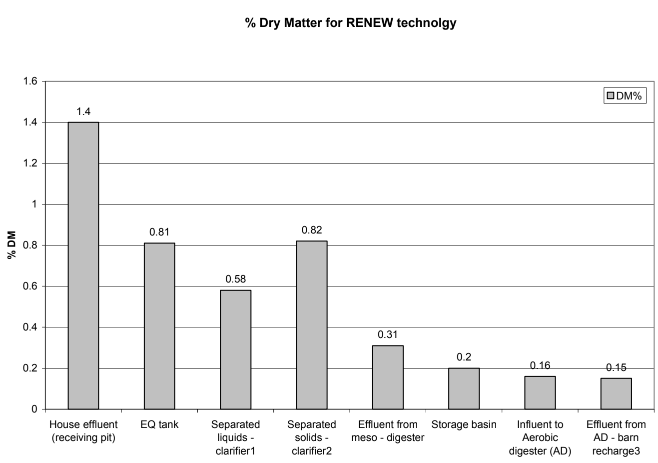

5d.

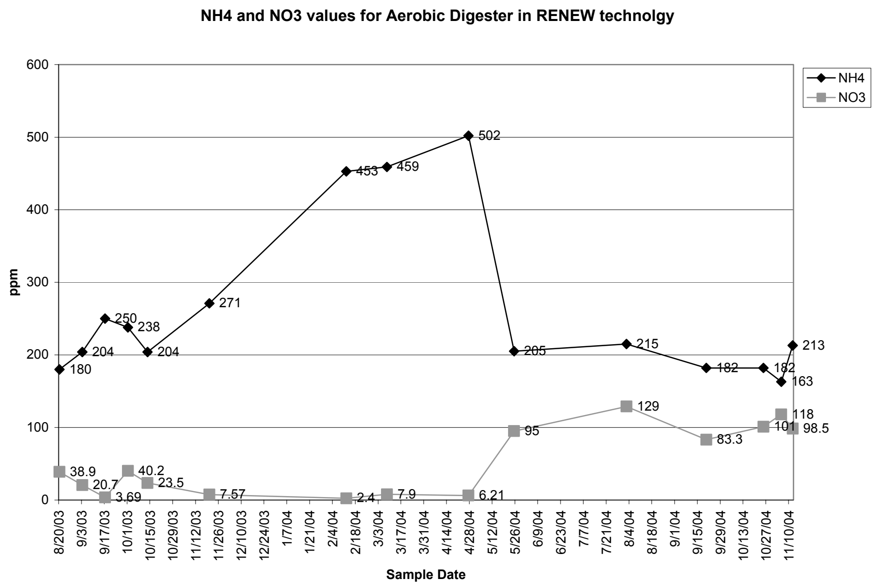

Table 2. The following table summarizes the sampling points, nutrient analyses (ppm), pH, %DM, and %VS for samples collected on 2/2/05 (Means):

Sample	N (Total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM %	%TS	%VS
House effluent (Lift station)	1615	1615	1316	.13	185	8.44	1.26	7.82	1.25	1.38	64.8
EQ tank influent	1614	1614	1431	.06	167	8.20	1.25	8.09	.70	.97	59.6
EQ tank effluent	1347	1347	1026	.02	220	10.4	1.57	7.43	1.05	1.74	71.2
Thickener (liquid)	1104	1104	891	.18	92.6	4.97	.79	7.94	.40	.78	58.5
Thickener (solid)	1569	1569	971	.20	381	20.1	2.19	6.98	1.49	1.90	71.8
Mesophilic Digester effluent	1293	1293	983	.35	191	11.9	1.83	7.35	.44	.76	53.2
Aerobic Digester influent	418	418	409	.16	39.5	.72	.28	7.73	.08	.31	35.4
Aerobic Digester Effluent (Flush tank Recharge)	397	397	359	.34	29	.65	.18	8.07	.09	.28	31.2

Table 3. Comparison of samples collected over the 15 month performance evaluation and the February 2, 2005 hourly composite sample collections.

Sample	N (Total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM%
House effluent (Lift station) (15)*	974	959	547	14	244	14	2.0	7.4	1.4
House effluent (Lift station) (2/2/05)	1615	1615	1316	.13	185	8.44	1.26	7.82	1.25
EQ tank influent (15)	898	887	489	12	128	7.3	1.1	7.6	.81
EQ tank influent (2/2/05)	1614	1614	1431	.06	167	8.20	1.25	8.09	.70
EQ tank effluent (2/2/05)	1347	1347	1026	.02	220	10.4	1.57	7.43	1.05
Thickener (liquid) (15)	898	889	766	9	53	1.7	.29	7.6	.58
Thickener (liquid) (2/2/05)	1104	1104	891	.18	92.6	4.97	.79	7.94	.40
Thickener (solid) (15)	1167	1159	894	8	158	4.9	.76	6.9	.82
Thickener (solid) (2/2/05)	1569	1569	971	.20	381	20.1	2.19	6.98	1.49
Mesophilic Digester effluent (15)	844	835	715	9	120	5.4	.84	7.3	.31
Mesophilic Digester effluent (2/2/05)	1293	1293	983	.35	191	11.9	1.83	7.35	.44
Aerobic Digester influent (15)	468	459	369	9	47	1.3	.20	7.7	.16
Aerobic Digester influent (2/2/05)	418	418	409	.16	39.5	.72	.28	7.73	.08
Aerobic Digester Effluent (Flush tank Recharge) (15)	398	346	261	52	46	1.0	.16	7.8	.15
Aerobic Digester Effluent (Flush tank Recharge) (2/2/05)	397	397	359	.34	29	.65	.18	8.07	.09

*Sample collection includes all ranges of animal ages (0-20 Weeks of Production) during the 15 month period. Animals were approximately 10 - 12 weeks of production during the 2/02/05 sample collection.

Table 4. Analysis of Sludge in the Mesophilic Digester, Storage Basin, and Aerobic Digester at the Vestal farm site (ppm unless otherwise noted) during February 05 sample collections. Depths refer to distance below the liquid surface.

Sample	N (Total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM %	%TS	%VS
Mesophilic Digester 3’	1523	1523	940	.26	284	20.8	2.8	7.2	.85	1.07	64.9
Mesophilic Digester 6’	1629	1629	961	.17	435	34.4	4.6	7.0	1.83	1.49	65.4
Aerobic Digester 3’	384	384	362	.37	37.9	.98	.23	8.1	.06	.29	31.5
Aerobic Digester 6’	538	538	367	.38	248	8.7	1.2	8.0	.16	.50	44.1
Storage Basin 3’	431	431	407	.27	48.4	1.2	.26	7.7	.10	.32	37.4
Storage Basin 9’	2346	2346	516	.30	1419	110.5	18.9	7.1	3.62	3.04	64.3

Flow rates and Volumes:

Approximately 77,000 gallons of manure slurry was delivered from eight flush style houses into two 4,000 gallon lift stations. The waste was then pumped using a parallel 5 hp submersible pump (each lift station) with solids handling controlled by liquid level floats and control panels to a 10,000 equalization tank daily. An existing screen in each of the lift stations was used to prevent foreign objects from passing to the EQ tank and to the concentrator. The waste was then pumped into a 10,000 gallon clarifier/ solids concentrator/ thickener with the sludge (solids) being fed to the 1 million gallon mesophilic digester and the supernatant (liquid) being transferred to a 21 million gallon storage basin. The original design utilized two 10,000 gallon equalization tanks to provide an approximate 6.4 hr hydraulic retention time (HRT) however, it was determined that one EQ tank was sufficient to manage the 77,000 gallons being pumped daily from both of the lift stations. The design also provided for 6 (4hour) batches of 10,000 gallons of slurry per day to be delivered to the concentrator/thickener with a 2 hp submersible pump from the EQ tanks. Due to system operation limited to farm operation hours, 6AM to 4PM, an accumulation of solids resulted in the 6 inch PVC pipe to the thickener when flows were stopped overnight. A 7 hp pump was installed in efforts to prevent clogs in the line. This created problems feeding the thickener and finally a 5 hp pump was installed with the 7 hp pump being used to mix the EQ tank to prevent the settling of solids during operation. With the challenges created by solids settling in the lines and alterations in pumps these retention times and deliveries were difficult to manage. During periods in the performance evaluation the waste from the EQ tank was delivered directly to the mesophilic digester (with the thickener acting as a conduit). During the February 2005 trial it was determined (volumetric container and timer) that of the 77,000 gallons of liquid sent to the EQ tanks approximately 73,000 gallons of wastewater was sent to the thickener and 4100 gallons to the storage basin. Once the wastewater was settled in the thickener, approximately 34,000 gallons of thickened slurry was fed to the mesophilic digester and 38,000 gallons of liquid was delivered to the storage basin. Approximately 34,000 gallons of treated waste was delivered to the storage basin from the mesophilic digester with the storage basin receiving a total of 77,000 gallons of wastewater per day from all technology components. The 500,000 gallon aerobic digester received 54,000 gallons of wastewater per day from the storage basin with the same amount being pumped from the aerobic digester to the 820 gallon tanks at each of the houses to be used as flush water. A more detailed description of the system flow rates and volumes is outlined in the ISSUES - RENEW Permit Application submitted to NCDENR listed in Appendix C.

Table 5. The following table summarizes the approximate flow rates and volume of waste water being treated with the Mesophilic digester and Aerobic digester technologies during existing farm operation hours (6AM to 4PM).

Volume (GPD)	Houses (Hses) Vestal 1 & 2	Lift station (LIS) Vestal 1 & 2	Equalization (EQ) Tank	Thickener	Mesophilic Digester (MD)[2]	Storage Basin (SB)	Aerobic Digester (AED)
In	54540	77060	76840	72750	34050	4100 38700 34050	53840
Out	77060	76840	72750 (TH) 4100 (SB)	34050 (MD) 38700 (SB)	34050 (SB)	53800 (AED)	54540
Difference	22520[1]	-	-	-	-	23050[3]	-

[1]Assumes 2.3 gallons of waste water (manure, urine, wasted water) produced per head (1224/hse) per day (g/h/d) x 8 houses. Resource: Permit Application – NCDENR.
[2]Influent is equal to Effluent volume – based on equilibrium.
[3] Land application is used to maintain permitted freeboard on storage basin.

Mass Balance of Nutrients:

Data analyses shown above include both the 15 month sampling period as well as the one-day hourly composite samples. The data for all parameters monitored during the 15 month trial are shown in Appendix A. Mass balance calculations reported below are based on the multiple-sampling protocol conducted over 15 months. A description of mass balance calculations and reductions and/or increases in nutrients is outlined in Appendix B.

Table 6a & 6b. The following tables describe the mass balance of nutrients and nutrient reduction observed for the RENEW technology.

6a.

Kg/day	House (In)	House (Out)	Mesophilic Digester (In)*	Mesoplhilic Digester (Out)	AED (In)	AED (Out)	Storage Basin (In)	Storage Basin (Out)
N(Total)	82.1	284.0	125.5 150.4	108.7	95.4	82.1	254.2	95.3
TKN	71.4	279.6	123.6 149.3	107.6	93.5	71.4	251.6	93.5
NH4	53.9	159.5	70.5 115.2	92.1	75.2	53.9	211.9	75.2
NO3	10.73	4.08	1.8 1.0	1.16	1.83	10.73	2.67	1.83
P	9.5	71.1	31.4 20.4	15.5	9.58	9.49	25.25	9.6
Zn	0.21	4.08	1.8 .63	.70	0.26	0.21	1.06	0.26
Cu	0.03	0.58	.26 .10	.10	0.041	0.033	0.16	0.04
Solids	310	4082	1804 1057	399	326	309.6	1373	325

*First entry reflects house effluent; second entry reflects effluent from thickener.

6b.

% Reduction	House (In - Out)	Mesoplhilic Digester (In - Out)*	AED (In - Out)	Storage Basin (In - Out)	Total System Reduction %
N(Total)	246+	13.4 27.7	13.9	62.5	66.0
TKN	292+	12.9 27.9	23.6	62.8	70.1
NH4	196+	30.6+ 20.1	28.3	64.5	85.5
NO3	62	35.6 16+	486+	31.5	282+
P	648+	50.6 24.0	0.9	62	44.6
Zn	1842+	61.1 11.1+	19.2	75.5	47.8
Cu	1833+	61.5 0	19.5	75	49.7
Solids	1217+	77.9 62.3	5.0	76.3	60.5

*First entry reflects house effluent; second entry reflects effluent from thickener.

Based on the results of data shown in Tables 1-4, some general observations are:

First, the gravity thickener used in this system was ineffective in concentrating the material from the equalization tank to the solids level desired. Had the biogas production and capture of energy as electricity been a component of this evaluation, the impact of the poor performance would be more striking since a substantial portion of the solids that would have been converted to biogas was decanted off the top into the storage basin. The storage basin was converted into a modestly loaded traditional anaerobic treatment lagoon. A modification to improve the thickener efficiency would be the use of a flocculation agent or utilization of another solid separation system.

Second, there is concern whether samples collected from the mesophilic digester were representative of the composition of the actual contents. It was noted (visual observation) during sampling on the February hourly sampling protocol that there was a significant accumulation of sludge in the mesophilic digester. The sampling device used to probe and collect samples had a filling valve opening that was judged to be too small to allow entry of a representative sample of the material in the lower level of the digester. For that reason, data on sludge composition in the mesophilic digester are reported, but not considered reliable for any balance calculations. In contrast, sludge samples taken in the storage basin (SB) and AED are assumed to be accurate, since there was much less fibrous material in each of these treatment cells. Also, the sludge particle size appeared to be significantly smaller and easier to collect in representative form in the SB and AED. The solids data (Table 4) support these concerns.

Third, it was observed during the hourly sampling event (February 2005) that there was a significant diurnal cycle on solids content of house flush, with highest solids in the early morning. Grab samples taken once a day would not reflect this cycle unless collection of the grab samples was taken specifically during that cycle. This observation was substantiated in several other of the technology evaluations conducted within this program.

Fourth, concerning nitrate concentrations in the aeration systems, as noted above in previous sections of this report, during warmer seasons the biological actions resulting in nitrate formation and ammonia reduction were more active (Figure 5d) (NH_4-N concentrations from 500 reduced to 200ppm and nitrate concentrations increased from less than 10 to over 100ppm).

Using the flow data shown in Table 5 and the analytical results shown in Table 1, the calculated daily flows of nutrients through the components of the system were determined and reported in Table 6a. Corresponding percentage reduction results are shown in Table 6b.

Two balance calculations are shown for the mesophilic digester based on the operation of the thickener (house effluent and thickened sludge). Based on the data supplied by the technology provider it is difficult to determine a weighted mean of the composition of the material transferred to the digester since the thickener served as a conduit periodically. Flows and samples were not taken during these events.

A 70 percent and 85.5 % reduction in total N and NH_4-N was observed respectively across the entire system. While it is not possible to determine the fate of the reduced nitrogen (emissions of ammonia, dinitrogen gas or accumulated organic nitrogen in sludge), the NO_3-N data shown in Figure 5d offer evidence that at least during warm season the production of dinitrogen gas might have been a major factor. From a component standpoint, the greatest reductions in nitrogen took place in the storage basin, indicating that as operated, this component functioned as an anaerobic treatment lagoon.

As with the other system evaluations in this report, the unaccounted minerals are assumed to be incorporated into the retained and accumulating sludge solids and are retained from release into the environment unless land applied.

Solids reduction was substantial, and as expected, was greatest in the mesophilic digester. The range of removal (62-77%) is similar to observed values noted in the in-ground digester reported in the Phase 1 (Barham Farm). The impact of the solids buildup observed in the digester cannot be accurately computed in these results due to concerns about sampling methodology.

As a check on the process, data collected were used to predict the daily nutrient output on an individual animal basis over the total cycle (average data used). This calculation resulted in a predicted output of 21g total N, 11g ammonia, 6.3g P, 0.4g Zn, 0.06g Cu and 385g solids. These estimates are similar to those computed for other portions of the ISSUES project and noted above.

Biogas:

It was estimated that the mesophilic digester (MD) located on the Vestal site would produce biogas consisting of approximately 65-70% methane; 30-35% carbon dioxide; and .05% of other gases including hydrogen sulfides and ammonia. The 40 mil HDPE synthetic MD cover with 6 inch Styrofoam insulation was installed to provide a resistance value of $3ft^2$ – hr- F/Btu and designed to allow the biogas to flow to one end of the digester for collection and to provide energy to both the heat exchanger and micro-turbine. Any excess biogas produced was to be vented through a flare to assure combustion of the methane and hydrogen sulfide. A more detailed description is outlined in the RENEW Permit Application to NCDENR listed in the Appendix C. Biogas production was monitored via flow meter and computer for August 2004 and is shown in Table 7. A peak yield of about 46,000 SCFD, corresponding to a calculated peak energy yield of 30M BTU/day was achieved.

The design data listed in Appendix C indicate a predicted volatile solids (VS) content of 80 percent of the total solids. Samples gathered during the evaluation were not analyzed for VS, but in the February sampling date VS was determined on the samples entering and leaving the digester. Average total solids (TS) concentration in the thickened material entering the mesophilic digester was 19g/l and VS was 71% of TS, giving a VS concentration of 14g/l in the influent. The effluent leaving the mesophilic digester contained 7.6g/l TS of which 53% was VS, for a VS concentration in the effluent of 4.0g/l. The flow across the mesophilic digester averaged 128,845l/day. Using the single day data (February 2005), it can be calculated that 1,803kg VS entered the digester per day, and 515kg left in the effluent. The disappearance of VS is 1,288kg per day. It is assumed that in swine waste the yield of biogas from VS destruction is approximately 35 SCF/kg. Using these data, had the February inputs and outputs been observed in August, when biogas was measured, the 1288kg VS should have resulted in 45,000SCF production, almost exactly what was observed between August 14 and August 29, 2004.

Due to negotiations with the local electric utility company and the technology supplier, the microturbine system was not included in this evaluation, thus further discussion concerning the biogas data are not possible.

Table 7. Mesophilic digester biogas production (SCFM – Standard Cubic Feet per Minute; SCFD – Standard Cubic Feet per Day) located at the Vestal farm site during August 2004.

Biogas Production		
Date	**SCFM**	**SCFD**
8/6/04	15.07	21693.60
8/7/04	17.88	25740.00
8/8/04	27.71	39906.72
8/9/04	29.68	42744.96
8/11/04	27.54	39656.16
8/14/04	30.28	43606.08
8/16/04	31.22	44953.92
8/17/04	30.41	43784.64
8/18/04	30.15	43421.76
8/19/04	30.42	43797.60
8/20/04	31.09	44763.84
8/21/04	32.42	46680.48
8/22/04	32.78	47204.64
8/23/04	31.95	46012.32
8/24/04	32.06	46166.40
8/25/04	32.10	46229.76
8/26/04	32.40	46657.44
8/27/04	31.59	45789.60
8/28/04	29.11	41914.08
8/29/04	25.80	37149.12

Water Reuse:

A water reuse component was installed in 2004 to provide further treatment of the nitrified aerobic digester effluent which would ultimately serve as animal drinking water, however, the water reuse module was not a component of the original project funded through the NCAG/SF/PSF/FF Initiative. The water reuse module included a series of clarifiers with aeration; the addition of flocculent; and settling. The settled solids were fed to the storage basin. The separated liquid was pumped through a sand filter, reverse osmosis, and finally through a UV filter. The final product was to be used for animal consumption as drinking water.

Figure 5. Process flow diagram of Water Reuse module.

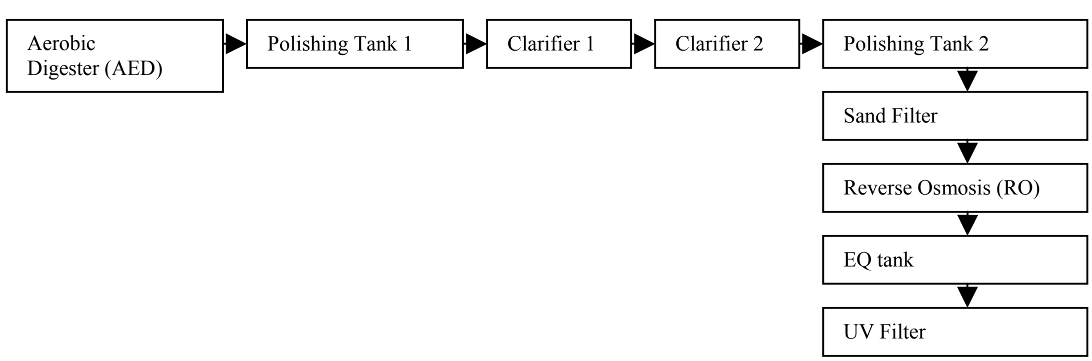

Table 8. The following table summarizes the sampling points, nutrient analyses (ppm), pH, and %DM for samples collected from the water reuse component (Means). Samples were submitted to both NCDA C&S Waste Solutions and Solutions laboratories for sample analysis.

Sample	N (Total)	TKN	NH4	NO3	P	Zn	Cu	pH	DM%
Water Reuse influent (AED effluent)	381	275	191	106	50	.94	.14	7.7	.15
Water Reuse effluent (Post UV light)	67	31	27	37	9	3	.09	7.7	.06
Post Sand filter*	-	-	113	157	37	.06	.02	7.3	-
Post Reverse Osmosis*	-	-	19	29	1	0	0	6.5	-
Post UV light*	-	-	19	29	.42	.01	0	6.8	-

* Samples analyzed at NCDA C&S Analytical Solutions laboratory.

The water reuse system with its many components presented many difficulties to sustained operation. Based on the nutrient data, it demonstrated that water can be recovered from swine waste and processed to potentially meet drinking water standards (with the exception of NO_3-N) for animals. The original intent of the project was to provide such water to finishing pigs and follow their performance, health and subsequent meat quality. That was not possible with the number of functional failures encountered in the system. It is also possible, based on an evaluation of each of the components used here, to determine which steps could be eliminated without compromising the production of the desired water quality. The latter could have an impact on the complexity of operation and should constitute the next step in this process. Pathogen/coliform reductions would also need to be considered.

Conclusions:

Based on the RENEW operation during this evaluation, several conclusions can be drawn: a. the thickener sized to produce a feedstock to the mesophilic anaerobic digester with solids content of 3 percent or more was ineffective, resulting in the transfer of a significant portion of the solids that could have been recovered as usable biogas to the storage basin; b. as a result of (a), the storage basin functioned as a modestly loaded anaerobic treatment lagoon; c. nitrogen reduction was effective in this system, with over 70 or greater percent reduction observed for total N and NH_4-N, but without indication of the disposition (emission as ammonia or dinitrogen gas or accumulation as organic N in sludge in the digester, storage basin or aerobic digester); d. nitrification in the aerobic digester was effective and especially so during warm weather; e. solids removal was modestly effective overall, and effective across the mesophilic digester, with conversion to biogas at up to 46,000 SCFD.

In a redesign of this system, a different method for concentrating solids prior to transfer to the digester is needed (if solids content of 5 percent or more is desired). Omitting the EQ tank and thickener could also be an option utilizing the lift stations as EQ tanks. The evaluation of the microturbine, an intended component of the system, should be completed when the agreements are in place to provide an outlet for the electrical energy generated. If water reuse is to be a standard part of this system, complexity and reliability need to be improved and the intended animal data collected.

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Appendix A

Nutrient Analysis Data

ABS - Nutrient Analysis

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Date	**Sample**	**Code**	**N (total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
2/24/2004	Hse effluent	C1									
	Lag - ABS	C2	628.5	617	547	536	11.5	70.5	73.3	3.13	1.14
	Lagoon	C3	658.1	645	577	564	13.1	67.7	57.1	1.92	0.64
	IESS lag	C4	374.5	360	265	251	14.5	94.7	24.1	0.53	0.14
	ABS mist	C5	370.5	356	266	251	14.5	89.9	27.6	0.52	0.14
No house effluent sample collected due to flushing schedule.											
3/17/2004	Hse effluent	C1	684.72	682	591	589	2.72	90.3	78	2.65	0.76
	Lag - ABS	C2	645.19	643	535	533	2.19	107	53.4	2.25	0.67
	Lagoon	C3	649.12	647	540	538	2.12	107	51.5	1.38	0.43
	IESS lag	C4	377.67	375	269	266	2.67	106	28.9	1.53	0.14
	ABS mist	C5	394.6	392	247	245	2.6	145	24.2	0.85	0.11
3/29/2004	Hse effluent	C1	870.9	856	701	686	14.9	155	90	2.98	1.37
	Lag - ABS	C2	818.8	804	630	616	14.8	174	147	6.46	3.42
	Lagoon	C3	933	919	668	654	14	251	238	12.6	6.16
	IESS lag	C4	397	383	292	278	14	91	35.4	0.96	0.36
	ABS mist	C5	407.1	393	297	283	14.1	95.9	30.1	0.66	0.19
4/30/2004	Hse effluent	C1	706	691	682	667	15	9.29	67.3	1.62	0.63
	Lag - ABS	C2	731.1	716	596	581	15.1	120	72.5	2.18	1.04
	Lagoon	C3	580.5	566	538	523	14.5	28.2	63.2	1.27	0.56
	IESS lag	C4	332.9	318	238	223	14.9	79.5	36.1	0.86	0.31
	ABS mist	C5	302.3	287	220	205	15.3	66.5	34	0.77	0.24
5/24/2004	Hse effluent	C1									
	Lag - ABS	C2	669.63	662	512	504	7.63	150	58.4	1.1	0.55
	Lagoon	C3	687.09	681	523	517	6.09	158	66.2	1.32	0.62
	IESS lag*	C4	395.13	388	258	251	7.13	130	34	0.84	0.32
	ABS mist	C5	399.78	394	273	267	5.78	121	30.9	0.53	0.21
Site visit - blower for IESS system operational / no house effluent sample collected due to flushing schedule.											
6/21/2004	Hse effluent	C1	674.8	662	505	493	12.8	157	81.3	3.21	1.17
	Lag - ABS	C2	553.3	541	485	473	12.3	55.7	49	1.06	0.39
	Lagoon	C3	590.7	578	488	475	12.7	90.8	67.8	1.35	0.59
	IESS lag	C4	546.1	531	459	444	15.1	71.8	38	0.51	0.14
	ABS mist	C5	569.8	556	414	400	13.8	142	36.7	0.67	0.15

ABS - Nutrient Analysis

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Date	**Sample**	**Code**	**N (total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
8/17/2004	Hse effluent	C1	575.3	562	370	356	13.3	192	71.3	2.66	0.6
	Lag - ABS	C2	440.7	427	329	315	13.7	98.8	72.6	1.82	0.47
	Lagoon	C3	446.9	434	301	289	12.9	132	89	3.04	0.97
	IESS lag	C4	222	52		8.57	**170**		49	0.69	0.16
	ABS mist	C5	226.3	60.3		6.29	**166**		51.3	1.55	0.29
9/15/2004	Hse effluent	C1									
	Lag.ABS	C2	420.6	408	311	298	12.6	96.5	74.2	1.33	0.47
	Lagoon	C3	377.1	365	328	316	12.1	36.7	69.1	1.09	0.35
	IESS lag	C4	196.3	29.3		21.5	**167**		52.6	0.51	0.2
	ABS mist	C5	108.5	10.9		9.41	**97.6**		46.9	0.76	0.2
No house effluent sample collected due to flushing schedule.											
Site visit on 10/8/04 - blower for IESS system not operating & ABS nozzles not misting - no samples collected.											
10/13/2004	Hse effluent	C1	798.7	787	302	290	11.7	485	405	26.3	5.08
	Lag.ABS	C2	473.5	462	353	342	11.5	108	112	4	1.63
	Lagoon	C3	388.5	375	329	315	13.5	46.3	61.6	2.01	0.49
	IESS lag	C4	158.3	23.3		13.5	**135**		43.1	2.06	0.28
	ABS mist	C5	160.8	57.8		38.8	**103**		53.5	3.49	0.33

ABS - Nutrient Analysis

As reported by NCDA													
Date	**Sample**		**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
2/24/2004	Hse effluent	C1											
	Lag - ABS	C2	1213	205	68.3	63.2	6.25	0.96	1.74	492	276	7.55	0.33
	Lagoon	C3	1214	200	55.8	64.7	4.64	0.72	1.76	505	270	7.49	0.31
	IESS lag	C4	980	143	42.4	51.8	2.99	0.32	1.56	410	217	7.8	0.12
	ABS mist	C5	1011	164	46.3	50.6	2.53	0.32	1.63	441	222	7.75	0.12
3/22/2004	Hse effluent	C1	1086	216	66.7	70.6	5.3	0.95	1.52	516	254	7.6	0.3
	Lag - ABS	C2	1040	159	47.3	73.3	3.36	0.6	1.53	502	228	7.55	0.22
	Lagoon	C3	1037	205	52.5	66.6	3.52	0.54	1.52	506	232	7.52	0.23
	IESS lag	C4	1033	160	44.1	67.7	2.18	0.36	1.47	444	240	7.89	0.14
	ABS mist	C5	939	149	39.7	53.3	1.74	0.32	1.35	439	216	7.87	0.08
3/29/2003	Hse effluent	C1	1219	235	76.7	70.5	7.45	2.98	1.68	580	271	7.62	0.41
	Lag - ABS	C2	1153	270	121	77.4	13.1	2.02	1.62	551	257	7.49	0.43
	Lagoon	C3	1037	353	173	86	22.4	3.69	1.49	548	231	7.45	0.63
	IESS lag	C4	1102	167	50.7	54	2.98	0.47	1.54	467	245	8.14	0.08
	ABS mist	C5	1081	165	47.3	51.8	2.17	0.45	1.52	473	241	7.99	0.11
4/30/2004	Hse effluent	C1	1395	212	60.6	72.8	4.32	0.73	1.75	605	308	8.04	0.28
	Lag - ABS	C2	1108	186	62.2	64.4	5.12	0.81	1.4	568	245	7.73	0.33
	Lagoon	C3	1232	188	57.3	67	3.54	0.61	1.55	516	271	7.76	0.39
	IESS lag	C4	989	161	44.7	49.8	2.12	0.49	1.25	475	220	8.23	0.25
	ABS mist	C5	1071	164	45.9	53.1	2.18	0.35	1.34	490	238	8.28	0.24
5/24/2004	Hse effluent	C1											
	Lag - ABS	C2	1174	158	58.7	60.8	3.56	0.52	1.71	508	254	7.78	0.29
	Lagoon	C3	1278	182	66.3	66.8	4.4	0.66	1.88	515	278	7.71	0.16
	IESS lag	C4	1061	174	48.5	58.1	2.25	0.39	1.58	451	236	8.6	0.24
	ABS mist	C5	1013	147	43.3	51.5	2.14	0.31	1.51	442	222	8.26	0.22
6/21/2004	Hse effluent	C1	1109	151	65.9	52.2	6.8	1.01	1.93	506	239	7.66	0.36
	Lag - ABS	C2	910	114	46.4	39	2.62	0.42	1.57	498	196	7.62	0.31
	Lagoon	C3	1197	116	57	48.9	3.36	0.52	2	503	254	7.6	0.32
	IESS lag	C4	954	111	46.3	46.9	1.72	0.24	1.59	405	207	7.44	0.29
	ABS mist	C5	920	113	45.8	45	1.88	0.27	1.59	405	199	7.41	0.31

ABS - Nutrient Analysis

As reported by NCDA													
Date	**Sample**		**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
8/17/2004	Hse effluent	C1	1073	142	62.1	65.8	4.48	0.66	2.2	521	239	7.38	0.27
	Lag - ABS	C2	1213	155	67.3	69.7	3.67	0.53	2.42	518	270	7.61	0.29
	Lagoon	C3	1242	157	77.7	73.7	4.91	0.73	2.4	527	274	7.61	0.25
	IESS lag	C4	1130	103	60.8	65.4	1.7	0.22	2.17	523	245	7.92	0.26
	ABS mist	C5	1080	131	63.8	66.2	1.81	0.28	2.3	479	239	7.12	0.21
9/15/2004	Hse efluent	C1											
	Lag.ABS	C2	962	143	67.4	41	3.56	0.62	1.55	488	228	7.53	0.42
	Lagoon	C3	1042	138	65.7	41.6	2.94	0.54	1.57	492	247	7.58	0.39
	IESS lag	C4	1053	130	64.1	51.2	2.1	0.33	1.61	457	246	8.36	0.39
	ABS mists	C5	917	133	61	47.2	2.06	0.34	1.45	256	215	7.46	0.24
10/13/2004	Hse effluent	C1	1354	580	245	106	42.4	9.45	1.92	519	311	7.14	1.08
	Lag.ABS	C2	1066	188	96.5	50.4	8.76	1.37	1.71	536	242	7.56	0.27
	Lagoon	C3	1061	128	61.2	44	3.44	0.58	1.68	514	237	7.57	0.17
	IESS lag	C4	922	100	54.1	57.3	1.74	0.29	2.06	440	199	8.95	0.07
	ABS mist	C5	1043	138	66.3	174	2.99	0.37	1.68	447	237	7.63	0.08

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Date	**Sample**	**Code**	**N (total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
7/31/2003	Hse effluent (to covered lagooon)*	H1	4954.7	***4913***	1791	1750	41.7	3122	1325	71.9	13
	Liquid - permeable covered lagoon	H2	587.77	585	584	582	2.77	0.16	76.8	1.27	0.2
	Aerobic digester	H3	386.67	378	377	369	8.67	0.1	36.4	1.47	0.19
	Storage basin	H4	37.1	31.4	19.8	14.1	5.7	11.6	4.85	1	0.07
	Hse effluent (to existing lagooon)	H5	466.06	466	401	401	0.06	65	63.4	1.86	0.29
	Lagoon (existing)	H6	335.52	333	261	258	2.52	72.8	56.7	1.21	0.21
8/12/2003	Hse effluent (to covered lagooon)	H1	703.53	695	640	631	8.53	55.6	63.4	2.91	0.39
	Liquid - permeable covered lagoon	H2	602.66	594	534	525	8.66	59.9	86.7	3.19	0.32
	Aerobic digester	H3	472.13	463	371	362	9.13	92.2	46.8	1.72	0.17
	Storage basin	H4	228.3	216	190	178	12.3	25.7	27.1	1.47	0.12
	Hse effluent (to existing lagooon)	H5	357.55	351	281	275	6.55	69.7	71.5	3.3	0.35
	Lagoon (existing)	H6	327.02	319	253	245	8.02	66.3	66.5	3.06	0.31
8/27/2003	Hse effluent (to covered lagooon)	H1	661.9	631	465	434	*30.9*	166	61.1	1.87	0.26
	Liquid - permeable covered lagoon	H2	696.7	666	550	520	*30.7*	116	97.5	1.32	0.17
	Aerobic digester	H3	475.7	443	357	324	*32.7*	86.8	48.5	1.22	0.11
	Storage basin	H4	194	164	101	71.4	*30*	63	28.4	0.72	0.05
	Hse effluent (to existing lagooon)	H5	517.9	487	235	204	*30.9*	252	82.6	2.69	0.3
	Lagoon (existing)	H6	500.7	469	231	200	*31.7*	238	70	1.53	0.21
9/10/2003	Hse effluent (to covered lagooon)*	H1	2795.4	**2783**	1252	1239	12.4	1531	917	40.2	6.56
	Liquid - permeable covered lagoon	H2	624.4	613	591	580	11.4	21.7	100	2.09	0.29
	Aerobic digester	H3	441.3	423	387	369	18.3	36	41	0.98	0.15
	Storage basin	H4	183.3	172	144	133	11.3	27.5	28.4	0.85	0.11
	Hse effluent (to existing lagooon)	H5	401.9	390	298	286	11.9	91.8	57.8	2.62	0.37
	Lagoon (existing)	H6	412.5	400	279	266	12.5	121	59.9	2.13	0.32
9/24/2003	Hse effluent (to covered lagooon)	H1	1166.66	1159	1157	1149	7.66	1.87	120	4.13	0.61
	Liquid - permeable covered lagoon	H2	595.22	589	580	573	6.22	9.82	85.2	1.11	0.27
	Aerobic digester	H3	471.25	464	382	374	7.25	82.3	44.7	0.81	0.18
	Storage basin	H4	186.6	151	117	81.5	*35.6*	34.2	33.3	1.06	0.82
	Hse effluent (to existing lagooon)	H5	434.84	429	303	297	5.84	127	62.9	1.39	0.3
	Lagoon (existing)	H6	357.35	351	265	259	6.35	85.8	45.8	0.83	0.23

*Solids build-up in lift station due to pump operation

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Date	**Sample**	**Code**	**N (total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
10/8/2003	Hse effluent (to covered lagooon)	H1	828.04	828	501	201	0.04	327	200	15.8	1.89
	Liquid - permeable covered lagoon	H2	701	701	531	531	0	170	77.5	0.52	0.18
	Aerobic digester	H3	475.03	474	317	316	1.03	157	39.1	0.2	0.06
	Storage basin	H4	242.46	240	119	117	2.46	120	0	0.1	0.03
	Hse effluent (to existing lagooon)	H5	565	565	250	250	0	315	61.1	1.16	0.31
	Lagoon (existing)	H6	516.72	515	278	276	1.72	238	52.3	0.47	0.18
11/17/2003	Hse effluent (to covered lagooon)*	H1	2843.6	**2821**	2297	2274	22.6	525	552	22.1	4.07
	Liquid - permeable covered lagoon	H2	633.2	610	590	567	23.2	20.4	68.8	0.5	0.09
	Aerobic digester	H3	516.1	493	445	422	23.1	48.6	49.5	0.4	0.09
	Storage basin	H4	173.2	145	136	108	28.2	8.96	33	0.28	0.04
	Hse effluent (to existing lagooon)	H5	506.5	484	386	364	22.5	97.5	53.5	0.86	0.21
	Lagoon (existing)	H6	415.3	393	307	285	22.3	85.6	51	0.69	0.17
12/15/2004	Hse effluent (to covered lagooon)	H1	964.4	962	842	839	2.4	121	133	4.02	0.71
	Liquid - permeable covered lagoon	H2	549.87	548	485	483	1.87	62.5	89.8	0.62	0.23
	Aerobic digester	H3	540.19	539	444	442	1.19	95.8	62.1	0.56	0.19
	Storage basin	H4	159.9	147	86.8	74	12.9	60	40.7	0.87	0.19
	Hse effluent (to existing lagooon)	H5	571.23	569	329	326	2.23	241	70.8	1.6	0.33
	Lagoon (existing)	H6	447.66	445	308	305	2.66	137	53.4	0.79	0.22
1/14/2004	Hse effluent (to covered lagooon)	H1	1397.7	1391	1376	1369	6.7	15.4	110	5.99	0.76
	Liquid - permeable covered lagoon	H2	655.1	645	627	617	10.1	18.2	82.5	0.6	0.13
	Aerobic digester	H3	583.6	569	527	512	14.6	42.5	54.9	0.49	0.09
	Storage basin	H4	148.9	114	86.4	51.5	*34.9*	27.3	31.7	0.28	0.04
	Hse effluent (to existing lagooon)	H5	677	677	482	482	0	194	225	6.55	0.62
	Lagoon (existing)	H6	532	532	422	422	0	111	56.7	0.77	0.2
1/26/2004	Hse effluent (to covered lagooon)	H1	791	791	627	627	0	164	84.2	2.65	0.4
	Liquid - permeable covered lagoon	H2	660	660	625	625	0	34.9	74.2	0.87	0.15
	Aerobic digester	H3	608	608	531	531	0	76.6	45.9	0.63	0.1
	Storage basin	H4	136	136	104	104	0	31.6	28.7	0.37	0.05
	Hse effluent (to existing lagooon)	H5	727	727	468	468	0	259	120	4.38	0.55
	Lagoon (existing)	H6	553	553	449	449	0	103	57.4	1.08	0.22

*Solids build-up in lift station due to pump operation

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Date	**Sample**	**Code**	**N (total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
2/25/2004	Hse effluent (to covered lagooon)	H1	768.2	756	679	667	12.2	77.2	122	6.33	0.77
	Liquid - permeable covered lagoon	H2	775.4	764	669	658	11.4	95.1	70.2	0.91	0.19
	Aerobic digester	H3	716	705	619	608	11	85.9	57.2	0.83	0.17
	Storage basin	H4	314	302	265	253	12	37.2	36.6	0.44	0.09
	Hse effluent (to existing lagooon)	H5	746.8	735	621	609	11.8	114	134	6.51	0.95
	Lagoon (existing)	H6	609.8	597	523	511	12.8	74.1	63.3	1.23	0.28
3/24/2004	Hse effluent (to covered lagooon)	H1	1142.2	1130	712	700	12.2	418	292	13.4	1.9
	Liquid - permeable covered lagoon	H2	727.6	716	671	659	11.6	45.5	91.2	2.41	0.52
	Aerobic digester	H3	686.5	676	637	627	10.5	38.7	55.3	1	0.22
	Storage basin	H4	355.1	344	286	275	11.1	57.7	34.4	0.8	0.17
	Hse effluent (to existing lagooon)	H5	635	624	522	511	11	102	53.4	1.5	0.32
	Lagoon (existing)	H6	661.1	650	559	548	11.1	91.2	74.1	1.93	0.46
4/28/2004	Hse effluent (to covered lagooon)	H1	1565.8	1550	812	796	15.8	738	1004	40.5	6.65
	Liquid - permeable covered lagoon	H2	787.1	773	722	708	14.1	51.8	78.4	1.01	0.23
	Aerobic digester	H3	736.4	713	650	626	*23.4*	63	64.2	1.24	0.24
	Storage basin	H4	301	286	228	213	15	58	40.1	0.97	0.16
	Hse effluent (to existing lagooon)	H5	874.9	860	763	748	14.9	97.2	50.2	1.73	0.4
	Lagoon (existing)	H6	704.7	689	579	563	15.7	110	58.5	1.67	0.35
5/21/2004	Hse effluent (to covered lagooon)	H1	925.99	921	789	784	4.99	133	83.3	2.33	0.47
	Liquid - permeable covered lagoon	H2	917.48	912	770	765	5.48	142	109	2.01	0.41
	Aerobic digester	H3	813.24	808	679	674	5.24	129	53.9	0.76	0.22
	Storage basin	H4	303.91	298	216	210	5.91	82.2	46.9	0.64	0.23
	Hse effluent (to existing lagooon)	H5	685.85	680	527	522	5.85	153	59.3	1.49	0.4
	Lagoon (existing)	H6	754.07	747	616	609	7.07	132	61.1	1.35	0.41
5/31/2004	Hse effluent (to covered lagooon)	H1	965.9	955	864	853	10.9	91.5	184	6.71	0.57
	Liquid - permeable covered lagoon	H2	802.53	793	731	721	9.53	62.7	93.2	1.78	0
	Aerobic digester	H3	672.32	663	619	610	9.32	43.5	53.2	1.09	0
	Storage basin	H4	317.5	307	228	217	10.5	79.3	37.9	0.75	0
	Hse effluent (to existing lagooon)	H5	846	836	580	570	10	256	91	4.04	0.26
	Lagoon (existing)	H6	659.77	650	580	570	9.77	70.6	65.2	1.43	0.3
End of original ISSUES system - installation of Evaporation system											

*Solids build-up in lift station due to pump operation

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Date	**Sample**	**Code**	**N (total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
8/13/2004	Hse effluent (to covered lagooon)*	H1	3065.89	**3056**	2945	2935	9.89	111	705	51.5	9.29
	Liquid - permeable covered lagoon	H2	784.1	773	521	510	11.1	251	86.3	1.75	0.18
	Aerobic digester	H3	638.4	628	351	341	10.4	277	51.7	1.56	0.13
	Storage basin	H4	226.8	208	86.3	67.5	18.8	122	30.4	1.05	0.08
	Hse effluent (to existing lagooon)	H5	440.8	430	175	164	10.8	255	69	2.34	0.4
	Lagoon (existing)	H6	448.86	439	235	225	9.86	204	68.6	4.48	1.19
	Evap not operating @ sampling										
8/23/2004	Hse effluent (to covered lagooon)	H1	1499	1467	720	688	*32*	746	442	27.1	4.02
	Liquid - permeable covered lagoon	H2	754.9	724	678	648	*30.9*	45.4	74.9	0.83	0.13
	Aerobic digester	H3	590.8	560	512	481	*30.8*	48.7	57.8	0.65	0.11
	Storage basin	H4	186	151	124	89.1	*35*	26.7	28.2	0.52	0.04
	Hse effluent (to existing lagooon)	H5	727.4	697	332	302	*30.4*	365	242	10.9	1.71
	Surface H20 on PC lagoon	H7	168	139	82.6	53.7	*29*	56.1	37.4	1.05	0.09
	Evap operating during sampling										
	Aeration in AD operating 40/20										
9/29/2004	Hse effluent (to covered lagooon)	H1	1040.9	1028	729	717	12.9	299	184	11	1.43
	Liquid - permeable covered lagoon	H2	627.1	611	473	457	16.1	138	81.1	1.39	0.22
	Aerobic digester	H3	601	584	405	388	17	178	58.2	0.89	0.26
	Storage basin	H4	331.6	301	194	164	*30.6*	107	44.7	1.16	0.19
	Hse effluent (to existing lagooon)	H5	372.5	356	191	175	16.5	165	71.7	1.77	0.32
	Lagoon (existing)	H6	377.6	363	230	216	14.6	133	66	2.22	0.36

*Solids build-up in lift station due to pump operation

As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
7/31/2003	Hse effluent (to covered lagooon)*	843	2255	766	274	161	24.6	2.19	438	188	6.61	12.04
	Liquid - permeable covered lagoon	879	154	71.6	21.3	3.89	0.45	1.55	456	198	7.25	0.36
	Aerobic digester	760	143	40.8	19.1	3.51	0.31	1.3	385	172	8.35	0.31
	Storage basin	80.8	92.8	20.7	8.22	1.6	0.19	0.37	36.9	32.9	9.2	0.06
	Hse effluent (to existing lagooon)	851	138	54.7	39.5	4.79	0.57	1.51	387	198	8.26	0.39
	Lagoon (existing)	722	129	57.1	30.6	3.44	0.35	1.31	337	169	7.74	0.15
8/12/2003	Hse effluent (to covered lagooon)	961	144	37.4	54.1	5.1	0.74	1.62	437	219	8.24	0.39
	Liquid - permeable covered lagoon	931	135	69.1	28.7	3.76	0.47	1.48	376	202	7.32	0.28
	Aerobic digester	866	122	46.2	21.6	2.42	0.28	1.36	333	194	7.97	0.18
	Storage basin	407	92.4	30.6	11.4	1.75	0.23	0.77	158	95.4	7.84	0.07
	Hse effluent (to existing lagooon)	1002	136	58.2	35.2	4.67	0.53	1.54	420	234	7.66	0.39
	Lagoon (existing)	937	133	55.8	32	3.96	0.48	1.61	401	210	7.71	0.3
8/27/2003	Hse effluent (to covered lagooon)	1056	163	44.8	45.2	4.12	0.59	1.79	444	238	8.31	0.53
	Liquid - permeable covered lagoon	959	149	78.6	27.3	3.23	0.48	1.59	423	214	7.3	0.35
	Aerobic digester	940	137	44.5	24.4	2.24	0.29	1.58	388	211	8.19	0.25
	Storage basin	467	91.1	30.5	12.1	1.32	0.21	0.87	195	109	8.29	0.23
	Hse effluent (to existing lagooon)	888	162	66.9	44.1	4.8	0.64	1.66	366	208	7.88	0.39
	Lagoon (existing)	840	144	59.1	39.9	3.44	0.42	1.58	331	192	7.81	0.34
9/10/2003	Hse effluent (to covered lagooon)*	1622	1534	480	195	86.6	13.7	2.6	634	301	7.05	4.81
	Liquid - permeable covered lagoon	889	200	82.5	32.7	4.62	0.65	1.58	372	183	7.28	0.33
	Aerobic digester	854	148	44.2	26.1	2.5	0.27	1.5	356	182	7.98	0.48
	Storage basin	453	112	34.2	14.2	1.78	0.24	0.87	183	102	7.9	0.31
	Hse effluent (to existing lagooon)	965	148	46.3	41.6	4.29	0.43	1.6	454	209	7.96	0.57
	Lagoon (existing)	837	165	57.1	45	3.93	0.41	1.57	336	177	7.72	0.45
9/24/2003	Hse effluent (to covered lagooon)	701	217	52	76.7	11.7	1.2	0.98	395	160	8.67	0.27
	Liquid - permeable covered lagoon	985	167	72.6	32	3.07	0.44	1.43	431	211	7.36	0.38
	Aerobic digester	864	148	45.3	26.3	2.22	0.3	1.29	413	186	7.99	0.44
	Storage basin	503	133	38.7	16.2	3.31	0.33	0.77	220	116	7.7	0.17
	Hse effluent (to existing lagooon)	841	160	49.8	40.5	4.46	0.54	1.31	398	177	7.85	0.36
	Lagoon (existing)	807	143	44.5	36.7	3.25	0.37	1.24	384	173	7.97	0.44

*Solids build-up in lift station due to pump operation

As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
10/8/2003	Hse effluent (to covered lagooon)	946	298	116	56.2	20.7	4.01	1.62	418	223	7.14	1.21
	Liquid - permeable covered lagoon	891	169	68.8	26.4	3.11	0.52	1.63	407	203	7.5	0.4
	Aerobic digester	772	147	41.2	25.7	2.47	0.36	1.41	311	177	8.09	0.26
	Storage basin	544	110	34.1	16.2	1.78	0.26	1.02	220	131	8.35	0.25
	Hse effluent (to existing lagooon)	1022	156	46.7	46	4.87	0.59	1.88	426	227	7.92	0.51
	Lagoon (existing)	847	160	46.2	46.8	3.9	0.46	1.64	358	194	7.82	0.59
11/17/2003	Hse effluent (to covered lagooon)*	1728	703	369	209	41.3	8.46	2.83	932	328	6.82	4.38
	Liquid - permeable covered lagoon	802	175	68.6	24.5	2.45	0.45	1.37	401	175	7.05	0.35
	Aerobic digester	920	163	47.7	26.5	2.01	0.32	1.5	370	198	7.69	0.2
	Storage basin	576	121	36.2	17	1.36	0.23	1.01	246	128	7.91	0.08
	Hse effluent (to existing lagooon)	896	170	48.4	53.2	3.55	0.44	1.56	412	191	7.75	0.3
	Lagoon (existing)	841	164	46.7	47	3.13	0.38	1.43	379	180	7.63	0.29
12/15/2003	Hse effluent (to covered lagooon)	1140	326	80.6	78.7	9.34	1.78	1.94	477	242	8.54	0.62
	Liquid - permeable covered lagoon	880	205	63.1	35.2	2.34	0.49	1.62	360	193	7.35	0.15
	Aerobic digester	960	215	44.1	31.1	2.24	0.37	1.73	370	211	7.87	0.13
	Storage basin	521	176	39.7	21.8	2.09	0.35	1.1	218	128	8.04	0.05
	Hse effluent (to existing lagooon)	852	200	47.3	53.7	4.74	0.72	1.58	359	186	8.21	0.18
	Lagoon (existing)	849	214	41.5	55.2	3.68	0.44	1.66	346	181	7.96	0.14
1/19/2004	Hse effluent (to covered lagooon)	1345	285	55.5	108	10.3	1.92	1.63	623	296	7.94	0.68
	Liquid - permeable covered lagoon	938	184	63	32.4	2.63	0.56	1.4	452	202	7.2	0.2
	Aerobic digester	1077	189	42.9	22.8	2.36	0.36	1.59	416	226	7.73	0.07
	Storage basin	480	137	36	14.4	1.71	0.28	0.79	202	115	7.88	0.06
	Hse effluent (to existing lagooon)	1029	293	171	67.1	22.5	2.37	1.52	446	222	7.4	0.75
	Lagoon (existing)	851	181	44.9	53.9	3.84	0.48	1.3	449	182	7.36	0.13
1/26/2004	Hse effluent (to covered lagooon)	827	245	60.9	34.6	6.71	1.12	1.7	439	183	7.73	0.22
	Liquid - permeable covered lagoon	876	210	59.9	33.7	3.26	0.64	1.71	436	187	7.23	0.07
	Aerobic digester	831	189	38.8	19.9	2.68	0.63	1.62	392	178	7.68	0.07
	Storage basin	471	170	36.9	16	2.09	0.37	1.13	202	104	8.05	0.06
	Hse effluent (to existing lagooon)	748	270	83.2	52.1	10.6	1.75	1.47	395	173	7.5	0.31
	Lagoon (existing)	799	193	45.1	43.3	4.19	0.55	1.55	395	171	7.66	0.07

*Solids build-up in lift station due to pump operation

PCS - Nutrient Analysis

As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
2/25/2004	Hse effluent (to existing lagooon)	1030	259	81.8	37.1	9.68	1.61	1.68	439	230	7.41	0.36
	Liquid - permeable covered lagoon	882	185	56.5	29.4	3.38	0.58	1.51	418	194	7.11	0.22
	Aerobic digester	927	196	47	24.4	3.38	0.43	1.58	408	203	7.46	0.2
	Storage basin	646	150	38.6	16.8	2.44	0.32	1.2	267	148	7.65	0.07
	Hse effluent (to existing lagooon)	955	268	81.3	52	9.7	1.86	1.46	399	220	7.34	0.44
	Lagoon (existing)	880	190	48.8	36.7	5.08	0.56	1.42	375	200	7.41	0.15
3/24/2004	Hse effluent (to covered lagooon)	1157	505	168	69.8	24.2	4.55	1.33	420	238	7.15	1.36
	Liquid - permeable covered lagoon	901	255	80.2	74.7	16.9	1	1.11	409	209	7.06	0.19
	Aerobic digester	918	214	49.8	40.8	3.35	0.45	1.15	410	201	7.55	0.22
	Storage basin	680	194	42.2	31.8	6.27	0.37	0.87	280	157	8	0.06
	Hse effluent (to existing lagooon)	829	179	42.6	44.5	4.8	0.52	1	373	180	7.69	0.2
	Lagoon (existing)	900	227	62.9	35.5	6.37	0.73	1.11	380	199	7.42	0.07
5/21/2004	Hse effluent (to covered lagooon)	1423	1191	551	148	72.8	16.3	1.78	459	277	6.62	4.11
	Liquid - permeable covered lagoon	855	206	65.8	32.9	3.31	0.66	1.32	436	193	7.19	0.2
	Aerobic digester	885	173	45.5	21.7	3.11	0.46	1.35	407	191	7.7	0.25
	Storage basin	728	169	38.8	16.8	2.23	0.34	1.19	318	165	8.07	0.17
	Hse effluent (to existing lagooon)	983	200	45.6	53.5	5.08	0.62	1.4	498	212	8.15	0.32
	Lagoon (existing)	941	198	49.1	35.5	4.58	0.34	1.38	430	207	7.69	0.23
5/24/2004	Hse effluent (to covered lagooon)	1098	225	62.1	51.1	5.21	1	1.63	498	245	7.8	0.33
	Liquid - permeable covered lagoon	975	217	86.5	35.8	5.01	1.03	1.53	442	213	7.28	0.16
	Aerobic digester	914	190	44.1	26.4	2.63	0.43	1.44	426	199	7.76	0.13
	Storage basin	856	168	44.1	22.8	3.91	0.33	1.35	357	190	8.33	0.07
	Hse effluent (to existing lagooon)	1037	169	50.2	40.6	4.94	0.6	1.55	452	226	7.91	0.13
	Lagoon (existing)	1046	168	51.9	38.3	4.72	0.57	1.58	453	222	7.87	0.25
5/31/2004	Hse effluent (to covered lagooon)	1092	278	106	70.4	9.98	2.11	1.63	540	246	7.63	0.64
	Liquid - permeable covered lagoon	966	190	62.9	35.2	2.78	0.58	1.56	444	202	7.26	**0.31**
	Aerobic digester	910	192	41.6	32.4	2.42	0.43	1.56	422	188	7.82	**0.25**
	Storage basin	789	140	33.5	20.6	1.41	0.24	1.46	386	163	8.25	0.07
	Hse effluent (to existing lagooon)	953	164	61.9	48.1	6.39	0.89	1.58	496	198	7.71	0.45
	Lagoon (existing)	1017	166	50	38.1	4.41	0.5	2.23	492	215	7.81	0.24

*Solids build-up in lift station due to pump operation

PCS - Nutrient Analysis

As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
8/13/2004	Hse effluent (to covered lagooon)*	2567	1096	460	304	69.9	17.6	4.59	1249	490	7.42	4.7
	Liquid - permeable covered lagoon	1017	172	77.6	34.3	2.3	0.64	2.32	431	226	7.37	0.23
	Aerobic digester	1047	162	45.4	32.6	2.08	0.49	2.26	394	232	8.24	0.22
	Storage basin	753	110	35.5	21.9	1.43	0.27	1.73	299	167	8.46	0.15
	Hse effluent (to existing lagooon)	1145	139	56.2	47.3	4.44	0.61	2.42	449	251	8.05	0.29
	Lagoon (existing)	904	140	53.5	39.5	4.95	0.68	2.06	402	200	7.92	0.27
8/23/2004	Hse effluent (to covered lagooon)	1190	576	270	102	43.7	9.99	1.82	442	258	6.51	2.7
	Liquid - permeable covered lagoon	895	166	69.1	27.9	4.17	0.62	1.52	417	199	7.2	0.18
	Aerobic digester	928	158	55.6	30.2	3.62	0.48	1.5	442	205	7.66	0.06
	Storage basin	711	135	38.7	20.9	2.57	0.31	1.25	307	157	8.12	0.06
	Hse effluent (to existing lagooon)	961	295	141	63	18.6	3.92	1.46	419	211	6.53	0.86
	Surface H20 on PC lagoon	421	124	42.4	26.6	2.48	0.34	0.97	219	95.8	8.33	0.07
9/29/2004	Hse effluent (to covered lagoon)	1099	298	118	73.3	15.6	3.21	1.56	626	242	7.3	0.88
	Liquid -permeable covered lagon	893	160	73.4	32.7	2.25	0.63	1.34	466	194	7.17	0.19
	Aerobic Digester	887	173	58.4	30.4	2.37	0.61	1.33	459	194	7.64	0.11
	Storage Basin	805	147	47.3	26.2	2	0.44	1.26	410	176	8.01	0.15
	Hse effluent (to existing lagoon)	782	131	50.8	40.1	4.04	0.57	1.22	433	166	7.7	0.14
	Lagoon (existing)	804	157	59.2	45.8	4.1	0.61	1.29	371	175	7.58	0.24

*Solids build-up in lift station due to pump operation

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Some technology components unavailable for sample collections due to operation.											
Date	**Sample**	**Code**	**N(Total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
8/20/2003	House effluent (receiving pit)	V0	352.91	348	283	278	4.91	65.2	86.3	2.97	0.6
	EQ tank	V1	1913.01	1909	620	616	4.01	1289	376	14.4	2.71
	Separated solids - clarifier	V2									
	Separated liquids - clarifier	V3									
	Effluent from meso - digester	V4	575.09	571	534	530	4.09	36.4	79.6	2.07	0.52
	Storage basin	V5	359.86	356	283	279	3.86	72.4	70.4	2.06	0.82
	Influent to Aerobic digester (AD)	V6	467.26	463	291	287	4.26	172	64.8	1.73	0.65
	Effluent from AD - barn recharge	V7	286.9	248	219	180	**38.9**	28.8	61.1	1.6	0.21
	Reuse water	V22									
9/3/2003	House effluent (receiving pit)	V0	1226	1210	467	451	16	743	440	25.2	3.45
	EQ tank	V1	3185.8	3169	426	409	16.8	2743	899	78.1	13.2
	Separated solids - clarifier	V2									
	Separated liquids - clarifier	V3									
	Effluent from meso - digester	V4	578.8	561	561	543	17.8	0.03	105	1.36	0.16
	Storage basin	V5	366.8	351	312	296	15.8	38.7	72.2	1	0.16
	Influent to Aerobic digester (AD)	V6	392.9	377	328	313	15.9	48.4	70.4	2.06	0.2
	Effluent from AD - barn recharge	V7	272.7	252	225	204	**20.7**	27.8	47.4	0.79	0.13
	Reuse water	V22									
9/17/2003	House effluent (receiving pit)	V0	1419.55	1416	492	488	3.55	924	505	27.6	4.37
	EQ tank	V1	542.17	537	405	400	5.17	131	107	5.93	0.91
	Separated solids - clarifier	V2									
	Separated liquids - clarifier	V3									
	Effluent from meso - digester	V4	522.61	519	493	489	3.61	26	108	2.75	0.36
	Storage basin	V5	361.38	356	319	314	5.38	37	59.9	1.12	0.28
	Influent to Aerobic digester (AD)	V6	337.34	334	302	298	3.34	32.5	53.9	0.79	0.22
	Effluent from AD - barn recharge	V7	301.69	298	253	250	**3.69**	44.7	46.8	1.26	0.28
	Reuse water	V22									

* Samples collected from the water reuse components were split and analyzed in both the Waste and Solutions laboratories located at the NCDA CS Agronomic Division.

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.												
Some technology components unavailable for sample collections due to operation.												
Date	**Sample**	**Code**	**N(Total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
10/1/2003	House effluent (receiving pit)	V0	667.8	644	237	214	23.8	407	234	20.2	2.11
	EQ tank	V1	1623	1606	300	283	17	1306	252	15.6	1.77
	Separated solids - clarifier	V2									
	Separated liquids - clarifier	V3									
	Effluent from meso - digester	V4	650.19	642	517	509	8.19	124	101	1.2	0.21
	Storage basin	V5	466.91	459	305	297	7.91	153	50.2	1.02	0.08
	Influent to Aerobic digester (AD)	V6	390.75	381	299	290	9.75	81.6	46.4	0.5	0.1
	Effluent from AD - barn recharge	V7	356.2	316	279	238	**40.2**	36.8	45.2	0.71	0.11
	Reuse water	V22									
10/13/2003	House effluent (receiving pit)	V0	600.5	557	324	280	43.5	233	142	8.96	0.9
	EQ tank	V1	826.1	815	552	541	11.1	263	182	9.81	1.75
	Separated solids - clarifier	V2									
	Separated liquids - clarifier	V3									
	Effluent from meso - digester	V4	589.86	580	470	460	9.86	109	89.6	1.04	0.08
	Storage Basin	V5	404.2	394	306	296	10.2	87.9	58.3	0.95	0.08
	Influent to Aerobic digester (AD)	V6	368.01	360	302	294	8.01	58	58.2	1.21	0.15
	Effluent from AD - barn recharge	V7	337.5	314	227	204	**23.5**	86.5	51.8	1.17	0
	Reuse water	V22									
11/20/2003	House effluent (receiving pit)	V0	1234.7	1227	586	578	7.7	641	341	14.4	2.02
	EQ tank	V1									
	Separated solids - clarifier	V2									
	Separated liquids - clarifier	V3									
	Effluent from meso - digester	V4	949.9	939	762	751	10.9	177	149	7.25	1.59
	Storage basin	V5	378	367	315	304	11	52.1	43.7	0.57	0.08
	Influent to Aerobic digester (AD)	V6	363.41	355	307	298	8.41	48.6	34.7	0.68	0.09
	Effluent from AD - barn recharge	V7	329.57	322	279	271	**7.57**	42.7	33.6	0.46	0.07
	Reuse water	V22									

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As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Some technology components unavailable for sample collections due to operation.											
Date	**Sample**	**Code**	**N(Total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
2/12/2004	House effluent (receiving pit)	V0	929.03	927	667	665	2.03	260	212	11.7	1.28
	EQ tank	V1									
	Separated solids - clarifier	V2									
	Separated liquids - clarifier	V3									
	Effluent from meso - digester	V4	914.77	911	910	907	3.77	0.59	81.6	2.39	0.5
	Storage basin	V5	563.4	561	504	501	2.4	57.5	46.1	0.85	0.18
	Influent to Aerobic digester (AD)	V6	540.28	538	489	487	2.28	48.8	47.9	1.03	0.18
	Effluent from AD - barn recharge	V7	512.4	510	455	453	**2.4**	55.2	34.9	0.63	0.15
	Reuse water	V22									
3/8/2004	House effluent (receiving pit)	V0	1355.09	1347	778	770	8.09	569	37	2.86	0.44
	EQ tank	V1	824.51	817	647	639	7.51	170	10.8	0.5	0.08
	Separated solids - clarifier	V2	1237.13	1230	839	831	7.13	391	25.4	1.48	0.22
	Separated liquids - clarifier	V3	949.76	943	837	830	6.76	106	6.26	0.32	0.06
	Effluent from meso - digester	V4	1036.63	1029	889	882	7.63	139	12.2	0.47	0.09
	Storage basin	V5	582.72	575	458	450	7.72	118	4.77	0.1	0.02
	Influent to Aerobic digester (AD)	V6	545.35	538	486	479	7.35	52.4	5.03	0.08	0.02
	Effluent from AD - barn recharge	V7	554.9	547	467	459	**7.9**	80	5.03	0.18	0.02
	Reuse water (1st settling tank)	V22	373.06	366	295	288	7.06	70.7	4.34	0.09	0.02
4/27/2004	House effluent (receiving pit)	V0	1377.53	1371	886	879	6.53	486	352	16.6	2.92
	EQ tank	V1	1681.32	1672	1269	1259	9.32	403	904	60.7	10.2
	Separated solids - clarifier	V2	1373.99	1367	1154	1147	6.99	213	239	2.41	0.53
	Separated liquids - clarifier	V3									
	Effluent from meso - digester	V4	1358.18	1352	1305	1299	6.18	47.2	119	4.68	0.97
	Storage basin	V5	704.94	699	571	565	5.94	127	62.4	1.36	0.35
	Influent to Aerobic digester (AD)	V6	671.52	666	504	498	5.52	162	55.7	3.96	0.65
	Effluent from AD - barn recharge	V7	683.21	677	508	502	**6.21**	169	65.6	2.44	0.5
	Reuse water	V22									

* Samples collected from the water reuse components were split and analyzed in both the Waste and Solutions laboratories located at the NCDA CS Agronomic Division.

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Some technology components unavailable for sample collections due to operation.											
Date	**Sample**	**Code**	**N(Total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
5/25/2004	House effluent (receiving pit)	V0	679	641	445	407	38	196	239	13.2	2.04
	EQ tank	V1	687	670	499	482	17	170	118	6.72	1.44
	Separated solids - clarifier	V2	0								
	Separated liquids - clarifier	V3	0								
	Effluent from meso - digester	V4	1175.5	1161	1089	1074	14.5	72.7	74.5	2.75	0.45
	Storage basin	V5	690.9	676	527	512	14.9	149	51.6	1.92	0.41
	Influent to Aerobic digester (AD)	V6	698.3	684	536	521	14.3	148	44.2	1.46	0.2
	Effluent from AD - barn recharge	V7	428	333	300	205	**95**	32.8	52.9	1.73	0.25
	Reuse water (thru floculant)	V22	272	197	175	100	75	22	47.6	1	0.08
8/2/2004	House effluent (receiving pit)	V0	371.5	360	349	338	11.5	10.1	52.7	2.18	0.29
	EQ tank	V1	612.9	601	447	435	11.9	154	99	5.17	0.66
	Separated solids - clarifier	V2	890.3	880	716	705	10.3	164	211	10.8	1.53
	Separated liquids - clarifier	V3	845.6	835	712	701	10.6	123	100	3.15	0.51
	Effluent from meso - digester	V4	836.2	826	688	677	10.2	138	176	8.89	1.33
	Storage basin	V5	502.44	493	434	425	9.44	58.8	48.7	0.88	0.1
	Influent to Aerobic digester (AD)	V6	511.47	502	443	434	9.47	58.9	40.6	0.62	0.06
	Effluent from AD - barn recharge	V7	487	358	343	215	**129**	14.6	50.5	0.97	0.13
	Reuse water (thru UV)	V22	96.8	65.5	59.7	28.4	31.3	5.79	6.27	0.8	0.03
	MD wet well (sludge)	VMS	57481	57213	3790	3522	268	53423	22172	2610	776
9/20/2004	House effluent (receiving pit)	V0	688.44	681	366	359	7.44	315	225	11.1	1.64
	EQ tank	V1	0								
	Separated solids - clarifier	V2	0								
	Separated liquids - clarifier	V3	0								
	Effluent from meso - digester	V4	875.17	870	641	636	5.17	229	260	18.1	2.76
	Storage basin	V5	404.68	402	322	320	2.68	80	55.5	0.81	0.12
	Influent to Aerobic digester (AD)	V6	375.91	374	318	316	1.91	55.8	50.9	0.78	0.15
	Effluent from AD - barn recharge	V7	330.3	247		182	**83.3**		73.1	1.46	0.2
	Reuse water (thru UV)	V22	0								
	MD wet well (sludge)	VMS	0								
	H2O reuse not operational - out of floculant										

* Samples collected from the water reuse components were split and analyzed in both the Waste and Solutions laboratories located at the NCDA CS Agronomic Division.

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.											
Some technology components unavailable for sample collections due to operation.											
Date	**Sample**	**Code**	**N(Total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
10/25/2004	House effluent (receiving pit)	V0	915.7	905	631	620	10.7	274	109	6.35	1.01
	EQ tank	V1	1174.2	1161	655	642	13.2	506	128	7.47	1.18
	Separated solids - clarifier	V2	0								
	Separated liquids - clarifier	V3	0								
	Effluent from meso - digester	V4	827.3	816	723	711	11.3	93.8	107	8.04	1.07
	Storage basin	V5	355.5	344		391	11.5		47.7	1.35	0.21
	Influent to Aerobic digester (AD)	V6	410.7	399	363	351	11.7	36.2	36.4	0.8	0.1
	Effluent from AD - barn recharge	V7	336	235		182	**101**		38.2	1.21	0.12
	Reuse water (thru UV)	V22	48.6	15.5		22	33.1		11.7	1.28	0.12
Waste*	**Aeration Tank 1**	**AT1**	**338**	**195**		**138**	**143**		**48.6**	**2.02**	**0.24**
	Pre sand	**PRES**	**269.6**	**78.6**		**95.8**	**191**		**37**	**1.01**	**0.07**
	Post sand	**POSS**	**269**	**75**		**97.3**	**194**		**35.5**	**2.29**	**0.19**
	Post RO	**RO**	**56.6**	**15.5**		**20.9**	**41.1**		**7.26**	**1.1**	**0.08**
Solutions*	**Reuse water (thru UV)**	**V22B**			**45.5**	**14.2**	**31.3**		**0.52**	**0**	**0**
	Post sand	**POSSB**			**284**	**78.4**	**205**		**31.5**	**0.07**	**0.02**
	Post RO	**ROB**			**47.2**	**15.4**	**31.8**		**1.35**	**0**	**0**
11/5/2004	House effluent (receiving pit)	V0	1481	1466	629	614	15	837	627	40.9	6.92
	EQ tank	V1	0								
	Separated solids - clarifier	V2	0								
	Separated liquids - clarifier	V3	0								
	Effluent from meso - digester	V4	966.9	952	564	549	14.9	388	190	13	1.5
	Storage basin	V5	0								
	Influent to Aerobic digester (AD)	V6	504.4	490	308	294	14.4	182	52.6	2.3	0.17
	Effluent from AD - barn recharge	V7	397	279		163	**118**		49.7	0.57	0.13
	Reuse water (thru UV)	V22	69.2	23.3		28.4	**45.9**		9.78	10.1	0.13
Waste*	**Pre sand**	**PRES**	**323**	**142**		**107**	**181**		**48.9**	**1.01**	**0.11**
	Post sand	**POSS**	**260**	**110**		**111**	**150**		**50.2**	**1.54**	**0.1**
	Post RO	**RO**	**73.3**	**23.6**		**25.8**	**49.7**		**8.76**	**5.37**	**0.09**
Solutions*	**Reuse water (thru UV)**	**V22 sol**			**51.3**	**18.6**	**32.7**		**0.49**	**0.01**	**0**
	Post sand	**POSS**			**247**	**103**	**143**		**40.2**	**0.03**	**0.01**
	Post RO	**POSRO**			**51.1**	**18.9**	**32.2**		**0.54**	**0.01**	**0**

* Samples collected from the water reuse components were split and analyzed in both the Waste and Solutions laboratories located at the NCDA CS Agronomic Division.

As reported by NCDA - for liquid samples N(total) = TKN(free and bound NH4) + N03 - All values reported in ppm except pH and %DM.												
Some technology components unavailable for sample collections due to operation.												
Date	**Sample**	**Code**	**N(Total)**	**TKN**	**IN-N**	**NH4**	**NO3**	**OR-N**	**P**	**Zn**	**Cu**
11/12/2004	House effluent (receiving pit)	V0	1307.8	1293	1276	1261	14.8	17.5	57.5	1.79	0.34
	EQ tank	V1	0								
	Separated solids - clarifier	V2	0								
	Separated liquids - clarifier	V3	0								
	Effluent from meso - digester	V4	803.3	790	725	712	13.3	64.8	151	6.43	1.06
	Storage basin	V5	0								
	Influent to Aerobic digester (AD)	V6	440.9	427	387	373	13.9	40	44.7	0.75	0.12
	Effluent from AD - barn recharge	V7	356.5	258		213	98.5		39.7	0.51	0.1
	Reuse water (thru UV)	V22	55.3	18.6		29.5	36.7		6.69	0.57	0.06
Waste*	**Pre sand**	**PRES**	**386**	**251**		**166**	**135**		**50.6**	**2.37**	**0.28**
	Post sand	**POSS**	**319**	**189**		**166**	**130**		**40.1**	**0.56**	**0.11**
	Post RO	**RO**	**52.4**	**15.5**		**26.7**	**36.9**		**8.92**	**0.24**	**0.05**
Solutions*	**Reuse water (thru UV)**	**V22**			**46.8**	**22.8**	**24**		**0.33**	**0.02**	**0**
	Post sand	**POSS**			**282**	**159**	**123**		**38.2**	**0.09**	**0.02**
	Post RO	**PORO**			**45.8**	**22.1**	**23.6**		**1.18**	**0**	**0**

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As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
8/20/2003	House effluent (receiving pit)	296	129	44.6	45.3	3.5	1.56	1.76	202	87.3	7.52	0.37
	EQ tank	476	587	205	130	28.3	7.09	1.95	283	126	5.26	5.87
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	287	89.2	40.1	28.1	2.02	1.36	2.19	196	85.8	7.26	0.18
	Storage basin	267	94.6	37.9	42.7	3.13	1.6	2.54	167	77.6	7.53	0.23
	Influent to Aerobic digester (AD)	331	187	46.6	31.1	2.38	1.05	2.29	171	105	7.51	0.19
	Effluent from AD - barn recharge	221	120	33.5	32.7	2.07	0.75	1.74	162	69.3	7.75	0.07
	Reuse water											
9/3/2003	House effluent (receiving pit)	522	603	275	84.5	39	8.09	1.01	191	128	6.85	2.84
	EQ tank	577	2161	424	408	138	19.3	1.75	181	134	6.02	9.75
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	497	182	88.3	22	2.8	0.67	1.14	185	119	7.11	0.3
	Storage basin	458	157	65.7	27.6	2.4	0.55	1	163	115	7.53	0.39
	Influent to Aerobic digester (AD)	458	150	64.4	31.4	2.59	0.56	1	156	116	7.48	0.3
	Effluent from AD - barn recharge	434	135	48	24.6	2.23	0.42	0.89	161	114	7.87	0.3
	Reuse water											
9/17//2003	House effluent (receiving pit)	606	765	309	89.9	39	8.22	0.99	259	157	6.62	3.13
	EQ tank	582	228	88.3	42.7	8.94	1.52	1	228	148	7.32	0.54
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	565	172	101	27.1	3	0.62	1	225	140	7.15	0.3
	Storage basin	482	157	65.4	28.9	2.8	0.44	0.88	205	121	7.48	0.37
	Influent to Aerobic digester (AD)	532	148	60.4	28.4	2.49	0.37	0.92	195	130	7.54	0.19
	Effluent from AD - barn recharge	517	164	56.5	29.7	2.91	0.39	0.9	188	131	7.85	0.28
	Reuse water											

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As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
10/1/2003	House effluent (receiving pit)	579	328	144	70	20.5	3.04	1.03	166	133	7.19	0.89
	EQ tank	607	449	181	122	23.5	3.76	1.34	188	145	7.65	1.86
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	506	181	95.3	31.9	3.12	0.7	1.02	219	122	7.14	0.26
	Storage basin	435	124	49.1	31	1.86	0.36	0.9	186	101	7.65	0.31
	Influent to Aerobic digester (AD)	406	131	47.9	26.2	1.9	0.36	0.84	205	96.7	7.69	0.2
	Effluent from AD - barn recharge	474	165	51.8	30.8	2.62	0.42	0.96	199	115	7.73	0.12
	Reuse water											
10/13/2003	House effluent (receiving pit)	636	238	96.6	59.8	14	1.87	1.39	286	145	7.18	0.54
	EQ tank	805	299	130	82.7	14.9	2.21	1.75	267	172	7.27	0.86
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	604	185	79.9	37.1	2.69	0.5	1.41	258	143	7.32	0.17
	Storage basin	523	172	59.2	35.4	3.16	0.43	1.2	251	128	7.64	0.2
	Influent to Aerobic digester (AD)	520	140	52.9	35.3	2.64	0.41	1.18	223	123	7.63	0.24
	Effluent from AD - barn recharge	543	156	52.2	35.8	2.54	0.36	1.28	275	133	7.9	0.21
	Reuse water											
11/20/2003	House effluent (receiving pit)	888	909	518	70.4	52.9	3.91	1.38	222	241	6.08	2.51
	EQ tank											
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	852	499	248	56.2	37.3	1.9	1.36	322	257	7.06	0.39
	Storage basin	654	329	115	31.6	5.16	0.32	1.07	235	216	7.61	0.07
	Influent to Aerobic digester (AD)	548	311	110	38	5.21	0.23	0.99	205	194	7.6	0.07
	Effluent from AD - barn recharge	573	271	96.1	30.6	4.66	0.19	0.99	188	193	7.77	0.09
	Reuse water											

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As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
2/27/2004	House effluent (receiving pit)	825	360	127	74.5	15	2.73	1.44	330	199	7.64	0.65
	EQ tank											
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	808	217	53.3	49.7	5.22	1.04	1.32	361	205	7.36	0.15
	Storage basin	637	168	39	31.7	2.85	0.51	1.1	262	163	7.73	0.08
	Influent to Aerobic digester (AD)	553	164	41.1	28.9	3.07	0.56	1	253	144	7.76	0.07
	Effluent from AD - barn recharge	576	149	30.8	31.1	2.37	0.37	1.01	263	145	7.98	0.07
	Reuse water											
3/2/2004	House effluent (receiving pit)	89.9	51.4	19.8	10.3	3.63	0.83	0.14	352	20.4	7.01	2.16
	EQ tank	78	23.5	6.95	5.59	0.87	0.16	0.13	308	18.9	7.59	0.43
	Separated solids - clarifier	84.3	36.5	15.1	8.41	2.21	0.43	0.15	347	17.7	7.17	0.94
	Separated liquids - clarifier	92.4	22.3	4.49	7.07	0.69	0.11	0.16	389	19.9	7.8	0.61
	Effluent from meso - digester	74.5	28.2	8.05	5.01	1.03	0.18	0.13	326	18.7	7.18	0.27
	Storage basin	70.8	19.5	4.31	3.2	0.29	0.05	0.11	250	18.1	7.66	0.25
	Influent to Aerobic digester (AD)	68.1	18.6	4.32	3.13	0.28	0.05	0.11	248	17.5	7.56	0.11
	Effluent from AD - barn recharge	62.9	18.9	4.18	3.53	0.33	0.06	0.11	250	15.5	7.92	0.07
	Reuse water	55.5	18.1	4.38	3.36	0.29	0.05	0.1	209	14.1	8.05	0.07
4/27/2004	House effluent (receiving pit)	1012	581	206	94.1	28.9	6.88	1.13	416	240	7.06	1.93
	EQ tank	1253	1730	491	281	109	19.6	2.21	418	273	6.14	7.39
	Separated solids - clarifier	893	220	178	44.1	5.38	2	1.12	488	210	6.41	0.56
	Separated liquids - clarifier											
	Effluent from meso - digester	996	278	90.1	49.6	8.77	1.92	1.33	402	219	7.43	0.24
	Storage basin	634	182	51.6	24	3.31	0.68	0.81	276	149	7.59	0.08
	Influent to Aerobic digester (AD)	590	207	54.5	30.9	4.17	0.82	0.72	284	145	8.01	0.08
	Effluent from AD - barn recharge	683	208	58.3	34.9	4.83	0.87	0.79	283	163	7.99	0.17
	Reuse water											

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As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
5/25/2004	House effluent (receiving pit)	1006	412	168	75	20.9	5.12	1.61	395	248	8.08	0.64
	EQ tank	668	246	81.2	56.2	10.7	2.39	0.96	426	165	7.86	0.71
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	782	160	52.8	33.4	4.44	1.09	1.21	495	190	7.58	0.3
	Storage basin	629	175	41.7	19.3	2.94	0.61	1.07	322	143	7.99	0.07
	Influent to Aerobic digester (AD)	571	158	37.4	25.3	3.64	0.56	0.92	307	127	7.92	0.16
	Effluent from AD - barn recharge	524	160	48.1	21.5	3.07	0.62	0.96	285	121	7.81	0.06
	Reuse water	614	171	56	22.3	1.56	0.4	1.06	308	144	8	0.05
8/2/2004	House effluent (receiving pit)	678	134	49.2	36.9	4.78	0.81	1.48	330	147	8.66	0.33
	EQ tank	731	209	80.6	46.4	10.1	1.63	1.79	345	163	8.3	0.54
	Separated solids - clarifier	1022	321	148	80.8	18.8	3.94	2.02	464	213	7.11	0.97
	Separated liquids - clarifier	1050	207	83.4	61.9	7.35	1.46	2.13	478	222	7.46	0.55
	Effluent from meso - digester	854	237	141	53.2	16.2	2.38	1.72	353	188	7.33	0.46
	Storage basin	792	138	53.9	22.2	2.67	0.45	1.52	332	182	8.08	0.15
	Influent to Aerobic digester (AD)	684	119	44.3	18.8	1.96	0.33	1.42	324	154	8.04	0.25
	Effluent from AD - barn recharge	749	141	57.1	24.8	3	0.44	1.5	306	172	7.95	0.26
	Reuse water	74.7	77.8	14.9	7.02	1.52	0.19	1.15	32.6	28	7.87	0.06
	MD wet well (sludge)	9393	38224	14458	9173	5938	736	18.2	2940	2068		**2.96**
9/20/2004	House effluent (receiving pit)	915	331	153	64.8	20.2	3.93	1.42	337	231	7.98	1.1
	EQ tank											
	Separated solids - clarifier											
	Separated liquids - clarifier											
	Effluent from meso - digester	872	341	199	77	31.7	4.48	1.62	376	208	7.11	0.73
	Storage basin	689	158	61.6	23.1	2.5	0.48	1.42	280	164	7.67	0.33
	Influent to Aerobic digester (AD)	681	138	56.6	21.1	2.16	0.42	1.39	276	160	7.71	0.28
	Effluent from AD - barn recharge	665	170	72.5	22.5	4.14	0.67	1.18	271	162	7.59	0.23
	Reuse water											
	MD wet well (sludge)											

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As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
10/25/2004	House Effluent (Receiving Pit)	877	243	74	62.4	13.5	2.11	1.37	425	232	7.27	0.8
	EQ Tank	738	256	110	59.4	14.3	2.65	1.25	484	194	7.16	0.73
	Separater Solids - Clarifier											
	Separated Liquids - Clarifier											
	Effluent from Meso-digester	837	228	104	49.5	12.4	2.04	1.36	484	226	7.24	0.24
	Storage Basin	728	119	49.5	27.4	3.06	0.56	1.27	332	176	7.56	0.06
	Influent to Aerobic Digester (AD)	646	114	40.6	25.2	1.97	0.35	1.18	329	157	7.69	0.06
	Effluent from AD	706	135	50.5	26.9	2.47	0.37	1.25	261	169	7.7	0.07
	Reuse Water (through UV)	78.7	70.7	13.3	11.6	1.74	0.22	0.94	43.7	28.5	7.53	0.06
Waste	***Aeration Tank 1***	**698**	**143**	**50.3**	**27.9**	**4.58**	**0.65**	**1.25**	**312**	**166**	**7.36**	**0.06**
	Pre sand	**633**	**104**	**43.1**	**27.1**	**1.57**	**0.27**	**1.16**	**283**	**150**	**7.08**	**0.07**
	Post sand	**623**	**118**	**44.8**	**23.9**	**1.94**	**0.27**	**1.12**	**287**	**153**	**7.07**	**0.06**
	Post RO	**80.8**	**52.5**	**9.76**	**11.5**	**1.19**	**0.15**	**0.9**	**17**	**26.5**	**7.22**	**0.06**
	Reuse water (through UV)	**72.4**	**0.67**	**0.22**	**1.79**	**0**	**0**	**0.87**	**12.8**	**14.8**	**6.48**	
	Post Sand	**616**	**49.5**	**34.6**	**17.2**	**0.14**	**0.08**	**1.12**	**323**	**143**	**7.06**	
	Post RO	**79.1**	**2.06**	**1.05**	**1.66**	**0.01**	**0**	**0.89**	**10.5**	**16.4**	**6.36**	
11/5/2004	House Effluent (Receiving Pit)	1153	992	370	168	81.4	11.4	1.62	404	311	6.87	2.34
	EQ Tank											
	Separated Solids - Clarifier											
	Separated Liquids - Clarifier											
	Effluent from Meso-Digester	879	318	139	65.7	17.6	3	1.3	478	241	7.33	0.33
	Storage Basin											
	Influent to Aerobic Digester (AD)	796	167	54.7	29.5	2.73	0.49	1.2	325	203	7.68	0.07
	Effluent from AD	798	165	55.1	26.4	2.35	0.41	1.26	308	200	7.76	0.06
	Reuse Water (Through UV)	91.9	120	22.2	14.3	2.18	0.29	0.98	20.8	41.8	7.86	0.05
	Pre sand	**787**	**162**	**56.5**	**22**	**1.89**	**0.38**	**1.19**	**288**	**201**	**7.33**	**0.06**
	Post sand	**780**	**161**	**55.8**	**23.3**	**1.68**	**0.36**	**1.24**	**330**	**198**	**7.43**	**0.05**
	Post RO	**92.3**	**114**	**20.9**	**11.1**	**1.71**	**0.27**	**1.04**	**46.1**	**39.9**	**6.98**	**0.06**
	Reuse Water (Through UV)	**79.4**	**2.98**	**0.27**	**0.63**	**0.12**	**0.02**	**0.84**	**11.9**	**15.3**	**7.02**	
	Post Sand	**589**	**48.8**	**28.8**	**13.2**	**0.1**	**0.08**	**0.91**	**222**	**130**	**7.41**	
	Post RO	**75.7**	**2.05**	**0.43**	**0.64**	**0.04**	**0.01**	**0.81**	**12.2**	**14.3**	**6.81**	

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As reported by NCDA												
Date	**Sample**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**B**	**Cl**	**Na**	**pH**	**DM%**
11/12/2004	House Effluent (Receiving Pit)	1163	169	46.8	92.4	5.13	0.69	1.76	764	322	8.73	0.49
	EQ Tank											
	Separated Solids - Clarifier											
	Separated Liquids - Clarifier											
	Effluent from Meso-Digester	906	280	116	53.6	13.5	2.3	1.44	458	244	7.12	0.36
	Storage Basin											
	Influent to Aerobic Digester (AD)	696	161	46.8	26.8	2.48	0.43	1.25	307	172	7.67	0.17
	Effluent from AD	669	149	44.5	24.8	2.33	0.36	1.21	296	164	7.58	0.13
	Reuse Water (Through UV)	70.7	104	18.7	10.4	1.76	0.26	1	51.4	32.8	7.41	0.06
	Pre sand	**753**	**168**	**48**	**29.9**	**4.68**	**0.64**	**1.32**	**330**	**188**	**7.39**	**0.2**
	Post sand	**663**	**143**	**44.6**	**25.7**	**2.38**	**0.36**	**1.2**	**287**	**165**	**7.37**	**0.17**
	Post RO	**88.9**	**94.4**	**18**	**4.05**	**1.64**	**0.23**	**1.01**	**38.3**	**35.4**	**7.1**	**0.05**
	Reuse Water (Through UV)	**55.7**	**0.46**	**0.11**	**35.5**	**0.05**	**0**	**0.93**	**16.2**	**18.5**	**6.92**	
	Post Sand	**606**	**50.6**	**28.1**	**20.3**	**0.32**	**0.08**	**1.03**	**285**	**146**	**7.27**	
	Post RO	**65**	**2.32**	**1.05**	**13.3**	**0.02**	**0**	**0.86**	**12.1**	**14**	**6.46**	

* Samples collected from the water reuse components were split and analyzed in both the Waste and Solutions laboratories located at the NCDA CS Agronomic Division.

Appendix B

Calculations

Mass Balance Example: (Used for all mass balance tables listed in each technology section)
Mass Balance Calculations for the lagoon shown in ABS section - Table 4a., page 14 for Total Nitrogen:

Kg/day	House (In)	House (Out)	Lagoon (In)	Lagoon (Out)	IESS (In)	IESS (Out)
N(Total)	350.1	510.0	513	414	113.0	51.7

Volumes utilized for calculations for each ABS component shown in Table 3, page 14.

Flow gal/day	**Houses (12 flushes/day)**	**Lagoon**	**IESS cell**	**Aeration tanks**	**ABS mist**
IN (12 -13)	38,400 (IESS)	41,700		3,000	
OUT	**41,700***		**38,400**	**2400 + 600**	
IN (5 -11)	134,400 (lagoon)	146,000			
OUT	**146,000***	**134,400**			
Other (in)		2400	50000 + 600		2400
Other (out)		**50,000**	**3000**		**2400**
TOTAL (in)	172,800	190,100	50,600	3000	2400
TOTAL (out)	**187,700***	**184,400**	**41,400**	**3000**	**2400**
Difference**	**+14,900**	**+5,700*****	**+9200**	0	0

*Assumes 2.3 gallons of waste water (manure, urine, wasted water) produced per head (720/hse) per day (g/h/d).
** Difference does not include precipitation or natural evaporation.
***Land application – Total lagoon liquid land applied from April 26 to September 23, 2004 was 3,188,745 gallons.

Total Nitrogen data shown in Table 2, page 11.

Sample	**N (total)**
House effluent	718
Lagoon	594
ABS mist	330

The primary lagoon located at the ABS technology site received waste from all of the 9 finishing houses and was misted with treated waste water from the IESS/aeration tanks. Approximately 50,000 gallons of waste water was transferred from the primary lagoon to the IESS cell daily for treatment and 184,000 gal/d was utilized as tank recharge for flushing 7 of the 9 finishing houses (5-11). Calculations were made for each component separately since often influent into one component was not equal to effluent from the same component.

IN - 187,000 gal/d into lagoon from houses + 2400 gal/d from ABS mist = 710,257 + 9082 L/d;
From houses = 718mg/L Total N (510 Kg); from ABS mist = 330 mg/L Total N (3 Kg) = 513Kg;

OUT* – 134,400 gal/d to houses from lagoon + 50,000 gal/d to the IESS cell = 697,770 L/d;
From lagoon = 594 mg/L Total N (414 Kg) = 414 Kg
513 In – 414 Out = +99 Kg = 19% daily reduction of Total N in the primary lagoon.
* Does not account land application, natural evaporation, or precipitation

Table Appendix B - 1. PCS - Evaporation System waste water flow.

WK	House				PC lag - freeboard maintained @ 19" Sept and Oct					AED - freeboard maintained @ 24" Sept and Oct.				SB					freeboard"	storage	diff strg vol
date	house in*	fresh in	rainfall "	evap "	pc lag in	pc lag out	rainfall	nat evap	evap sys	aed in*	aed out*	rainfall	nat evap	sb in*	sb evap	sb land	rainfall	nat evap	Aug =50"	volume	805155
9/4/2004	196000	31360	3.4	4.1	227360	227360	160275	44800	92400	227360	227360	48983	12732	31360	92400		65536	17243	25	427781	377374
9/11/2004	196000	35680	2		231680	231680	94279	44800	100800	231680	231680	28814	12732	35680	100800		38551	17243	32	542897	-115116
9/18/2004	196000	36440	1		232440	232440	47140	44800	0	232440	232440	14407	12732	36440	0		19275	17243	28	486083	56814
9/25/2004	196000	39120	0		235120	235120	0	44800	100800	235120	235120	0	12732	39120	100800	274080	0	17243	nr	486083	0
10/2/2004	196000	38760	1	2.95	234760	234760	47140	25787	201600	234760	234760	14407	7329	38760	201600	100740	19275	9925	40	669758	-183674
10/9/2004	196000	37560	0		233560	233560	0	25787	302400	233560	233560	0	7329	37560	302400		0	9925	36	616359	53398
10/16/2004	196000	38400	1.2		234400	234400	56568	25787	0	234400	234400	17288	7329	38400	0		23130	9925	30	524124	92236
10/23/2004	196000	32032	0		228032	228032	0	25787	0	228032	228032	0	7329	32032	0	498480	0	9925	69	1046342	-522218
10/30/2004	196000	33760	0.4		229760	229760	18856	25787	100800	229760	229760	5763	7329	33760	100800		7710	9925	68	1032393	13949
Total - 9wks	**1764000**	**323112**			**2087112**	2087112	**424258**	308135	**898800**	2087112	2087112	**129662**	87573	**323112**	898800	873300	**173477**	118597			-227237

*28,000 gal/d from AED to recharge flush tanks on houses 2 and 3; 3687 (rounded up to 3700) gallons sent to SB from AED.

key

house in - flush tank recharge from AED
fresh in - actual fresh water utilized in houses and assumes to be equal to flush water + waste water from animals/spillage - varies based on animal age and season

pc lag in - waste water from lift station (test houses)
pc lag out - waste water pumped to AED
rainfall - calculated - rain inches x surface area of water holding structure x conversions to gallons
nat evap - calculated - expected evap rate x surface area of water holding structure x conversions to gallons
evap sys - water applied over pc lagoon from storage basin

aed in - waste water pumped from pc lagoon
aed out - water pumped to recharge test houses and to storage basin
rainfall - calculated - rain inches x surface area of water holding structure x conversions to gallons
nat evap - calculated - expected evap rate x surface area of water holding structure x conversions to gallons

sb in - water received from aed
sb evap - water sprayed over pc lagoon
sb land - water land applied
rainfall - calculated - rain inches x surface area of water holding structure x conversions to gallons
nat evap - calculated - expected evap rate x surface area of water holding structure x conversions to gallons
freeboard " - recorded freeboard in storage basin

Table Appendix B - 2. Water Balance for PCS Evaporation System. **(Note: this is to be used as a reference for parameters needed to determine the Evaporation System efficiency.)**

Harrells Covered Lagoon EVAPORATIVE SYSTEM

	Sprinkle		Water Balance Covered Lagoon & Aerobic Basin & Storage Basin										Measured			Wk. Gain/Loss	
DATE	Sprinkle (hr.)	Sprinkle Volume (**Psp+Esp**) (gal)	Drinking Water (**DW**) (gal)	Rainfall (in)	Rainfall Covered (**P1**) (gal)	Natural Evaporation Covered (**E1**) (gal)	Rainfall Aerobic (**P2**) (gal)	Natural Evaporation Aerobic (**E2**) (gal)	Rainfall Storage (**P3**) (gal)	Natural Evaporation Storage (**E3**) (gal)	Irrigation Storage (**I**) (gal)	NET Vol. (**WB**) (gal)	Fbd (in)	Freeboard Vol (gal)	NET Vol. Difference (**FB**) (gal)	WB-FB (gal)	% Loss Sprinkle
9/4/04	11	92400	31360	3.4	160,275	44,800	49,211	12,732	65,536	17,243		231,607	25	427,781			
9/11/04	12	100800	35680	2	94,279	44,800	28,948	12,732	38,551	17,243		122,683	32	542,897	(115,115.9)	237,798	**236%**
9/18/04		0	36440	1	47,140	44,800	14,474	12,732	19,275	17,243		42,554	28	486,083	56,814.0		
9/25/04	12	100800	39120		-	44,800	-	12,732	-	17,243	274,080	(309,735)	-	#N/A			
September		294000	142600		301,693	179,201	92,632	50,927	123,362	68,972	274,080	87,108			(58,302.0)	145,410	**49%**
10/2/04	24	201600	38760	1	47,140	25,787	14,474	7,329	19,275	9,925	100,740	(24,132)	40	669,758	(183,674.7)	159,542	**79%**
10/9/04	36	302400	37560		-	25,787	-	7,329	-	9,925		(5,481)	36	616,359	53,398.4	(58,880)	**-19%**
10/16/04		0	38400	1.2	56,568	25,787	17,369	7,329	23,130	9,925		92,425	30	524,124	92,235.9		
10/23/04		0	32032		-	25,787	-	7,329	-	9,925	498,480	(509,489)	69	1,046,342	(522,218.4)		
10/30/04	12	100800	33760	0.4	18,856	25,787	5,790	7,329	7,710	9,925		23,074	68	1,032,393	13,948.6	9,126	**9%**
October		604800	180512		122,563	128,937	37,632	36,643	50,116	49,626	599,220	(423,603)			(546,310.2)	122,707	**20%**
Sept & Oct		898800	323112		424,256	308,138	130,264	87,569	173,478	118,598	873,300	(336,495)			(604,612.2)	268,117	**30%**

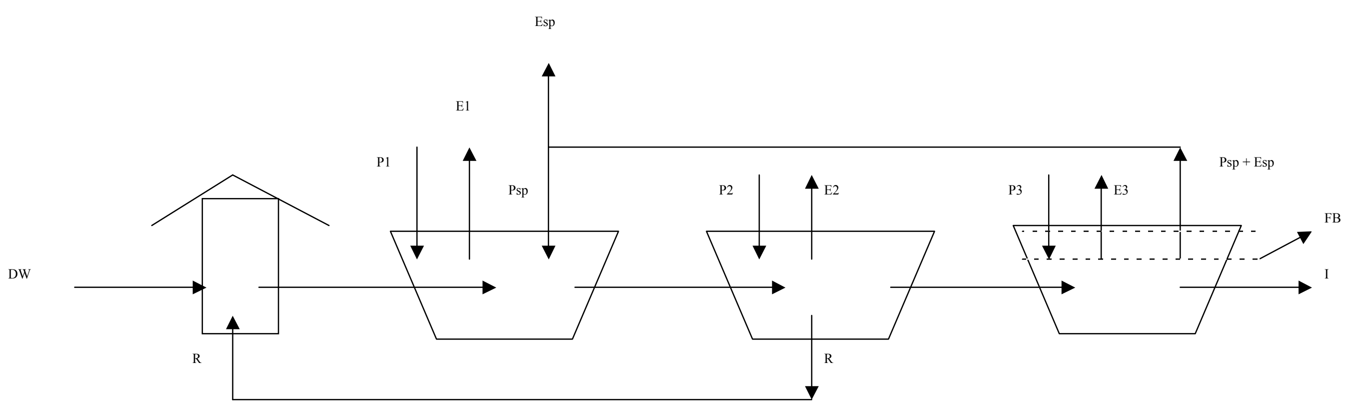
INPUTS + GENERATED = OUTPUT + CONSUMED

WHERE:

INPUTS = DW + P1+ P2 + P3 = 1,051,110
GENERATED = FB + R + Psp = 604,612 + R + Psp
OUTPUT = E1+ E2 + E3 + I + Esp = 1,387,606 +Esp
CONSUMED = R + Psp = 0 + R + Psp

(1,051,110) + (604,612 + R + Psp) = (1,387,606 + Esp) + (R + Psp)

Esp = 268,117 gallons **Where Esp is the fraction of the total sprinkle volume lost to evaporation**
Or
30 % **of sprinkle volume lost to evaporation**



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Appendix C

Technology Descriptions – Permit Applications to NCDENR

Items listed in the Technology Permit Applications as Attachments are not shown in this report.

INNOVATIVE PERMIT APPLICATION

For the

Aerobic Blanket System

ABS

CARROLL'S FARM #2529

An

ISSUES
(Innovative Sustainable Systems Utilizing Economical Solutions)
Technology

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February 27, 2003

NARATIVE OF INNOVATIVE TECHNOLOGY
ISSUES PROJECT: Aerobic Blanket System
Carroll's Farm #2529
By

Prince Dugba, Ph.D.,P.E.
Smithfield Foods Inc.

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3.0 Aerobic Digester 4
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5.0 Nutrient Utilization 6
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0.0 **INTRODUCTION**

This is a request for modification of the innovative permit no. AWI310740 (included as Attachment A), dated September 15, 2000 and issued to Carroll's Foods Inc., now known as Murphy-Brown LLC. The current permit authorizes the operation of an animal waste collection, treatment, storage and land application system. The system consists of two anaerobic lagoons with design capacity of 1,513,712 cubic feet, and an aerobic digester with design capacity of 665,409 cubic feet. The system serves a 1000 Farrow-to-Finish swine operation with a total finishing space of 6,480 head. The modification requested is to allow the installation of an add-on Aerobic Blanket System (ABS), an ISSUES (Innovative Sustainable Systems Utilizing Economic Solutions) technology. The ABS is one of the environmentally superior technologies selected by North Carolina State University per the Attorney/SFI/PSF agreement for development and demonstration.

A detailed description of the existing waste utilization system (WUS), and its performance is provided in Attachment B. The current WUS meets all the permit requirements. Therefore, the aerobic blanket system is added for research and demonstration purposes.

A schematic of the ABS system is given in Figure 1-1. About 50,000 gallons of flush water per day is fed from the finishing barns into the first-stage lagoon "A". The same volume is fed into the aerobic digester, "C", for additional reduction in oxygen demand. As explained in Attachment B by Dr. Westerman and Dr. Arogo, about 86% reduction in ammonia is accomplish in the aerobic pond, resulting in well-treated wastewater effluent with insignificant odor. This treated water is then pumped through a filter system and into the 9,000-gallon conditioning tank (Figure 1-1), equalized and fed into the aerobic blanket system (ABS). A detail description of the ABS is provided in section 5.0 and an engineering drawing included as Attachment C. The key goal of the blanket is to create micro water droplets that will act as nucleation centers to adsorb molecules in lagoon emission and return them back to the lagoon. Because most of the odorous emissions from lagoons are VOCs and other highly soluble compounds, the blanket will minimize odor emission.

Note that in addition to the first-stage lagoon labeled "A" in Figure 1-1, another anaerobic lagoon, operated as a single-stage, will receive, treat and store about 7,700 gallons of manure water flushed from the sow buildings as shown in the Figure.

The entire system will be controlled automatically using a WinPLC-based automation. A Think-and-Do ™ software will be used to run the control interface consisting of digital and analog inputs and outputs. This will allow accurate spray of both air and water for every minute that the system is on.

1.0 OBJECTIVE

- Demonstrate a substantial reduction in atmospheric emissions of ammonia and odorous compounds from existing anaerobic lagoons through the use of an aerobic blanket system.

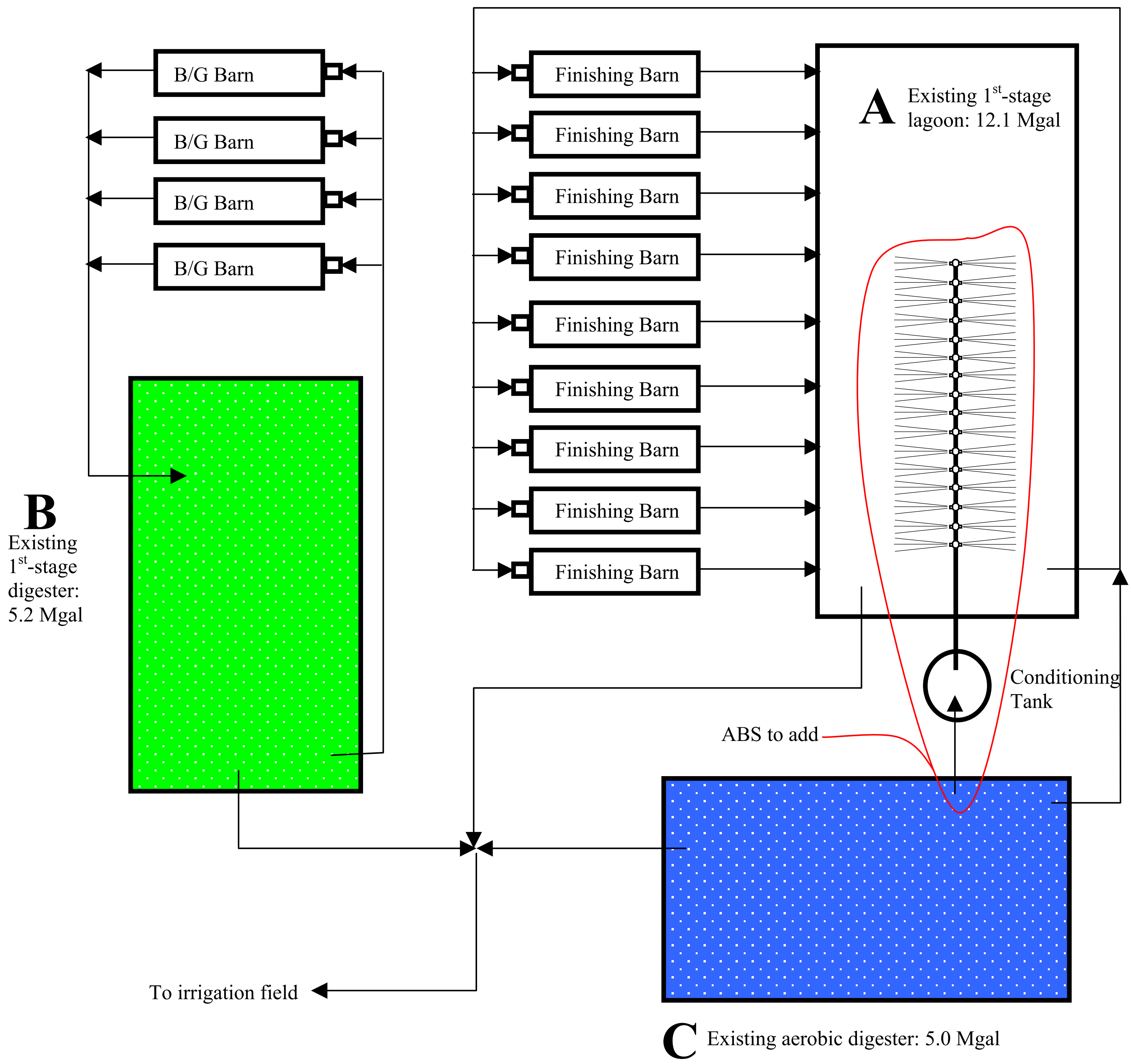

Figure 1-1 Aerobic Blanket System (ABS) at Carroll's Farm #2529

2.0 MANURE PRODUCTION AND CHARACTERISTICS

The Carroll's Farm 2529 is a farrow-to-finish operation with manure characteristics similar to that of a typical modern swine operation. Table 2-1 lists the key parameters of the manure and wastewater inputs from the finishing farms affected by the proposed aerobic blanket system.

Table 2-1 Manure and wasterwater characteristics (NRCS 1998, MWPS-18, 1993, Murphy-Brown LLC, 2001)

Input Parameter	Symbol	Units	Finishing
Number of Animals	-	hd	6,480
Animal Liveweight	LAW	lb	135
Animal Unit	AU	1000 lbs	875
Manure Volume	-	cu ft/AU/d	0.74
Manure Volume	-	cu ft/d	647
Total Solids (dry)	TS	lb/AU/d	6.0
Volatile Solids (dry)	VS	lb/AU/d	4.8
Percent VS: TS/VS	-	%	1.25
Total TS per day	-	lb/d	5,249
Total VS per day	-	lb/d	4,199
Total dry solids	-	tons/yr	958
BOD5 per day	BOD5	lb/AU/d	1.71
BOD5 per day	BOD5	lb/d	1,495
Total N per Day	N	lb/AU/d	0.25
Total P2O5 per day	P	lb/AU/d	0.08
Total K2O per day	K	lb/AU/d	0.16
Total N per Day	N	lb/d	222.68
Total P2O5 per day	P	lb/d	69.98
Total K2O per day	K	lb/d	142.58
Feces, urine, excess washwater	FUW	g/hd/d	2.30
TS in flushwater, total	1 % C	lb/d	2,915
Flush water	FW	g/hd/d	5.40
Total FW (flushwater)	FW	gpd	34,992
Total FUW	V	gpd	14,904
Total wastewater: FUW +FW	V	gpd	49,896

3.0 AEROBIC DIGESTER SYSTEM

A detail description of the aerobic digester and its performance is given in AttachmentB. Table 3-1 lists some of the key parameters of the aerobic digester design, inputs and outputs.

Table 3-1 Design and operational parameters of the aerobic digester

Line Item	Symbol	Units	Value
Flowrate, influent from 1st-stage lagoon	Qd	gpd	50,000
Flowrate, flushing	Qf	gpd	40,549
Flowrate, Feces, urine, wastewater (FUW)	Qwr	gpd	17,270
Total solids concentration in infuent	TS	mg/L	3,983
Volatile solids concentration in influent	VS	mg/L	2,390
BOD5 concentration in influent	BOD5	mg/L	851
Ammonia concentration in influent	Cnh3	mg/L	561
Oxygen demand to nitrogen ration	OD		4.57
BOD5/BOD-ultimate	u		0.60
Effluent BOD5, proposed	BOD5	mg/L	30
Effluent ammonia concentration, proposed	NH3-N	mg/l	80
Total oxygen demand	TOD	lb/d	1,487
Diffuser efficiency	Ed	%	25.00
Percent of oxygen in atmosphere		%	21.00
Density of air @ 70 F, 50% RH		lb/cu.ft.	0.074
Total volume of air needed		cfm	266
Oxygen demand met by fine-bubble aerator		cfm	266
Oxygen demand met by Air-Jammer		lb/day	0
Blower HP, calculated		HP	16.4
Blower HP, installed		HP	30.0
Aerobic digester volume per oxygen demand	V	gal	188,608
Aerobic digester treatment volume, actual	V	gal	4,977,259
Aerobic digester treatment volume, actual	V	cu.ft.	665,409
Aerobic digester volume, total	V	gal	5,920,514
Hydraulic retention, actual	HRT	d	100
VS reduction rate	VSRR	%	70
VS in effluent	VS	mg/L	717
TS in effluent	TS	mg/L	1,195
BOD reduction rate	BODr	%	96
Nitrate in the effluent	NO3-N	mg/L	481
NH3-N reduction rate	NH3-Nr	%	86

The horse power required for the blower (Table 3-1) was computed using equation 3-2 (Metcalf and Eddie, 1991). The actual HP of the blower is 30-HP

$$HP = \frac{wRT}{550ne}\left[\left(\frac{P_2}{P_1}\right)^{0.283} - 1\right] \qquad 3\text{-}2$$

Where w = mass flow rate (lb/s); R = gas constant, n = 0.283 (air); e = blower efficiency; P_1 = blower inlet pressure; P_2 = blower outlet pressure; and HP = horse power = 16.4 HP (computed as shown in Table 3-1).

4.0 AEROBIC BLANKET SYSTEM (ABS)

A schematic of the aerobic blanket system is shown in Figure 1-1. A detail engineering drawing of the system is included in Attachment C.

As listed in Table 4-1, about 3,034 gallons of treated wastewater is required per day to operate the aerobic system. This water is pumped to 32 nozzles as specified in Table 4-1 along with 6.16 scfm of air per nozzle. The air will help nucleate the water to form adsorption centers for emission compounds.

A 7.5-hp compressor will be used to pressurize air and store it in a 660-gallon buffer tank at 125 psig. A 1.5-HP liquid pump will feed the 32 nozzles at 25 gpm. Please see Attachment D for the specifications on the system equipment and calculations.

Table 4-1 Design and operational parameters of the ABS

Design element	Abbrev.	Unit	Value
Number of nozzles, liquid		each	32
Flow rate per nozzle, liquid	Qn	gph	47.4
Time of operation	T	hour/day	2
Flow rate, total for liquid	Qt	gpd	3,034
Flow rate, total for liquid	Qt	gpm	25
Number of nozzles, air		each	32
Flow rate per nozzle, air	Qn-a	scfm/noz.	6.16
Flow rate, total for air	Qt-a	scfm	197
Air tank refill time, maximum	T	Hour	22
Air tank refill flow rate		scfm	30
Nozzle System Inlet Pressure, liquid	P	psi	77
Pressure, air	Pa	psig	61.2
Density of air @ 70 F, 50% RH		lb/cu.ft.	0.074
Liquid Effluent Pump, HP	HP	HP	1.5
Blower, HP, minimum	HPa	HP	3.0
Blower, HP, actual		HP	7.5

5.0 NUTRIENT UTILIZATION

No changes to the existing Waste Utilization Plan (WUP) are being proposed due to the addition of the Aerobic Blanket System. A copy of the current WUP is included in Attachment E.

REFERENCES

1. AWWA (American Water Works Association). 1990. Water Quality and Treatment. 4th Edition. McGraw Hill, Inc, New York.
2. Metcalf and Eddy, Inc. 1991. Wastewater Engineering: Treatment, Disposal and Reuse. 3rd ed. McGraw-Hill, Inc. New York, NY.
3. Zhang, R. H. and P. W. 1997. Westerman. Solid-Liquid Separation of Animal Manure for Odor Control and Nutrient Management. Transactions of the ASAE. Vol. 13(3): 385-393.

ATTACHMENT A
PERMIT NO. AWI310740
&
ADDENDUM TO EMERGENCY ACTION PLAN

ATTACHMENT B
AEROBIC DIGESTER TECHNICAL REPORT

ATTACHMENT C
SYSTEM PLAN AND PROFILE DRAWING

ATTACHMENT D
EQUIPMENT CALCULATIONS AND SPECIFICATIONS

ATTACHMENT E
WASTE UTILIZATION PLAN

INNOVATIVE PERMIT APPLICATION

For the

Permeable Cover System

PCS

HARRELLS FARMS

An

ISSUES (Innovative Sustainable Systems Utilizing Economical Solutions) Technology

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October 28, 2002

NARATIVE OF INNOVATIVE TECHNOLOGY
ISSUES PROJECT: Permeable Cover System
Harrells Farms
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0.0 **INTRODUCTION**

The permeable cover system (PCS) is an innovative manure water treatment system that will reduce nutrient and oxygen demand in addition to what the existing lagoon treatment system currently achieves. The system is proposed as a modification to the existing waste treatment and utilization system, permitted for Harrells Farm as NCDENR Permit No. AWG100000 and Certificate of Coverage No. AWS820028, included in Attachment A. The permit modification request is for the waste treatment of 2,448-head (two barns) of the 6,120-head (five barns) feeder to finish operation. The farm, located in Sampson County, is owned and operated by Murphy Farms, LLC.

A schematic of the PCS system is shown in Figure 1-1. Aerated water, rich in nitrates, is used to flush manure from two barns to a lift station as shown in the schematic. The flushed manure slurry is pumped from an existing lift station to an existing 4,278,620-gallon primary treatment lagoon at a daily flow rate of 18,850 gpd. This lagoon is to be covered with a floating permeable cover that acts as a biofilter and a physical barrier to lagoon emissions. Aerobic microbes will attach and propagate into a biological scrubbing matrix that will oxidize and neutralize ammonia, volatile organic compounds and other odorous anaerobic by-products from the lagoon. The covered primary treatment lagoon will reduce system organic (VS) loading of 1,586 lbVS/day by about 60%. The liquid from the covered lagoon is pumped at 18,850 gpd to a 700,000-gallon aerobic digester for further reduction in oxygen demand and subsequent nitrification.

A fine-bubble diffuser system will be used to deliver the dissolved oxygen (DO) needed to meet the daily oxygen demand of the aerobic digester. A 10-HP blower, rated at 104 cfm will be used to deliver the air and maintain about 1-2 mg/L of DO in the aerobic digester at all times. The hydraulic retention of the wastewater in the aerobic digester is roughly 36 days. This will provide about 86% reduction in BOD_5 and about 84% reduction in ammonia through nitrification.

A portion, 13,220 gpd, of the nitrified water will be returned to the barns for flushing. The nitrate-rich flush water will combine with raw manure to create a carbon-rich environment for denitrification. As such, more than 90% of the nitrified ammonia will be denitrified to nitrogen gas.

In addition to the aerated effluent stream used to flush the barns, about 5,630 gpd of the aerated water will be pumped to the storage/polishing (PS) basin shown in Figure 1-1. This basin will therefore be anoxic with significantly low ammonia and oxygen demand. Nutrient water will be irrigated from this basin based on the Waste Utilization Plan enclosed as Attachment B.

The entire system will be controlled automatically using a WinPLC-based automation. A Think-and-Do ™ software will be used to run the control interface consisting of digital and analog inputs and outputs. This will allow efficient feeding and treatment for every hour of the day.

1.0 OBJECTIVES

The specific objectives of the RENEW system are to:

- reduce oxygen demand of the total manure produced from the farm by at least 90%.
- reduce ammonia emissions by about 90- and 70%, respectively.
- demonstrate the use of a permeable cover to reduce odors and ammonia emission.

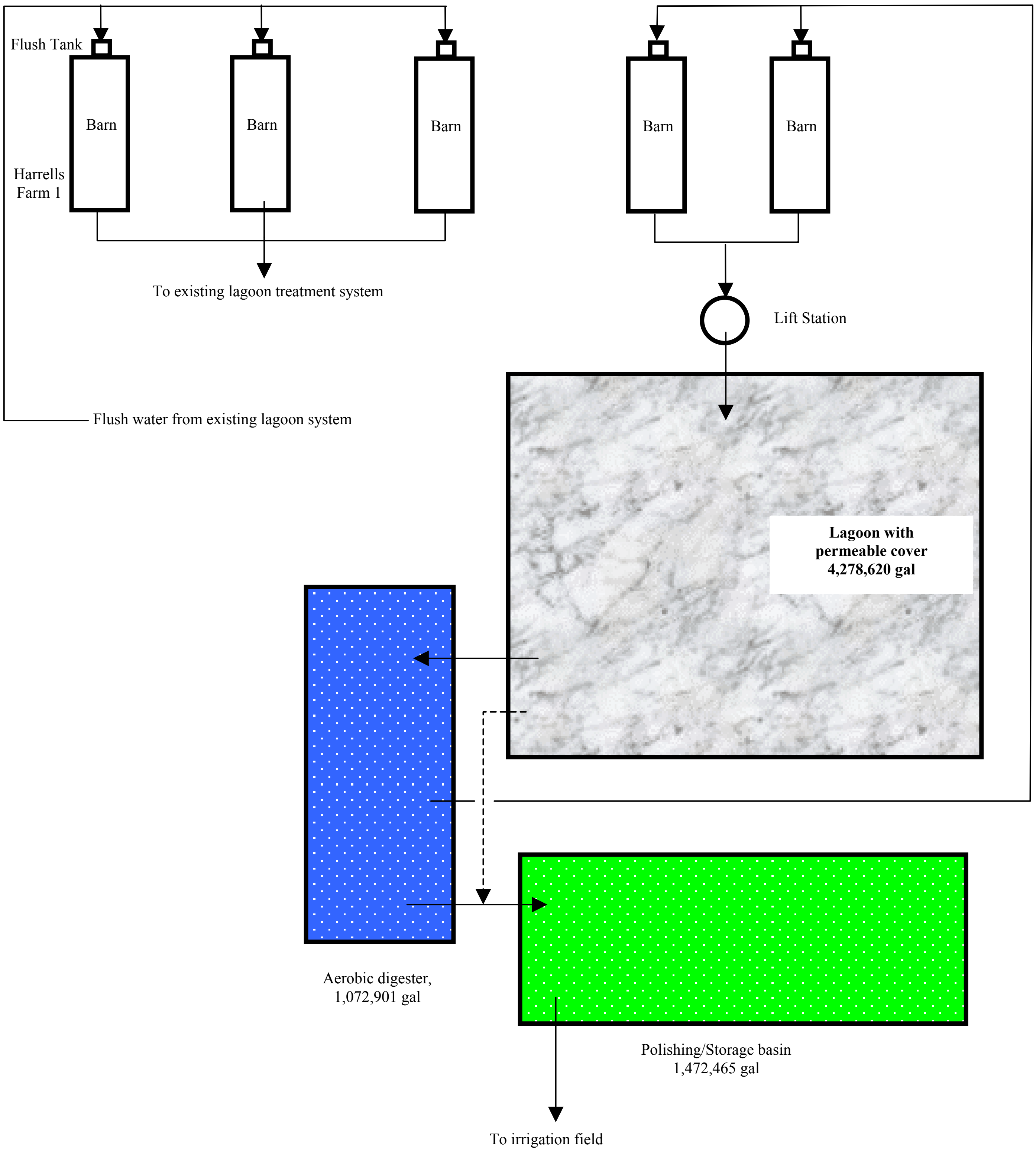

Figure 1-1 Schematic of the Permeable Cover Technology System

2.0 MANURE PRODUCTION AND CHARACTERISTICS

The Harrells farm is a finishing operation with manure characteristics similar to that of a typical modern feeder pig operation. Table 2-1 lists the key parameters of the manure and wastewater inputs.

Table 2-1 Manure and wasterwater characteristics (NRCS 1998, MWPS-18, 1993, Murphy-Brown LLC, 2001)

Input Parameter	Symbol	Units	Finishing
Number of Animals	-	hd	2,448
Animal Liveweight	LAW	lb	135
Animal Unit	AU	1000 lbs	330
Manure Volume	-	cu ft/AU/d	0.74
Manure Volume	-	cu ft/d	245
Total Solids (dry)	TS	lb/AU/d	6.0
Volatile Solids (dry)	VS	lb/AU/d	4.8
Percent VS: TS/VS	-	%	1.25
Total TS per day	-	lb/d	1,983
Total VS per day	-	lb/d	1,586
Total dry solids per year	-	tons/yr	362
BOD5 per day	BOD5	lb/AU/d	1.71
BOD5 per day	BOD5	lb/d	565
Total N per Day	N	lb/AU/d	0.25
Total P2O5 per day	P	lb/AU/d	0.08
Total K2O per day	K	lb/AU/d	0.16
Total N per Day	N	lb/d	84.12
Total P2O5 per day	P	lb/d	26.44
Total K2O per day	K	lb/d	53.86
Feces, urine, excess washwater	FUW	g/hd/d	2.30
TS in flushwater, total	1 % C	lb/d	1,101
Flush water (Pit Recharge)	FW	g/hd/d	5.40
Total FW (flushwater)	FW	gpd	13,219
Total FUW	0	gpd	5,630
Total wastewater: FUW +FW	0	gpd	18,850

3.0 FLUSHING SYSTEM

Manure will be flushed from the two, partially slatted buildings using 580-gallon tanks via existing 12-inch, Schedule 40 PVC to a 4,000-gallon lift station (Figure 1-1). The lift station has two 5-hp, submersible pumps installed in parallel configuration, with solids handling controlled by liquid level floats and control panels. Wastewater from the lift station is pumped through a 6-inch Schedule 40 PVC to a 4,278,620-gallon primary treatment lagoon (Figure 1-1). No modifications to the lift stations or parallel 5-hp pumps will be necessary. An existing screen in each of the lift stations will continue to be used to prevent foreign objects from passing on to the solids concentration system. Please see Sheet 1 of 4 of the engineering drawings in Attachment C for additional details. Table 2-1 lists the flow characteristics of the flushwater.

4.0 COVERED PRIMARY TREATMENT LAGOON AND WET WELL

The raw flushed manure wastewater will be digested anaerobically in the covered lagoon. The organic loading rate of the lagoon is 4.8 lbVS/1000-ft^2/day. About 60% of the loaded VS will be destroyed, resulting into the effluent characteristics shown in Table 5-1. The lagoon effluent is fed into the aerobic digester for further reduction of oxygen demand for both carbonaceous and nitrogenous BOD.

Unlike traditional lagoons, there will be a significant modification to the Harrells lagoon in that it will be covered with a permeable cover (see Attachment D for specifications and installation details). The woven, polypropylene material will form an aerobic matrix that will facilitate the growth of aerobic bacteria. The biological colonies established will facilitate biofiltration of VOCs, ammonia and other by-products of anaerobic digestion. It will also form a physical barrier that will minimize mass transfer between the lagoon and the ambient air. The goal is to develop and demonstrate the effect of a permeable cover on the emission of odor and volatile compounds.

In addition to the permeable cover, a 10-inch pipe will be installed to gravity feed effluent from the primary lagoon to a 5-foot diameter wet well located on the primary lagoon berm. The wet well, detailed in Attachment E, will accommodate the following pumps:

- PWW1 – pumps effluent from the wet well to the aerobic digester
- PWW2 – pumps effluent from the wet well to the polishing/storage basin

Pump calculations and pump specifications for PWW1 and PWW2 are included in Attachment E. A pipe layout (engineering sheet 2 of 4) and hydraulic profile (engineering sheet 3 of 4) of the system are included in Attachment C. Both pumps will be controlled using a WinPLC-based automation.

5.0 AEROBIC DIGESTER

Effluent from the primary lagoon is pumped to the aerobic digester at a feeding rate of 18,850 gpd to reduce the biological oxygen demand through aerobic digestion and ammonia through nitrification. The BOD_5 and ammonia concentrations in the aerobic digester influent will be about 1,437 mg/L and 429 mg/L respectively (Table 5-1). This will result in an oxygen demand of approximately 582 lb/d. The oxygen demand will be supplied by a blower and fine-bubble diffuser system detailed further in this section.

The aerobic digester influent TS, BOD_5, and NH_3-N concentrations will be about 6, 727, 1437, and 429 mg/L, respectively. The aerobic digester will reduce the oxygen demand in the effluent by about 86%, resulting in the digester effluent characteristics shown in Table 5-1.

Reduction of the oxygen demand will be accomplished based on the following biochemical process (Metcalf and Eddie, 1991):

$$COHNS + O_2 + \text{nutrients} \xrightarrow{\text{Bacteria}} CO_2 + NH_3 + \underbrace{C_5H_7NO_2}_{\text{new bacteria cell}} + \text{other end products}$$

Assuming a completely mixed reactor, the computed reactor volume based on oxygen demand would be 67,763 gallons, as shown in Table 5-1. This volume is computed using equation 5-1 as follows (Metcalf and Eddie, 1991):

$$V = \frac{SRT.\,Q.\,Y.\,(BOD_{in} - BOD_{out})}{MLSS.\,(1 + kd.\,SRT)} \qquad 5\text{-}1$$

where SRT (solids retention time) = 10 days; Q = daily flow rate = 18,850 gpd; Y = yield coefficient = 0.5 mg cell/mg BOD_5; BOD_{in} = influent BOD_5 = CBOD + NBOD (Table 5-1); BOD_{out} = effluent BOD_5 as in Table 5-1; MLSS = mixed liquor suspended solids = 2500 mg/L; kd = kinetic constant = 0.006 1/day; and V = volume of aerobic digester.

If the aerobic digester volume were to be computed based on a HRT of 30 days and a flow rate of 18,850 gpd, the required volume would be 565,488 gallons. The actual volume of the digester proposed for the Harrells Farm, is sized to provide 696,541 gallons of aerobic digestion. Using internal settling, instead of operating the reactor in a completely mixed mode will make it possible to achieve a hydraulic retention time (HRT) of the suspended solids in excess of 30 days.

A dissolved oxygen demand to maintain 1-2 mg/L at all times in the aerobic digester will be supplied by a fine-bubble diffuser system. The horsepower required for the blower (Table 5-1) was computed using equation 5-2 (Metcalf and Eddie, 1991).

$$HP = \frac{wRT}{550ne}\left[\left(\frac{P_2}{P_1}\right)^{0.283} - 1\right] \qquad 5\text{-}2$$

Where w = mass flow rate (lb/s); R = gas constant, n = 0.283 (air); e = blower efficiency; P_1 = blower inlet pressure; P_2 = blower outlet pressure; and HP = horse power = 6.4 HP (computed as shown in Table 5-1).

The influent and effluent flow inventory is listed in Table 5-1. Out of the total influent flow rate of 18,850 gpd, 13,219 gpd will be used for flushing two barns, while 5,630 gpd will be pumped to the polishing/storage basin for denitrification and further tertiary treatment. The flowrates from the aerobic digester will be controlled by two submersible pump as follows:

- PAED1 – pumps aerated wastewater from the aerobic digester to the PS basin
- Recycle – pumps aerated wastewater from the aerobic digester to two barn's flush tanks

Pump calculations and pump specifications for PAED1 and Recycle are included in Attachment E. A pipe layout (engineering sheet 1 of 4) and hydraulic profile (engineering sheet 3 of 4) of the systems are included in Attachment C.

In the event either of the PAED1 or Recycle pumps are turned off due to maintenance or operational requirements, a cross-over pipe will gravity feed excess wastewater to the PS basin. The elevation of the cross-over pipe invert is such that excess precipitation in the aerobic digester will discharge into the PS basin. Excess precipitation will discharge into the PS basin until its storage volume is full and then both the digester and basin liquid level will rise together to fill the volume designated for excess precipitation.

Table 5-1 Design and operational parameters of the aerobic digester

Line Item	Symbol	Units	Value
System flowrate	Qsys	gpd	18,850
Flowrate, influent from covered lagoon	Qd	gpd	18,850
Flowrate, flushing	Qf	gpd	13,219
Flowrate, Feces, urine, wastewater (FUW)	Qwr	gpd	5,630
Total solids concentration in influent from lagoon	TS	mg/L	6,727
Volatile solids concentration in influent from lagoon	VS	mg/L	4,036
BOD_5 concentration in influent from lagoon	BOD_5	mg/L	1,437
Ammonia concentration in influent from lagoon	Cnh3	mg/L	429
Oxygen demand to nitrogen ration			4.57
BOD_5/BOD-ultimate			0.60
Effluent BOD_5, proposed	BOD_5	mg/L	200
Effluent ammonia concentration, proposed	VS	mg/l	70
Total oxygen demand	TOD	lb/d	582
Diffuser efficiency	Ed	%	25.00
Percent of oxygen in atmosphere		%	21.00
Density of air @ 70 F, 50% RH		lb/cu.ft.	0.074
Total volume of air needed		cfm	104
Oxygen demand met by fine-bubble aerator		cfm	104
Oxygen demand met by Air-Jammer		lb/day	0
Blower HP, calculated		HP	6.4
Aerobic digester volume per oxygen demand	V	gal	67,763
Aerobic digester treatment volume per HRT	V	gal	565,488
Aerobic digester volume, total	V	gal	696,541
Hydraulic retention, proposed	HRT	d	30
Hydraulic retention, actual	HRT	d	37
VS reduction rate	VSRR	%	70
VS in effluent	VS	mg/L	1,211
TS in effluent	TS	mg/L	2,018
BOD reduction rate	BODr	%	86
Nitrate in the effluent	NO3-N	mg/L	359

The aerobic digester will be constructed as an earthen structure and lined with 40-mil HDPE. Engineering details pertaining to the construction of the aerobic digester are identified on sheet 1 of 4 and in Attachment F.

6.0 Polishing/Storage Basin

As mentioned above, 5,630 gpd of oxygenated water will be fed from the aerobic digester into the polishing/storage basin. The PS basin will provide tertiary treatment including denitrification. It will also provide storage and equalization for irrigation. The nutrient and BOD contents of the PS basin, influent and effluent are listed in Table 6-1.

Table 6-1 Design and operational parameters of the PS basin

Line Item	Symbol	Units	Value
System flowrate	Qsys	gpd	18,850
Flowrate, influent from aerobic digester	Qd	gpd	5,630
Flowrate, flushing	Qf	gpd	13,219
Flowrate, Feces, urine, wastewater (FUW)	Qwr	gpd	5,630
Total solids concentration in influent	TS	mg/L	2,018
Volatile solids concentration in influent	VS	mg/L	1,211
BOD5 concentration in influent	BOD5	mg/L	200
Ammonia concentration in influent	Cnh3	mg/L	70
Nitrate concentration in influent	NO3-N	mg/L	359
Denitrification efficiency		%	80
Effluent BOD5	BOD5	mg/L	100
Hydraulic retention, proposed	HRT	d	180
PS Basin treatment volume per HRT of 180	V	gal	1,013,472
PS Basin volume, total	V	gal	1,472,363
Hydraulic retention, actual	HRT	d	81 - 171
VS reduction rate	VSRR	%	70
VS in effluent	VS	mg/L	363
TS in effluent	TS	mg/L	605
BOD reduction rate	BODr	%	50
Nitrate concentration in effluent	NO3-N	mg/L	72
Nitrogen, total	N	mg/L	142
Phosphorous, total	P	mg/L	169
Potassium, total	K	mg/L	172

6.3 Nutrient Utilization

The additional treatment provided by the aerobic digester and PS basin will reduce BOD and nitrogen by about 75% respectively. This will reduce nutrients available for irrigation and agronomic plant uptake. The nutrient application design and plan, included in Attachment B, only assumes a 25% reduction of Plant Available Nitrogen (PAN) from the two barns, therefore, the plan is conservative for the proposed system.

REFERENCES

1. Metcalf and Eddy, Inc. 1991. Wastewater Engineering: Treatment, Disposal and Reuse. 3rd ed. McGraw-Hill, Inc. New York, NY.

ATTACHMENT A
GENERAL PERMIT NO. AWG100000
CERTIFICATE OF COVERAGE NO. AWS820028

ATTACHMENT B
WASTE UTILIZATION PLAN

ATTACHMENT C
ENGINEERING DRAWINGS

ATTACHMENT D
SPECIFICATIONS AND ENGINEERING DETAILS
FOR
PERMEABLE COVER

ATTACHMENT E
EQUIPMENT SPECIFICATIONS AND CALCULATIONS

ATTACHMENT F
CONSTRUCTION DETAILS AND CALCULATIONS FOR AEROBIC DIGESTER AND POLISHING/STORAGE BASIN

INNOVATIVE PERMIT APPLICATION

For the

Recycling of Existing Nutrients, Energy and Water

RENEW

System for

VESTAL FARMS

An
ISSUES (Innovative Sustainable Systems Utilizing Economical Solutions) Technology

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NARATIVE OF INNOVATIVE TECHNOLOGY
ISSUES PROJECT: RENEW Technologies
VESTAL FARMS
By

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0.0 **INTRODUCTION**

This narrative describes an innovative system of manure water treatment technologies called RENEW (Recycling of Existing Nutrients, Energy and Water). RENEW is proposed for a complete replacement of the existing AJT manure treatment system, which is already permitted for Vestal 1 & 2 Farm (NCDENR permit no. AWI310082, included in Attachment A). A permit modification is therefore requested. The farm is a 9,792-head finishing operation, located in Duplin County, and is owned and operated by Murphy Farms, LLC.

A schematic of the RENEW system is shown in Figure 1-1. Aerated nutrient water, with low oxygen demand, is used to flush manure from individual barns into one of two lift-stations as shown in the schematic. The flushed manure slurry is pumped from the lift station into two 10,000-gallon equalization tanks in parallel-flow configuration, at a daily flow rate of 75,398 gpd. Because nitrified water is used for flushing, the total equalization volume of 23,000 gallons enhances denitrification by providing 7.5 hours of hydraulic retention time (HRT).

The wastewater stream is pumped from the equalization tanks to the "concentrator" at 6 batches per day. The thickened sludge is pumped from the bottom of the concentrator to the mesophilic digester, while the supernatant is fed to the polishing/storage basin (PS basin) as shown in Figure 1-1. The mesophilic digester will be maintained at 95°F±3. Anaerobic digestion has been found to peak at this temperature (Dugba et al). Biogas (70% methane and 29% carbon dioxide) produced from the anaerobic digester will be used to fuel a 30-KW, Capstone micro-turbine generator to produce electricity. The waste heat from the generator will be used to heat the mesophilic digester. The digester effluent and the supernatant from the concentrator are fed to the polishing/storage basin. The mesophilic digester will reduce system organic (VS) loading of 6,345 lb/day by about 60%.

Effluent from the PS basin is fed to the aerobic digester at a system flow rate of 75,398 gpd. The residual BOD_5 and ammonia concentrations in the PS basin effluent will be about 925 mg/L and 429 mg/L respectively. This will result to an oxygen demand of about 1,792 lb/d in the aerobic digester influent.

A combination of fine bubble aeration and an Air-Jammer™ (aerator and mixer) will be used to deliver the dissolved oxygen (DO) needed to meet the daily oxygen need. A 20-HP blower, rated at 250 cfm will be used to deliver the fine bubbles. A DO of about 1-2 mg/L will be maintained in the aerobic basin. The aerobic treatment will provide about 78% reduction in BOD_5 and about 84% reduction in ammonia through nitrification.

After aeration, about 12,522 gpd of the nitrified water will be returned to the polishing and storage (PS) basin for denitrification and storage. The volatile solids loading rate on the polishing/storage (PS) basin from the equalization tanks, solids concentrator, and mesophilic digester is approximately 47.8% of the total volatile solids produced. The PS basin will provide secondary treatment to provide an additional 70% reduction in the organic solids fed to the basin. The system equilibrium BOD_5 and ammonia concentrations will be less than 400 mg/L and 200 mg/L.

About 52,877 gpd of the nitrified water will be returned to the barns for flushing. The nitrate-rich flush water will combine with raw manure to create a carbon-rich environment for denitrification. As such, more than 90% of the nitrified ammonia will be denitrified to nitrogen gas.

In addition to the aerated effluent stream that is used to flush the barns, about 10,000 gpd of the aerated water will be fed to the water reuse system. The nitrified water, consisting of 70 mg/L of ammonia and 200 mg/L of BOD_5 is treated further in the polishing tank #1 as shown in Figure 1-1. This additional aerobic treatment will further reduce the oxygen demand by about 75% resulting in effluent ammonia and BOD_5 concentrations of 20 mg/L and 50 mg/L, respectively.

The polished water is fed to the primary clarifier at the rate of 10,000 gpd for coagulation and flocculation. An organic polymer (PAA) is injected into the feeding pipe and distributed in the water using pipe mixing through turbulence created by 90-degree fittings. The clarifier will be operated in batch-mode to allow time for feeding, settling, and decanting. About 20% of the influent water is wasted as sludge into the PS basin. The supernatant TSS will be about 63 mg/L.

Supernatant from the clarifier is fed to the second polishing tank at a daily flow rate of 8,000 gpd, and will consist of about 266 mg/L of nitrate and 50 mg/L BOD_5. The goal of the second-stage polishing is to accomplish denitrification. Carbon source necessary to accomplish denitrification will be supplied by methanol. About 49 lb of methanol will be required per day.

The concentrations of nitrate, ammonia, BOD, and TSS in the denitrified water will be about 20-20-, 10 - and 5-mg/L, respectively. Effluent from the denitrification tank is fed to the second-stage clarifier as shown in Figure 1-1. About 95% of the solids will settle in the cone-bottom tank and returned to the PS basin at the rate of about 800 gpd.

Supernatant from the secondary clarifier is filtered through a Fuzzy™ filter at flow rate within the AWWA (1990) recommendation of 2-10 gpm/ft^2 filter surface area. The Fuzzy™ filter is used in front of the sand filters because it is easier to clean and can be adjusted to remove suspended solids ranging in size from 5- to 15-µm. The clean water stream will then flow through two sand filters per AWWA recommendation of 2-10 gpm/ft^2. The Fuzzy™ and sand filters will remove particles larger than 5 µm, but will not remove dissolved salts.

In order to remove particles smaller than 5µm along with dissolved salts including calcium, magnesium, sulfides, chlorides and other ions, the water is filtered through a reverse osmosis (RO) unit. The total dissolved solids in the RO influent will be less than 1,500 mg/L, and will be reduced by about 80%. After filtration, the water is disinfected using ozonation delivered at about 3 mg/L at a contact time of at least 20 minutes. The cleaned, disinfected water is then pumped into a 3,000-gallon equalization tank to be delivered into the existing fresh water lines of the farm. In order to maintain the effect of residual disinfection, the water is chlorinated at 3 mg/L prior to storage in the tank.

The entire system will be controlled automatically using a PC-based automation. A Think-and-Do™ software will be used to run the control interface consisting of digital and analog inputs and outputs. Real-time data access and control software will be installed to allow remote operation of the system.

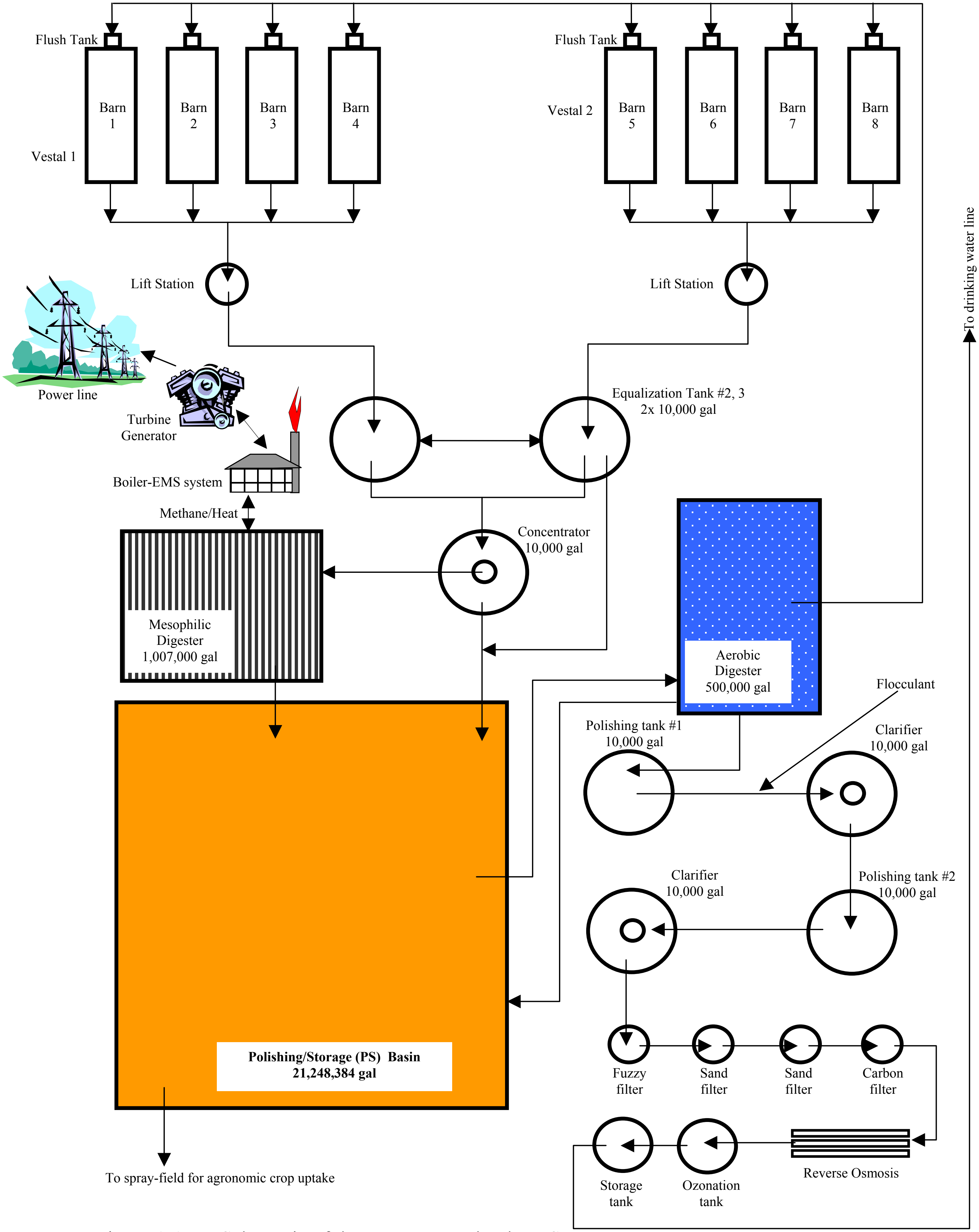

Figure 1-1 Schematic of the RENEW Technology System

1.0 OBJECTIVES

The specific objectives of the RENEW system are to:

- reduce oxygen demand of the total manure produced from the farm by at least 90%.
- reduce odor and ammonia emissions by about 90- and 70%, respectively.
- develop and demonstrate water purification system that meet the drinking water standards for monogastric animals.

2.0 MANURE PRODUCTION AND CHARACTERISTICS

Vestal farm is a finishing operation and characteristics of manure produced are that of a typical modern feeder pig. Table 2-1 lists the key parameters of the manure and wastewater inputs.

Table 2-1 Manure and wasterwater characteristics (NRCS 1998, MWPS-18, 1993, Murphy-Brown LLC, 2001)

Input Parameter	Symbol	Units	Finishing
Number of Animals	-	hd	9,792
Live Animal Weight	LAW	lb	135
Animal Unit	AU	1000 lbs	1321.9
Manure Volume	-	cu ft/AU/d	0.74
Manure Volume	-	cu ft/d	978
Total Solids (dry)	TS	lb/AU/d	6.00
Volatile Solids (dry)	VS	lb/AU/d	4.80
Percent VS: VS/TS	-	%	80
Total solids per day	-	lb/d	7,932
Total volatile solids per day	-	lb/d	6,345
Total dry solids per year	-	ton/yr	1,448
BOD_5 per day	BOD_5	lb/AU/d	1.71
BOD_5 per day	BOD_5	lb/d	2,259
Total nitrogen per day	N	lb/AU/d	0.25
Total P_2O_5 per day	P	lb/AU/d	0.08
Total K_2O per day	K	lb/AU/d	0.16
Total N per Day	N	lb/d	336
Total P_2O_5 per day	P		105.75
Total K_2O per day	K		215.45
Feces, urine, excess washwater	FUW	g/hd/d	2.30
TS in flushwater, total	1 % C	lb/d	4,405
Flush water	FW	g/hd/d	5.40
Total FW (flushwater)	FW	gpd	52,877
Total FUW (feces, urine and wastewater)		gpd	22,522
Total wastewater: FUW +FW	FUW + FW	gpd	75,398

3.0 FLUSHING SYSTEM

Manure will be flushed from the eight, partially-slatted buildings using 820-gallon tanks via existing 12-inch, Schedule 40 PVC to one of the two 4,000-gallon lift stations (Figure 1-1). Each lift station has parallel 5-hp, submersible pumps with solids handling controlled by liquid level floats and control panels. Wastewater from each lift station is pumped through a 6-inch Schedule 40 PVC to the equalization tanks (Figure 1-1). No modifications to the lift stations or parallel 5-hp pumps will be necessary. An existing screen in each of the lift stations will continue to be used to prevent foreign objects from passing on to the solids concentration system. Please see Sheet 1 of 7 of the engineering drawings in Attachment C for additional details. Table 3-1 lists the flow characteristics of the flushwater.

Table 3-1 Flushwater flow characteristics

Line Item	Symbol	Units	Value		
Characteristics of Wastewater			EQ1*	EQ2	Total
Flow Rate, Feces, urine, washwater	FUW	gpd	11,261	11,261	22,522
Flow rate, flushwater	FW	gpd	26,438	26,438	52,877
Influent Flow Rate, total	FUW+FW	gpd	37,699	37,699	75,398
Total solids, FUW	TSFUW	lb/d	3,966	3,966	7,932
Total solids, FW	TSFW	lb/d	2,202	2,202	4,405
Total solids, FUW + FW	TS	lb/d	6,168	6,168	12,336
Concentration of TS influent	C	mg/L	19,641	19,641	19,641
Hydraulic concentration efficiency	Eh	%	80	80	80
Solid concentration efficiency	Es	%	90	90	90
Flowrate, thickened sludge	Qs	gpd	30,159	30,159	60,319
Flowrate, supernatant	Qc	gpd	7,540	7,540	15,080
Sludge water concentration	Cs	mg/L	22,097	22,097	22,097
Supernatant concentration	Cc	mg/L	9,821	9,821	9,821
Size of Equalization Tanks					
Concentrator tank volume	EQ	g	10,000	10,000	20,000
Hydraulic Retention Time	HRT	d	0.27	0.27	0.27

* *EQ = Equalization basin*

3.1 Flow Equalization

As shown in Figure 1-1, there are two equalization tanks. Each of the equalization tanks is a 10,000-gallon HDPE container operated in parallel. Modifications to the tank will include the installation of a 3-hp submersible solids handling pump, detailed in Sheet 4 of 7 of Engineering drawings in Attachment C. A 6-inch pipe is used to convey any excess wastewater to the aerobic digester (section 7.0). Liquid level floats will be used to control the pumps in the two equalization tanks. Table 3-1 lists the wastewater flow characteristics. The equalization tanks will provide a total flow equalization volume of 20,000 gpd, or 6.4-hour HRT.

In the event of an emergency, or need to bypass the RENEW system, gate valves to the equalization tanks can be closed forcing the wastewater through two 6-inch PVC pipes directing the discharge to the PS basin. A schematic of the piping and valve system is detailed in Sheet 5 of 7 of Engineering drawings in Attachment C.

4.0 SOLIDS CONCENTRATION SYSTEM

One of the challenges of installing a heated digester on a flushing system is the need to minimize heating excess water. The goal of the concentrator is to minimize this challenge. As shown in Table 4-1, wastewater from the equalization tanks will contain about 2% TS, and is concentrated to about 3% before feeding to the heated anaerobic digester. The concentrator will be operated in 4-hour batches at 10,000 gallons per batch. Because the concentrator has a 90-degree cone-bottom, sludge water will be pumped at about 200 gpm from the bottom of the tank while supernatant will be pumped with a submersible pump installed on a float. A 6-inch overflow pipe connects each tank with a final 6-inch pipe discharging directly into the aeration basin. Additional details are shown on Sheets 3 and 4 of 7 in Attachment C.

Table 4-1 Solids concentration parameters.

Line Item	Symbol	Units	Value
Characteristics of Wastewater			
Influent Flow Rate, total	Q	gpd	60,319
Total solids, TS	TS	lb/d	7,932
Concentration of TS in influent	TS	mg/L	19,641
Hydraulic concentration efficiency	Eh	%	50
Solid concentration efficiency	Es	%	70
Flowrate, thickened sludge	Qs	gpd	30,159
Flowrate, supernatant	Qc	gpd	30,159
TS concentration in sludge water	Cs	mg/L	27,498
TS concentration in supernatant	Cc	mg/L	11,785
Size of Concentrator			
Concentrator tank volume	EQ	g	10,000
Hydraulic Retention Time	HRT	d	0.17

5.0 MESOPHILIC DIGESTER AND ENERGY MANAGEMENT SYSTEM

The mesophilic digester system consists of the following three key operating units:

- The mesophilic anaerobic digester, section 5.0.
- Biogas collection and digester heating system, section 5.1.
- Micro-Turbine electricity generation unit, section 5.2.

The underflow from the concentrator, consisting of about 3% TS concentration, is fed into the mesophilic digester at a daily flow rate of 30,159 gpd (Table 5-1). Even though this is only 40% of the system hydraulic flow of 75,398 gpd, it will carry 87% of the total daily TS generated on the farm to the mesophilic digester for treatment. This primary treatment will destroy about 60% of influent organic solids to form biogas consisting of about 65-70% methane, 30-35% carbon dioxide, and about 0.5% of other gases including hydrogen sulfides and ammonia. Other characteristics of influent and effluent wastewater of the digester are listed in Table 5-1.

Table 5-1 The design and operating parameters of the mesophilic digester

Line Item	Symbol	Units	Value
Characteristics of Wastewater			
Flowrate, total	Qd	gpd	75,398
Flowrate to concentrator	Qcon	gpd	60,319
Flowrate to digester	Qs	gpd	30,159
Concentration of TS in influent	Cs	mg/L	27,498
Total solids in influent	TS	lb/d	6,908
Percent volatile solids	Pvs	%	80
Volatile solids concentration	VS	mg/l	21,998
Total volatile solids in digester	TVS	lb/d	5,527
Hydraulic retention, proposed	HRT	day	25.0
Hydraulic retention, actual	HRT	day	24.6
VS Loading rate	VSLR	g/L/d	2.0
VS Loading rate	VSLR	lb/1000g/d	16.7
Volume per VSRL	V	gal	331,625
Volume per HRT, liquid	V	gal	753,984
Volume, actual	V	gal	743,245
Number of Digesters	N	ea	1
Volume per Digester		gal	753,984
VS reduction rate	VSRR	%	60
VS in effluent	VS	lb/d	2,211
Concentration of VS in effluent	VS	mg/L	8,796
BOD5/VS ration			2.81
Concentration of BOD5 in effluent	BOD_5	mg/L	3,132

The digester will be constructed in-ground and lined with a 40 mil HDPE synthetic liner installed on a compacted backfilled soil liner. A 6-inch Styrofoam will be used to insulate the top of the digester to an insulation resistance value of about 3 ft^2-hr-F/Btu. The cover, detailed in engineering drawings on Sheet 4 of 7 will be installed to allow biogas flow to one end of the digester where it is collected through a pipe and fed to the energy management system (EMS).

5.1 Heating System of the Anaerobic Digester

The energy required to heat the digester to the mesophilic temperature of 95°F is 6.3M BTU/day. This heat energy is supplied with a 1,000,000-Btu/hr burner and a novel heat exchanger co-invented by Engineers from Smithfield Foods Inc. and Hoffland Environmental Inc. and fabricated by latter in Conroe, Texas.

The anaerobic digester liquid is pumped to a 4,000-gallon heat exchanger tank installed in a separate tank. The tank will be covered and sealed to eliminate the loss of entrained biogas. The tank will be equipped with a weir overflow near the top, providing gravity flow of the heated liquid back to the in-ground digester. The heat exchanger tank is constructed with adequate capacity and a serpentine heat-exchanger to allow for optimum heat transfer.

The serpentine coil will be 8-inch in diameter and will have a burner mounted in the inlet. The coil will be constructed to provide adequate surface area to provide the required surface area to heat the liquid. The serpentine coil will vent to the atmosphere at the exit. A mechanical mixer is used to create turbulent mixing to further enhance heat transfer. The mixer will be mounted in the tank top with a long shaft and turbine impeller and will provide sufficient mixing to not only suspend any solids contained in the tank influent but also provide adequate mixing to eliminate hot spot and continuously transfer the heat supplied by the biogas burner.

The burner is constructed of corrosion-resistant material suitable for burning biogas containing high concentrations of hydrogen sulfide. The burner is mounted in the initial section of the serpentine tube that is sufficiently large in diameter to receive the burner and is centered in a stainless steel tube that is internally insulated. The flame in the burner that produces 1,000,000 BTU/hr of heat is approximately 18-inch in diameter and will extend 3 feet from the burner. This area will be covered with insulation to prohibit the flame from impinging upon the metal, which would rapidly deteriorate the metal. After the flame zone, the pipe is reduced to 8-inch diameter and becomes a serpentine construction to be able to fit the required length of pipe in the small diameter tank. The small area that is insulated has a stainless steel shell. Any sulfur dioxide gas that migrates through the insulation will not attack the stainless steel shell. As an added insurance to prohibit the sulfur dioxide from attacking the metal serpentine tube, when the burner is extinguished, the combustion air blower of the burner will remain on for 30 minutes to flush any residual sulfur dioxide from the serpentine coil before it ceases and reverts to the stand-by mode.

The system will be started either manually or by timer. The pump will pump the liquid through the tank and gravity flow back to the digester basin. The mixer will continuously mix the tank contents. A preset temperature controller will sense the temperature of the liquid and if below the set point, it will ignite the burner. The burner will be on/off with modulating control. The burner will fire until the set point of the temperature control is achieved. The burner will extinguish but the combustion air blower will continue to force fresh air through the serpentine coil for a preset time or it may continue to run until the system is turned off.

The excess biogas will be vented through a flare to assure combustion of the methane and hydrogen sulfide. The system is controlled by the pressure sensor on the digester biogas line. When the pressure exceeds a preset limit of 6-inch water column, the inline biogas blower will start to pressurize the gas line. A gas solenoid valve in the line to the flare will open to permit the gas to vent through the flare. An auto ignition pilot using propane gas will ignite. A combustion control package will sense the pilot and open the gas solenoid valve. When the biogas flame is sensed the propane pilot will be turned off. Alarms are built in to the flame detector system to shut off the flare and provide an alarm for loss of pilot, failure to ignite, and loss of biogas flame.

5.2 Micro-Turbine Electric Generator

Conversion of part of the Biogas into electricity will also be developed and demonstrated using a 30-KW Capstone micro-turbine generator. To maximize energy utilization efficiency, the hot vent gases from the turbine will be sent through a separate serpentine coil also mounted in the heat exchanger tank to head the digester liquid. The turbine generator by itself is approximately 25% efficient, resulting to vent gases containing the rejected energy in heat form, which is approximately 75% of the input energy. The serpentine heat exchanger coil will recover approximately 50% of the vented energy. The overall efficiency of the turbine generator with the recuperative serpentine heat exchanger is 60-65%.

The Capstone Micro-turbine is a compact, ultra low emission, power generator providing electrical power up to 30 kW. Microprocessor-based electronics allow grid-connect operation, stand-alone battery support and automatic grid/stand-alone switching options. The Microturbine can efficiently use the biogas to generate electricity.

The 30-kW Micro-turbine power plant incorporates a recuperator, combustor, turbine, and permanent magnet generator (PMG). Rotating components are mounted on a single shaft that rotates at speeds up to 96,000 RPM (full load) and is supported by air bearings. The generator is cooled by intake airflow, eliminating the need for liquid cooling. Output of the system is 480 Volt/3 Phase/60 Hz to match the power grid.

Design and installation specifications of the micro-turbine are listed in Attachment E.

6.0 STORAGE AND POLISHING (PS) BASIN

A polishing and storage (PS) basin sized at 2,840,693 ft^3 will provide secondary treatment for the digester effluent and the bypass from the concentrator. The overall VS loading rate (VSLR) to the PS basin will be only 47.8% of the total VS produced by the 9,792 hogs (Table 6-1) .

6.1 PS Basin

The PS basin will be used for secondary treatment and will remove about 70% of organic solids fed to it. In addition to this additional polishing, it will also provide about 180 days of temporary storage for the nutrient water.

6.2 Land Application

The anticipated nutrient removal by the RENEW system is identified in Table 6-1. This environmentally superior technology will reduce an additional 75% of plant available nitrogen compared to traditional lagoon systems. However, the available land set aside for the agronomic

uptake of nutrients is based on the traditional lagoon and spray field system. The Waste Utilization Plan proposed for this facility is enclosed as Attachment F.

Table 6-1 Inventory of Nutrients in the RENEW system

Constituent	System Influent	Mesophilic Digester	PS Basin	Aerobic Digester	Water Reuse
	Percent of constituent in influent removed				
	%				
Total Solids, TS	7,932	48	60	56	98
Volatile Solids, VS	6,345	60	75	70	98
BOD5	2,259	88	83	78	97
Nitrogen, N	336	5	19	84	95
Phosphorous as P2O5	106	0	50	35	95
Potasium as K2O	215	0	50	20	95
	Mass of constituent in effluent				
	lb/d				
Total Solids, TS	7,932	4,041	1,680	739	2.0
Volatile Solids, VS	6,345	2,487	504	242	1.3
BOD5	2,259	235	113	56	0.6
Nitrogen, N	336	256	262	43	0.3
Phosphorous as P2O5	106	80	53	34	0.2
Potasium as K2O	215	164	108	86	0.6
	Percent of constituent in influent as a % of system total				
	%				
Total Solids, TS	7,932	98.0	53.0	21.2	1.2
Volatile Solids, VS	6,345	98.0	31.8	12.7	1.0
BOD5	2,259	88.2	28.6	11.4	0.9
Nitrogen, N	336	80.0	96.0	77.8	1.7
Phosphorous as P2O5	106	76.0	100.0	50.0	4.3
Potasium as K2O	215	76.0	100.0	50.0	5.3

7.0 AEROBIC DIGESTER

Effluent from the PS basin is fed to the aerobic digester at a feeding rate of 75,398 gpd. The BOD_5 and ammonia concentrations in the aerobic digester influent will be about 926 mg/L and 429 mg/L respectively (Table 7-1). This will result to an oxygen demand of about 1,792 lb/d.

Reduction of the oxygen demand will be accomplished based on the following biochemical process (Metcalf and Eddie, 1991):

$$COHNS + O_2 + \text{nutrients} \xrightarrow{\text{Bacteria}} CO_2 + NH_3 + \underbrace{C_5H_7NO_2}_{\text{new bacteria cell}} + \text{other end products}$$

The aerobic digester will use internal settling to achieve at least 10 days bacteria retention time at a much shorter hydraulic loading rate (HRT). Assuming a completely mixed reactor, the computed reactor volume of 222,911 gallons based on oxygen demand, shown in Table 7-1, was computed using equation 7-1 as follows (Metcalf and Eddie, 1991):

$$V = \frac{SRT.\,Q.\,Y.\,(BOD_{in} - BOD_{out})}{MLSS.\,(1 + kd.\,SRT)} \qquad 7\text{-}1$$

where SRT (solids retention time) = 10 days; Q = daily flow rate = 75,398 gpd; Y = yield coefficient = 0.5 mg cell/mg BOD_5; BOD_{in} = influent BOD_5 = CBOD + NBOD (Table 7-1); BOD_{out} = effluent BOD_5 as in Table 7-1; MLSS = mixed liquor suspended solids = 2500 mg/L; kd = kinetic constant = 0.006 1/day; and V = volume of aerobic digester.

Table 7-1 Design and operational parameters of the aerobic digester

Line Item	Symbol	Units	Value
Characteristics of Wastewater			
System flowrate	Qsys	gpd	75,398
Flowrate, influent from PS basin	Qd	gpd	75,398
Flowrate, flushing	Qf	gpd	52,877
Flowrate, water reuse	Qwr	gpd	10,000
Flowrate, back to PS basin for denitrification	Qps	gpd	12,522
BOD5 concentration in influent	BOD5	mg/L	926
Ammonia concentration in influent	Cnh3	mg/L	429
Oxygen demand to nitrogen ration			4.57
BOD5/BOD-ultimate			0.60
Effluent BOD5, proposed	BOD5	mg/L	200
Effluent ammonia concentration, proposed	Cnh3	mg/l	70
Total oxygen demand	TOD	lb/d	1,792
Diffuser efficiency	Ed	%	25.00
Percent of oxygen in atmosphere		%	21.00
Density of air @ 70 F, 50% RH		lb/cu.ft.	0.074
Total volume of air needed		cfm	320
Oxygen demand met by fine-bubble aerator		cfm	250
Oxygen demand met by Air-Jammer		lb/day	394
Bower HP, calculated		HP	15.4
Aerobic digester volume per oxygen demand	V	gal	222,911
Aerobic digester volume per HRT	V	gal	753,984
Aerobic digester volume, actual	V	gal	500,000
Hydraulic retention, proposed	HRT	d	10
Hydraulic retention, actual	HRT	d	6.6
VS reduction rate	VSRR	%	70
VS in effluent	VS	lb/d	538

The actual volume of the digester is 500,000 gallons. Using internal settling, instead of operating the reactor in a completely mixed mode, will make it possible to achieve solid retention time (SRT) in excess of 10 days even though the hydraulic retention will be about 8 days. Therefore, the constructed aerobic digester volume of 500,000 gallons is more than adequate.

Engineering details on the aerobic digester construction are given on sheet 4 of 7 in attachment C. Table 7-1 also lists additional specifications of the digester. The horse power required for the blower (Table 7-1) was computed using equation 7-2 (Metcalf and Eddie, 1991).

$$HP = \frac{wRT}{550ne}\left[\left(\frac{P_2}{P_1}\right)^{0.283} - 1\right] \qquad 7\text{-}2$$

Where w = mass flow rate (lb/s); R = gas constant, n = 0.283 (air); e = blower efficiency; P_1 = blower inlet pressure; P_2 = blower outlet pressure; and HP = horse power.

As shown in Table 7-1, about 78% of the total oxygen demand of 1,792 lb/d will be supplied by a blower rated at 20 HP, while the remaining oxygen demand will be met by an Air-Jammer™ unit. The Air-Jammer will also provide mixing to facilitate good distribution of dissolved oxygen in the aerobic pond. Lists of additional specifications on the Blower and Air-Jammer™ system are provided in Attachment D.

8.0 WATER REUSE SYSTEM

The RENEW system will also process about 10,000 gallons of aerated water into drinking water per standards recommended by the Task Force on Water Quality (TFWQ) standards: "Nutrient Requirements of Swine. 1998. 10th Edition by the sub-committee on Swine Nutrition, Committee on Animal Nutrition, Board of Agriculture, National Research Council."

Note that the water reuse component of the RENEW technologies is not necessary for the system to meet the NPDES permit requirements. The water reuse is added only for development and demonstration. It is therefore requested that permit be granted in the event the PI of the RENEW system recommend that the 10,000 gpd wastewater stream that is fed to the water reuse be diverted to the flushing line, onto the mesophilic digester, PS basin and finally to the spray-field.

As shown in Figure 1-1, the water reuse consists of polishing tanks I & II, clarifiesrs I & II, fuzzy and sand filters I & II, reverse osmosis, disinfection using ozone and chlorine, and storage for flow equalization. These components are described below.

8.1 Polishing Tank I

Aerated water with $CBOD_5$ and ammonia concentrations of 200 and 70 mg/L, respectively, will be fed from the aerobic digester to polishing tank I at the rate of 10,000 gpd (Figure 1-1). The key objective at this point in the treatment is to further reduce both carbonaceous and nitrogenous BOD. As shown in Table 8-1, the polished water is expected to reduce CBOD and NBOD by 75- and 71% respectively.

Table 8-1 Design parameters of polishing tank I: Nitrification

Line Item	Symbol	Units	Value
Characteristics of Wastewater			
Flowrate, influent from aerobic digester	Qd	gpd	10,000
BOD5 concentration in influent	BOD5	mg/L	200
Ammonia concentration in influent	Cnh3	mg/L	70
Oxygen demand to nitrogen ration			4.57
BOD5/BOD-ultimate			0.60
Effluent BOD5, proposed	BOD5	mg/L	50
Effluent ammonia concentration, proposed	VS	mg/l	20
Total oxygen demand	TOD	lb/d	40
Diffuser efficiency	Ed	%	25.00
Percent of oxygen in atmosphere		%	21.00
Density of air @ 70 F, 50% RH		lb/cu.ft.	0.074
Total volume of air needed		cfm	7
Oxygen demand met by fine-bubble aerator		cfm	7
Oxygen demand met by Air-Jammer		lb/day	0
Bower HP, calculated		HP	0.3
Aerobic digester volume per oxygen demand	V	gal	7,885
Aerobic digester volume per HRT	V	gal	10,000
Aerobic digester volume, actual	V	gal	10,000
Hydraulic retention, proposed	HRT	d	1
Hydraulic retention, actual	HRT	d	1.0
Suspended solids in effluent	TSS	mg/L	2,500

8.2 Clarifier I

Nitrified water from polishing tank I will be fed into clarifier I (Figure 1-1) at about 10,000 gpd. A flocculating agent, a mixture of a polyacrylamide polymer and ferric chloride will be injected inline to enhance coagulation. Zhang and Westerman (1997) found the combination to be effective for diluted swine manure with less than 0.5% TS. Although they found a combination of 700 mg/L of ferric chloride and 0.005% of the cationic polymer to be effective, the actual dosage to be used for the system proposed for the RENEW technologies will be determined by bench test. The pipe inline mixing will be designed to meet AWWA (1990) recommendation of velocity gradient of at least 800 per second per equation 8-1. Other water stream characteristics of the influent and effluent from clarifier I are given in Table 8-2.

$$G = \sqrt{\frac{P}{\mu \cdot V}} \qquad 8\text{-}1$$

where G = velocity gradient = 800 1/s, P = power dissipated = 1 hp per million gallons per day.

Design parameters of the clarifier are shown in Table 8-2.

Table 8-2 Design parameters of clarifier I

Line Item	Symbol	Units	Value
Characteristics of Wastewater			
Influent Flow Rate, total	Q	gpd	10,000
Concentration of TSS in influent	TSS	mg/L	2,500
Hydraulic concentration efficiency	Eh	%	20
Solid concentraion efficiency	Es	%	98
Flowrate, thickened sludge	Qs	gpd	2,000
Flowrate, supernatent	Qc	gpd	8,000
TSS concentraion in sludge water	Cs	mg/L	12,250
TSS concentration in supernatant	Cc	mg/L	63
Size of clarifier			
Concentrator tank volume	EQ	g	10,000
Hydraulic Retention Time	HRT	d	1.00

8.3 Polishing Tank II

Supernatant from the clarifier is fed to the second polishing tank at a daily flow rate of 8,000 gpd, and will consist of about 250 mg/L of nitrate and 50 mg/L BOD_5. The goal of the second-stage polishing is to accomplish denitrification. Carbon source necessary to accomplish denitrification will be supplied by methanol. About 48 lb of methanol will be required per day. Table 8-3 list characteristics of the influent and effluent streams of polishing tank II.

Table 8-3 Design parameters of polishing tank I: Nitrification

Line Item	Symbol	Units	Value
Characteristics of Wastewater			
Flowrate, influent from Clarifier no. 1	Qd	gpd	8,000
BOD5 concentration in influent	BOD5	mg/L	50
Ammonia concentration in influent	Cnh3	mg/L	20
Oxygen demand to nitrogen ration			4.57
BOD5/BOD-ultimate			0.60
Effluent BOD5, proposed	BOD5	mg/L	5
Effluent ammonia concentration, proposed	VS	mg/l	10
Total oxygen demand	TOD	lb/d	8
Diffuser efficiency	Ed	%	25.00
Percent of oxygen in atmosphere		%	21.00
Density of air @ 70 F, 50% RH		lb/cu.ft.	0.074
Total volume of air needed		cfm	1
Oxygen demand met by fine-bubble aerator		cfm	1
Oxygen demand met by Air-Jammer		lb/day	0
Bower HP, calculated		HP	0.1
Aerobic digester volume per oxygen demand	V	gal	1,512
Aerobic digester volume per HRT	V	gal	8,000
Aerobic digester volume, actual	V	gal	10,000
Hydraulic retention, proposed	HRT	d	1
Hydraulic retention, actual	HRT	d	1.3
Suspended solids in effluent	TSS	mg/L	5
Concentration of nitrate	NO3-N	mg/L	266
Total nitrogen to denitrify	NO3-N	lb/d	17.72
Methanol needed	CH4OH	lb/d	48.73

8.4 Clarifier II

Clarifier II is a cone-bottom tank that will be used for both water clarification and flow equalization for the filters downstream. The volume, influent and effluent characteristics of clarifier II are listed in Table 8-4.

Table 8-4 Design parameters of clarifier II

Line Item	Symbol	Units	Value
Characteristics of Wastewater			
Influent Flow Rate, total	Q	gpd	8,000
Concentration of TSS in influent	TSS	mg/L	1,500
Hydraulic concentration efficiency	Eh	%	10
Solid concentraion efficiency	Es	%	99
Flowrate, thickened sludge	Qs	gpd	800
Flowrate, supernatent	Qc	gpd	7,200
TSS concentraion in sludge water	Cs	mg/L	14,850
TSS concentration in supernatant	Cc	mg/L	17
Size of clarifier			
Concentrator tank volume	EQ	g	10,000
Hydraulic Retention Time	HRT	d	1.25

8.5 Filtration: Fuzzy Filter and Sand Filters 1&2

Supernatant from the secondary clarifier is filtered through a Fuzzy™ filter at flow rate within the AWWA (1990) recommendation of 2-10 gpm per filter surface area. The Fuzzy™ filter is used in front of the sand filters because it is easier to clean and can be adjusted to remove suspended solids ranging in size from 5- to 15-µm. The clean water stream will then flow through two sand filters per AWWA recommendation of 2-10 gpm. The Fuzzy™ and sand filters will remove particles larger than 5 µm, but will not remove dissolved salts.

Two sand filters will be used. They will piped such that both serial and parallel flow configurations will be developed and demonstrated. Both sand filters and the fuzzy filters are completely enclosed and watertight to allow filtration at pressures up to 20 psi. The filters are about 3.25 feet in diameter and 5 feet in height.

8.6 Reverse Osmosis

In order to remove particles smaller than 5µm along with dissolved salts including calcium, magnesium, sulfides, chlorides and other ions, the water is filtered through a reverse osmosis (RO) unit. The total dissolved solids in the RO influent will be less than 1,500 mg/L, and will be reduced by about 80%. Additional specifications on the RO unit are given in Attachment D.

8.7 Disinfection: Ozonation/Chlorination

After filtration, the water is disinfected using ozonation delivered at about 2 mg/L at a contact time of at least 20 minutes. The cleaned, disinfected water is then pumped into a 3,000-gallon equalization tank to be delivered into the existing fresh water lines of the farm. In other to maintain the effect of residual disinfection, the water is chlorinated at 3 mg/L prior to storage in the disinfection tank .

8.8 Flow Equalization

After purification, the clean water is stored in a 3000-gallon tank to provide flow equalization. Drinking water from the tank is fed into the existing drinking water system via a bladder pressurization system designed to maintain about 20 psi of line pressure.

The entire system will be controlled automatically using a PC-based automation. A Think-and-Do ™ software will be used to run the control interface consisting of digital and analog inputs and outputs. Real-time data access and control software will be installed to allow remote operation of the system.

REFERENCES

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4. Task Force on Water Quality (TFWQ) standards, 1998. Nutrient Requirements of Swine, 10th Edition, Sub-committee on Swine Nutrition, Committee on Animal Nutrition, Board of Agriculture, National Research Council.
5. Zhang, R. H. and P. W. 1997. Westerman. Solid-Liquid Separation of Animal Manure for Odor Control and Nutrient Management. Transactions of the ASAE. Vol. 13(3): 385-393.

ATTACHMENT A

PERMIT NO. AWI310082

ATTACHMENT B

EMERGENCY ACTION PLAN

ATTACHMENT C

ENGINEERING DRAWINGS

ATTACHMENT D

COMPONENT SPECIFICATIONS

D-1: MICRO-TURBINE GENERATOR SPECIFICATIONS

The Microturbine Generator Incorporates:

- **UL Listed Generator Set** – The complete generator set assembly is UL2200 listed.
- **Low Exhaust Emissions** – The Microturbine produces ultra low emissions. NOX is warranted to be less than 9 ppm (0.14 gm/hp-hr).
- **Low Sound Level** – 63 dBA @ 7 meters
- **One Moving Part.** No gears, belts or engine-driven accessories reduce service requirements.
- **Permanent Magnet Generator –** The generator rotor is part of the single rotating shaft.
- **Digital Power Conditioning.** Provides output choices for synchronous AC with built-in relay functions, optional standalone AC output.
- **Digital Control Technology.** Facilitates advanced control, monitoring, and diagnostic capabilities, both locally and remotely using an RS-232 link.
- **Integral Annular Recuperator** – Doubles thermal efficiency.
- **Internal Fuel Compression System** – Uses a digitally controlled, variable speed, rotary flow compressor that compresses and meters fuel gas to the Microturbine.
- **Air Flow Cooled Design** of the entire system, including engine and controller, eliminates the need for liquid coolants.
- **Maintenance-free Air Bearings** eliminate the need for oil or other lubricants.
- **Corrosion-resistant Aluminum Finish** – Reduced weather- and environment-related surface damage.

Microturbine Engine Specifications

The core of the Microturbine is the variable speed compressor-turbine section, which rotates between 45,000 and 96,000 rpm depending upon load. The engine is air-cooled and contains air bearings, which means there are no liquid coolants or lubricants to leak or require maintenance.

The Microturbine engine is equipped with an integral annular recuperator that increases the thermal efficiency of the generator set.

	Biogas Fuel
Genset Power Output	
Rated Output (+/- 1 kW)	28 Kw 35 kVA @ 0.8 pf
Thermal Efficiency (+/- 2%)	25%
Air Flow	
Combustion Air Flow, scfm (m3/min)	550 (16)
Maximum Inlet Air Restriction, in H2O (mm H2O)	0.5 (12.7)
Cooling Air Flow to Electronics (Grid), scfm (m3/min)	720 (20.4)
Cooling Air Flow to Electronics (Stand Alone), (m3/min)	970 (27.5)

Maximum Ambient Temperature, _F (_C)	122 (50)
Minimum Ambient Temperature, _F (_C)	-4 (-20)
Fuel	
Minimum Fuel Inlet Pressure, psi (kPA)	0.2 (1.4)
Fuel Consumption, Full Load Natural Gas HHV, BTU/hr (kJ/hr)	420,000 (440,000)
Exhaust	
Exhaust Temperature, _F (_C)	500 (260)
Exhaust Air Flow, scfm (m3/min)	575 (17)
Exhaust Energy, BTU/hr (kJ/hr)	290,000 (305,000)
Maximum Exhaust Restriction in H2O (mm)	8 (203)

<u>Specifications – Generator</u>

Design Permanent magnet variable speed

Stator Wound 3 phase

Rotor Permanent Magnet

Insulation System Class N

Exciter Type Permanent Magnet

Generator Cooling Cooled by airflow to impeller compressor

The Microturbine has an integrated permanent magnet alternator that delivers 3-phase variable frequency voltage to the power electronics.

The Power electronics portion of the generator set rectifies the variable frequency power to DC power at approximately 760 volts. The DC power is then converted to 3 phase 60 Hz AC power for the application loads.

<u>Available Output Voltages</u>

In the grid connect configuration, the output will follow the utility voltage as long as it is between

400 and 480 VAC.

Voltage	277/480
Rated Power kW (kVA @ 1.0 pf)	30 (30)
Rated Power kW (kVA @ 0.8 pf)	30 (37.5)
Motor Starting kVA	45
Rated Current, Amps	46
Maximum Current, Amps	54

Phase-to-Phase Imbalance

Power imbalance cannot exceed 20 kW between any two phases.

Single Phase Load

Single-phase loads can be applied that do not exceed the 20 kW imbalance between phases and current limit of 100 amps continuous or 110 amps maximum for 10 sec.

Power Factor

The Microturbine generator set can be operated at any power factor between 0 and 1.0. The only limitation is that the maximum current cannot exceed 100 amps per phase continuous or 54 amps for up to 10 seconds.

Microturbine Control System

The standard Microturbine is configured for connecting to the utility grid. The generator set is started using the utility grid to power the generator, which is used as the starter motor.

General Description

The low volume corrosion resistant blower will pressurize the biogas to approximately 30" water column pressure. The microturbine has a built in gas compressor to raise the pressure of the biogas stream to 55 psi which the turbine requires to operate efficiently.

The generator will operate continuously when adequate biogas is available. Upon sensing low-pressure supply of biogas, the microturbine generator will automatically cease and revert to stand-by until adequate gas in once again available to operate.

The hot vent gases from the microturbine engine will be divert through a serpentine coil mounted in the heat exchanger tank. The waste heat energy will be used to provide a portion of the required heat to maintain the desired operating temperature in the mesophilic digester.

The heat exchanger tank is constructed of carbon steel that is sand blasted and painted with epoxy paint. 200 gpm pump from wet well to HE.

ATTACHMENT E

POLISHING/ STORAGE BASIN DESIGN COMPUTATIONS

ATTACHMENT F

WASTE UTILIZATION PLAN