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Cost and Returns Analysis of Manure Management Systems Evaluated in 2005 under the North Carolina Attorney General Agreements with Smithfield Foods, Premium Standard Farms, and Front Line Farmers

TECHNOLOGY REPORT: SEQUENCING BATCH REACTOR (SBR)

Prepared as Part of the Full Economic Assessment of Alternative Swine Waste Management Systems Under the Agreement Between the North Carolina Attorney General and Smithfield Foods

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Summary of Results

Retrofit Cost per 1,000 pounds Steady State Live Weight per year: $221.43
Standardized Feeder-to-Finish Farm with 4,320 head (Tables SBR.28- SBR.36)
10-Year Amortization, Pit-Recharge, N limited Irrigation onto Forage

Includes:	Manure Evacuation:	$ 1.86 / 1,000 lbs. SSLW / Yr.
	Equalization Tank:	$ 38.32 / 1,000 lbs. SSLW / Yr.
	Primary Treatment Tank:	$167.77 / 1,000 lbs. SSLW / Yr.
	Operations Building:	$ 1.97 / 1,000 lbs. SSLW / Yr.
	Control System:	$ 14.30 / 1,000 lbs. SSLW / Yr.
	Return to Barns:	$ 1.29 / 1,000 lbs. SSLW / Yr.
	Decreased Land Application Cost:	$ -4.08 / 1,000 lbs. SSLW / Yr.

Range:	Across Farm Sizes and Types (Pit-Recharge):	$102.69 To 788.49 / 1,000 lbs. SSLW / Yr.
	Across Farm Sizes and Types (Flush):	$103.38 To 844.75 / 1,000 lbs. SSLW / Yr.

Confidence in Estimates:

Medium

Based on 8 months evaluation, real commercial setting data for treatment effects, electricity use, electricity prices, construction and operating expense

Costs by Category:

Direct Construction:	$116.37 / 1,000 lbs. SSLW / Yr.
Contractor Overhead	$ 39.34 / 1,000 lbs. SSLW / Yr.
Total Operating:	$ 69.80 / 1,000 lbs. SSLW / Yr.
Decreased Land Application Cost:	$ -4.08 / 1,000 lbs. SSLW / Yr.

Sensitivity Analysis

Effect of Expected Economic Life, Interest Rate, and Overhead Rate on Predicted Annualized Construction and Overhead Cost ($ / 1,000 lbs. SSLW)

Capital Recovery Factor (CRF)		Overhead Rate	
		20 %	43.1 %
Low-Cost Projection (15-year economic life, 6 % interest rate)	0.1030	$106.25	$120.82
Baseline Cost Projection (10-year economic life, 8 % interest rate)	0.1490	$134.63	**$155.71***
High-Cost Projection (7-year economic life, 10 % interest rate)	0.2054	$169.36	$198.42

* This predicted cost was estimated using the assumptions that are applied throughout the report—10-year economic life, 8 % interest rate, and 43.1 % overhead rate.

Effect of Electricity Price on Predicted Annual Operating Cost ($ / 1,000 lbs. SSLW)

Electricity Price ($ / kWh)	Predicted Annual Operating Cost ($ / 1,000 lbs. SSLW)
Low-Cost Electricity ($0.06 / kWh)	$57.08
Baseline Cost of Electricity ($0.08 / kWh)	**$69.80***
High-Cost Electricity ($0.10 / kWh)	$82.52

* This predicted cost was estimated using the assumption that is applied throughout the report--$0.08 / kWh.

The sensitivity of predicted costs and returns to a few critical assumptions is illustrated above by recalculating **annualized construction and overhead cost** with lower and higher values for amortization rate (cost recovery factor) and for overhead rate. The number in bold face, $155.71, is the actual predicted 2004 construction and overhead cost for the SBR technology on a 4,320 head feeder to finish farm with pit-recharge and nitrogen-limited land application to forage. Numbers are recalculated using two overhead rates: 20% and 43.1%, and three combinations of interest rate and maximum expected economic life: 15 year life and 6% interest rate, 10 year life and 8% interest rate, and 7 year life and 10% interest rate. The range of selected parameter values has a significant effect on the predicted value of annual construction and overhead costs.

Similarly, predicted **annual operating costs** of the SBR technology are recalculated using higher and lower prices for electricity. The 25% increase or decrease in electricity price has a significant effect (plus or minus $12.72 per 1,000 pounds SSLW per year) on the predicted annual cost reflecting significant electricity use by the aerator/mixer units.

Note that the sensitivity analysis is not intended to propose alternative costs and returns estimates. It is solely intended to illustrate the sensitivity of the results to changes in parameter values.

Break-even Analysis on By-product Prices

Breakeven analysis is conducted for systems that produce potentially marketable by-products in order to determine the by-product price required to cover the cost of the system. The SBR technology, as modeled and tested, has no marketable by-products. However, the technology providers have experimented with a mobile dewatering unit using the sludge removed from the primary treatment tank. In future generations of the SBR technology, there is the potential for a dewatered solids by-product (sludge cake).

The mobile dewatering system that was used to treat sludge from the SBR treatment tank was manufactured by Somat. Waste sludge exiting the SBR treatment tank (about 8,000 gallons per day) at 0.65% total solids content was decanted to a total solids content of 0.80% before entering the dewatering system as a feed sludge. Using a polymer at a rate of 21.2 lbs. of polymer / ton of dry solids, a sludge cake was produced with a total solids content of about 17%. Approximately 85% of all solids contained in the wasted sludge from the SBR tank were captured during the dewatering process. If the solids content of the feed sludge could be increased (from 0.80% to about 1.25%), it is likely that the solids capture rate for the Somat dewatering system would likewise increase (Eno).

The amount of sludge cake produced per day averaged 0.22 dry tons, or 440 dry pounds. Using an average of 8,000 gallons per day of wasted sludge from the SBR tank, the Somat dewatering system produced about 55 dry pounds of sludge cake per 1,000 gallons of wasted sludge. No break-even analysis was done for this by-product since the economics team received no cost data on the dewatering system and it was not included as part of the SBR system. It was assumed that wasted sludge was sent to the primary lagoon before being land applied along with the liquid effluent from the treatment tank.

1. Overview of the Sequencing Batch Reactor Technology

1.1. Farm Overview

The Sequencing Batch Reactor (SBR) wastewater treatment system proposed by Alternative Natural Technologies, Inc. (ANT) was evaluated on the R.C. Hunt Farm in Wilson, NC. This is a finishing farm containing 24 houses with a design capacity of 12,800 hogs. The SBR system constructed on RC Hunt Farm is designed to treat wastewater from six of these houses (4,200 hogs). Only half of the wastewater from these 6 barns was to be treated by the SBR technology (or waste from 2,100 hogs), with the remaining half of the wastewater to be sent to the existing primary lagoon. However, based on performance data, the SBR system treated 27,687 gallons / day of wastewater during its performance verification period—a total that is consistent with the predicted daily amount of wastewater produced by 3,568 hogs in a flush system house. Thus, it was assumed that the SBR technology treated the wastewater from 3,568 head of finishing hogs (481,680 pounds SSLW) during its performance verification at R.C. Hunt Farm.

Prior to the construction of the SBR technology, R.C. Hunt Farm's swine waste was being treated using two anaerobic lagoons. The dimensions of the primary lagoon, as measured at the top bank, are 800' x 280', while the secondary lagoon measures 330' x 310' at the top bank. Maximum lagoon depth is 15 feet and the side slope of the lagoon is 1/3.

All houses at R.C. Hunt Farm are naturally ventilated and incorporate open gutter flush systems for waste removal. Two flushing tanks per house are used and each tank has a liquid volume of 400 gallons. The flush frequency for the houses at R.C. Hunt Farm is approximately 5 flushes per day. Using this data, it is estimated that the total flush volume / per house / per day is 4,000 gallons at R.C. Hunt Farm (2 tanks / house * 400 gallons / tank * 5 flushes / day).

1.2. Technology Overview (As Proposed)

Waste from six of R.C. Hunt Farm's 24 houses was diverted to an equalization tank. This tank has a liquid volume of 81,660 gallons. Including the freeboard volume, the total volume of the equalization tank was 104,183 gallons. The equalization tank will remain in a full condition most of the time. Excess flow from the equalization tank will overflow to the head of the existing lagoon system in place at R.C. Hunt Farm. While in the equalization tank, two 7.5-HP floating mixers are used to keep the waste mixed and solids suspended. From the equalization tank, 40,380 gallons / day of waste will be pumped to the sequencing batch reactor (SBR) for treatment. A hydraulic retention time of 7 days was used in ANT's operating parameters to calculate the primary treatment tank's liquid volume of 285,810 gallons (40,830 gallons / day * 7 days). Including freeboard volume, the total volume of the SBR tank is 363,074 gallons. Also in the operating parameters given by the technology providers, biological solids are stated to have a retention time of 30 days (solids retention time). Given this parameter, 9,527 gallons / day of sludge are designed to be removed from the SBR tank (285,810 gallons of liquid volume / 30 days). All effluent and sludge that was removed from the SBR was discharged into R.C. Hunt Farm's existing lagoon treatment system.

Incoming flow (40,830 gallons / day) was added to the existing biomass in the SBR tank. Intermittent aeration is used to cycle between aerobic and anoxic conditions in the SBR tank, while continuous mixing occurs during the aeration process. Four aerator/mixer combination units were used in the SBR primary treatment tank—each floating aerator had a HP of 7.5, while each mixer had a HP of 30. Although four aerator/mixer units were included in the primary tank design, only two were used at any given time (with the remaining two being available as backup if needed). A fixed daily amount of sludge (9,527 gallons) was removed from the SBR and returned to the existing lagoon. Upon completion of the cyclic aeration process, all mixers and blowers are turned off allowing sedimentation/clarification to occur. After this settling stage is completed, the clear, treated water from near the SBR tank's surface can be pumped out. This effluent is pumped out of the SBR tank before gravity flowing through a meter and sampling box to the existing primary lagoon at R.C. Hunt Farm. At other sites, it is assumed that effluent from the SBR would be recycled as flushing/pit-recharge liquid.

To summarize, the five steps that occur in every 24-hour cycle for the SBR technology are: 1.) waste (solids are discharged while under complete mix conditions); 2.) settle (aerators and mixers are turned off, allowing solids to fall to the bottom of the tank); 3.) decant (clear water from the surface is pumped from the tank); 4.) fill (influent from the equalization tank is added to the primary treatment tank); 5.) react (a cycle of aeration and non-aeration (for an hour each) to promote nitrification and denitrification).

2. Mass Balances and Performance Data at R.C. Hunt Farm (As Operated)

The SBR primary treatment tank was designed based on a COD loading rate of 2,040 lbs. COD / day. Performance verification testing began on January 20, 2004, after technology start-up that lasted from October 28, 2003 to January 14, 2004. Samples were taken through the end of August, 2004. COD levels were kept constant (based on the system's design and optimization strategy) from January through the end of July. Beginning in August, the COD loading rate was deliberately increased in order to test the performance of the technology at higher loading levels. Hydraulic retention time (HRT), though stated as 7 days, was generally higher than this from January through the end of July. As loading rates increased starting in August, 2004, the HRT approached its stated parameter of 7 days. Average flow rates during normal loading (from January through July) were about 26,000 gallons / day. During the period of increased loading (August), flow rates rose to about 39,000 gallons / day. Solids retention time (SRT) was generally between 25-30 days during the period of normal loading. During August, SRT fell below 25 days due to the intentional overloading of the system (Classen and Liehr).

Tables SBR.1-SBR.3 show the actual flow rates and performance data for the SBR system. This technology was tested using two different treatment cycles. For the first cycle, the primary treatment tank was loaded once per day, followed by a 24-hour cycle of aeration/non-aeration. The second treatment cycle loaded the primary tank twice per day, and followed each loading with a 12-hour cycle of aeration/non-aeration.

Table 1 compares the flow rates for each of the two treatment cycles. Flow rates are higher for samples with 2-12 hour cycles because that timeframe includes the month of August when loading rates were intentionally increased. Higher loading rates resulted in decreased HRT and increased SRT, as seen in Table SBR.1. Tables SBR.2 and SBR.3 report influent and clarified liquid effluent levels for COD, TKN, and P for each of the two treatment cycles. For the 1-24 hour cycle, COD is reduced by 75.98%, TKN is reduced by 80.41%, and P is reduced by 33.42% as a result of treatment in the SBR primary tank. Reductions of 80.13% (COD), 71.58% (TKN), and 44.37% (P) are associated with the SBR technology using the 2-12 hour treatment cycle (Classen). The thickened liquid effluent containing settled solids had concentrations of nutrients that were the following percentages of the influent: COD (84%), TKN (47%), and P (128%).

3. Electricity Costs at R.C. Hunt Farm

Table SBR.4 lists the monthly electricity costs that were associated with operating the SBR technology at R.C. Hunt Farm. These costs were provided by Cavanaugh and Associates and are based on actual invoices. Monthly power bills were available from December, 2003 to September, 2004, which covers the entire duration of the SBR's performance verification. Electricity costs per month ranged from $1,618.25 to $4,512.68, with an average of $2,743.61. Kilowatt-hours of electricity consumed per month ranged from 12,720 to 47,560, with an average of 28,606. See Appendix A for an additional comment regarding actual electricity costs at R.C. Hunt Farm.

4. Costs of the SBR Technology as Constructed at R.C. Hunt Farm Demonstrational Facility

4.1. Invoiced Construction Costs at R.C. Hunt Farm (Tables SBR.5-SBR.8)

Reported cost estimates (Tables SBR.5-SBR.8) were based on cost invoices provided by Cavanaugh and Associates. The invoiced costs for the SBR technology as constructed at R.C. Hunt were separated into unit processes by Cavanaugh. Table SBR.5 reports the costs associated with the equalization tank. Primary treatment tank construction costs are reported in Table SBR.6. Table SBR.7 reports miscellaneous costs associated with the construction of the SBR technology at R.C. Hunt Farm. Finally, Table SBR.8 summarizes the invoiced construction costs for the SBR system. Total invoiced cost of the SBR technology as constructed at R.C. Hunt Farm was $461,544 (Table SBR.8). The primary treatment tank accounted for the majority of this total invoiced cost, with a unit process cost of $257,267 (see Table SBR.6), or 55.7% of the SBR system's total invoiced construction cost.

4.2. Modified Construction Costs at R.C. Hunt Farm (Tables SBR.9-SBR.10)

Tables SBR.9 and SBR.10 describe cost modifications that were made to the invoiced costs listed in Tables SBR.5-SBR.8. These modifications were made in order to remove research-related or unnecessary expenses from the technology's invoiced costs. Determining which, if any, costs to modify was based on the discretion of the economics team after meetings with the technology providers. Table SBR.9 lists the costs that were modified as well as the reason for the change. In Table SBR.10, a revised invoiced cost summary is shown. The total modified invoiced costs for the SBR technology decreased to $441,596; a $19,948 reduction (~ 4%) from the total reported in Table SBR.8.

5. Cost Modeling (Tables SBR.11-SBR.54)

5.1. Introduction

Original invoice costs were reported detailing the construction costs of the SBR technology as it was built on the R.C. Hunt Farm. These costs are reported by unit process in Tables SBR.5-SBR.7 and summarized in Table SBR.8. Modified construction costs were also determined based on meetings between the technology providers and the economic modeling team. The modified costs are reported in Table SBR.9 and total modified construction costs are summarized in Table SBR.10. In the next step, the economic modeling team examined the data reported in Tables SBR.5-SBR.8 for missing components and outdated prices. The resulting complete estimate of construction cost is intended to approximate adjusted invoiced cost that can be compared to those for other technologies analyzed under the Agreement. These approximated invoiced costs are summarized in Tables SBR.13-SBR.21. In the next step, estimates of costs that would occur on standard (representative) North Carolina farms were calculated. Necessary modeling assumptions used in the cost standardization process are described in Section 5.2 and in Tables SBR.11-SBR.12. These costs are presented in Tables SBR.22-SBR.30 for a 4,320-head feeder-to-finish facility using a flush system of manure removal. Tables SBR.31-SBR.39 present the costs associated with a standard North Carolina feeder-to-finish operation with a head capacity of 4,320 using a pit-recharge system of waste removal. A representative NC 8,800-head feeder-to-finish facility with a flush system for manure removal is reported in Tables SBR.40-SBR.48. The final standard NC farm described in these cost tables is a 4,000-sow farrow-to-wean operation using a flush system of manure removal (Tables SBR.49-SBR.57).

5.2. Standardized Modeling Assumptions (Tables SBR.11-SBR.12)

Both the equalization and primary treatment tanks used in the SBR technology were fabricated by Sollenberger Silos Corporation. These tanks were pre-cast, post-tensioned circular structures that were constructed using a series of concrete wall panels. Each panel had a width of about 7.5 feet, and the largest tanks that Sollenberger can fabricate contain 40 panels. For some farm size/farm type combinations, primary treatment tank volumes were larger than the treatment volume of one 40-panel tank. In these cases, multiple Sollenberger tanks were constructed in the standardized economic models.

Table SBR.11 lists some of the modeling assumptions that were used to calculate tank sizes. Both the equalization tank and primary treatment tank are 12 feet deep, including a 2-foot freeboard. The equalization tank was modeled to hold two days of discharged manure volume from the houses. The volume of the primary treatment tank was based on COD loading rates, and the retention time of influent in the tank will vary based on type of farm and type of manure evacuation system (pit-recharge or flush). Table SBR.12 lists the tank volumes for each representative farm size/farm type combination. These volumes are based on design equations provided by the technology providers. Once a tank volume is determined for a given farm size/farm type, the radius of the tank is calculated using the tank treatment depth of 10 feet (12 feet of depth minus 2 feet of freeboard). From this calculated radius, a circumference can be determined. Then, using a per panel width of 7.54 feet, the number of panels needed can be calculated. If the calculated number of panels is greater than 40, the standardized model will construct multiple tanks.

An example of a calculation to determine the number of panels follows:

1.) Assume: 4,320-head feeder-finish with pit-recharge
2.) For this size and type of farm, 3,225 lbs. / day of COD are predicted
3.) A treatment volume of 425,415 gallons (or 56,866 cubic feet) is necessary to treat this amount of COD—total tank volume, including freeboard, is equal to 510,498 gallons (68,239 cubic feet)
4.) Tank radius = sqrt(tank volume/(pi * (tank depth – freeboard)))
= sqrt(56,866/(pi * (12-2))) = 42.55 feet
5.) Tank circumference = 2 * pi * 42.55 = 267.32 feet
6.) Number of panels (rounded up) = 267.32 feet / 7.54 feet = 36 panels

The cost of each tank (equalization and primary treatment) in the standardized model is then calculated on the basis of dollars per panel, using the invoiced construction cost data from R.C. Hunt Farm.

Also listed in Table SBR.11 are the design equations for mixing horsepower in the equalization tank and aeration horsepower in the primary treatment tank. For every 10,000 gallons of equalization tank volume, an additional unit of mixing horsepower is required. That is, one 5-HP mixer is required for every 50,000 gallons of equalization tank volume. For the primary treatment tank, an additional unit of horsepower is required for every 36 pounds of COD loaded. For the 4,320-head example above, three 30-HP aerators are needed (a total of 90 HP) to treat the 3,225 pounds of COD loaded daily. The mixer(s) in the equalization tank will operate 24 hours per day, while the aerator(s) in the primary treatment tank will operate 11 hours per day. All design equations and parameters in this paragraph are based on communication with the technology providers.

Both sludge effluent and liquid effluent from the primary treatment tank are sent to the existing primary lagoon in the standardized models. After liquid is returned to the barns, the excess treated manure is land applied using the liquid application model (see Appendix B in the Combined Appendices Report). There is no land application of solids or subsequent solids treatment in the standardized model, although the technology providers experimented with the previously-described Somat dewatering system at R.C. Hunt Farm.

5.3. Estimated Adjusted Invoice Costs for SBR Technology at R.C. Hunt Farm (Tables SBR.13-SBR.20)

Table SBR.13 lists the assumptions (3,568-head finishing facility with flush system) for the cost estimate calculation and also summarizes annualized costs by land application scenario (nitrogen-based application to forages, nitrogen-based application to row crops, phosphorus-based application to forages, and phosphorus-based application to row crops).[1] Annualized costs for the whole farm and per 1,000 lbs. of SSLW (incremental cost) are reported. Table SBR.13 presents incremental costs for each of the four land application scenarios range from $287.01 (phosphorus-based application to forages) to $289.29 (nitrogen-based application to forages). Nitrogen-based application is more costly than phosphorus-based application with the SBR technology. Tables SBR.14-SBR.18 summarize costs associated with individual unit processes of the SBR technology. Costs are reported for the following unit processes: manure evacuation (SBR.14), equalization tank (SBR.15), primary treatment tank (SBR.16), operations building (SBR.17), and control system (SBR.18). Table SBR.18 also reports the total costs associated with the unit processes listed above. Total construction costs are predicted as $561,360, while annual operating costs are estimated as $39,206. The total annualized cost of the SBR technology before land application is estimated to be $141,874 for the 3,568-head feeder-to-finish facility at R.C. Hunt Farm. Table SBR.19 (lagoon effluent) reports land application costs associated with the SBR technology. Used in conjunction with the numbers reported at the end of Table SBR.18, the total annualized and incremental cost estimates are calculated and reported in Table SBR.13 for each of the four scenarios of land application. Table SBR.20 details the mass balance of nutrients associated with the SBR technology. The mass balance estimates are used to derive costs in Table SBR.19.

[1] For more on land application, see Appendix B in the Combined Appendices Report.

5.4. Standardized Costs for SBR Technology at a 4,320-Head Feeder-to-Finish Farm with Flush System (Tables SBR.21-SBR.29)

Tables SBR.21- SBR.29 provide estimates of the cost of constructing and operating the SBR technology on a standard (representative) North Carolina farm. The representative farm reported in this section is a 4,320-head feeder-to-finish facility using a flush system for waste removal. Table SBR.21 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for retrofitting the farm with standardized SBR technology. The standardized incremental costs range from $222.34 (phosphorus-based application to forages) to $227.25 (nitrogen-based application to forages), with an average incremental cost of $224.43 per 1,000 lbs. SSLW per year across the four land application scenarios. In the standardized SBR model (as in the model estimating actual SBR costs), nitrogen-based land application is more costly than phosphorus-based land application. Tables SBR.22-SBR.26 like Tables SBR.14-SBR.18 report standardized costs for the unit processes listed in the above section (in the same order). Within certain unit processes (e.g., manure evacuation), there are differences in individual components between the actual and standardized models. In these cases, the technology as it was constructed at R.C. Hunt Farm was not indicative of how it would be constructed on a representative NC farm. Table SBR.27 reports the costs of a return to barns unit process and summarizes the predicted total costs associated with the standardized SBR technology for a 4,320-head finishing facility with a flush system. Total construction costs are estimated at $530,880, while total annual operating costs are predicted as $41,147. Total annualized costs before land application are estimated at $134,908 for this representative farm size and type. Table SBR.28 (lagoon effluent) summarizes the land application costs predicted for this model for each of four scenarios. Table SBR.29 provides an estimated mass balance of nutrients for this representative NC farm size and type.

5.5. Standardized Costs for SBR Technology at a 4,320-Head Feeder-to-Finish Farm with Pit-Recharge System (Tables SBR.30-SBR.38)

Tables SBR.30- SBR.38 provide estimates of the cost of constructing and operating the SBR technology on a standard (representative) North Carolina 4,320-head feeder-to-finish facility using a pit-recharge system for manure removal. The only difference between the standard farm chosen to calculate the numbers in Tables SBR.30-SBR.38 versus the one chosen to estimate the numbers in Tables SBR.21-SBR.29 is the type of manure removal system used. Table SBR.30 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for the standardized SBR technology. The standardized incremental costs of retrofitting the farm with the SBR system range from $216.52 (phosphorus-based application to forages) to $221.43 (nitrogen-based application to forages), with an average incremental cost across the four scenarios of $218.62 per 1,000 lbs. SSLW per year. Nitrogen-based applications are more costly than phosphorus-based applications. The use of the pit-recharge system of manure removal decreases average incremental cost estimates by about 2.6% for a 4,320-head finishing facility as compared to using a flush system on the same facility. Tables SBR.31-SBR.36 list the costs of individual unit processes in this standardized model. The set of unit processes and components are identical to those in Tables SBR.22-SBR.27, while some of the costs change between the two sets of tables. Table SBR.36 also summarizes the total costs associated with the standardized SBR technology for a 4,320-head finishing facility with a pit-recharge system. Total construction costs are estimated at $511,093, while total annual operating costs are reported as $40,706. Total annualized costs before land application are estimated at $131,518 for this representative farm size and type. Table SBR.37 (lagoon effluent) summarizes the land application costs associated with this standardized model for each of four scenarios. Table SBR.38 provides an estimated mass balance of nutrients for the representative farm modeled in these tables.

5.6. Standardized Costs for SBR Technology at an 8,800-Head Feeder-to-Finish Farm (Tables SBR.39-SBR.47)

Tables SBR.39- SBR.47 provide estimates of the cost of constructing and operating the SBR technology on a standard (representative) North Carolina 8,800-head feeder-to-finish facility using a flush system for manure removal. Table SBR.39 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for retrofitting a farm with the standardized SBR technology. The standardized incremental costs for the 8,800-head finishing facility range from $217.76 (phosphorus-based application to forages) to $221.16 (nitrogen-based application to forages), with an average incremental cost of $219.64 per 1,000 lbs. SSLW per year across the four scenarios. This average incremental cost is about 2% less than that of a standardized 4,320-head finishing facility with a pit-recharge system. Based on this finding, the model suggests that very minimal economies of scale are present for the SBR technology when moving from one medium-sized farm to another. The next sections show that more significant economies of scale are predicted when moving from small farms to large farms (or, to a lesser degree, small farms to medium farms). Tables SBR.40-SBR.45 list the costs of individual unit processes in this standardized model. The set of unit processes and components are identical to those in Tables SBR.22-SBR.27 and SBR.31-SBR.36 although some of the costs change between the sets of tables. Table SBR.45 also summarizes the total costs associated with the standardized SBR technology for an 8,800-head finishing facility. Total construction costs are estimated at $1,001,631, while total operating costs are reported as $90,138. Total annualized costs before land application are estimated at $270,363 for this representative farm size and type. While these total construction costs are higher than in the standardized 4,320-head model, the costs per unit are slightly lower. That is because the 8,800-head facility contains 1,188,000 pounds of steady-state live weight (SSLW) as compared to the 583,200 pounds of SSLW housed in the 4,320-head facility. Table SS.46 (lagoon effluent) summarizes the land application costs associated with this standardized model for each of four scenarios. Table SBR.47 provides predicted mass balance of nutrients for the representative farm modeled here.

5.7. Standardized Costs for SBR Technology at a 4,000-Sow Farrow-to-Wean Farm (Tables SBR.48-SBR.56)

Tables SBR.48- SBR.56 provide estimates of the cost of constructing and operating the SBR technology on a standard (representative) North Carolina 4,000-sow farrow-to-wean operation using a flush system for manure removal. This representative farm contains 1,732,000 pounds of SSLW: the largest of any standard farm modeled for the SBR technology. Table SBR.48 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for the standardized SBR technology. The standardized incremental costs range from $120.55 (phosphorus-based application to forages) to $125.10 (nitrogen-based application to forages), with an average incremental cost of $123.36 per 1,000 lbs. SSLW per year across the four scenarios of land application. Nitrogen-based applications were modeled to be more costly than phosphorus-based applications. Tables SBR.49-SBR.54 provide details of the costs of individual unit processes in this standardized model. Table SBR.54 also summarizes the total costs of the standardized SBR technology for a 4,000-sow farrow-to-wean operation. Total construction costs are estimated at $839,260, while total annual operating costs are reported as $77,384. Total annualized costs before land application are estimated at $226,850 for this representative farm size and type. Although SSLW at this facility is greater than at the standard 8,800-head finishing farm (1,732,000 lbs. SSLW vs. 1,188,000 lbs. SSLW), the total annualized construction costs are lower ($226,850 vs. $270,363). This is a result of differences in COD production rates across farm types, and the corresponding differences in tank sizes for the SBR technology. Table SBR.55 (lagoon effluent) summarizes the land application costs associated with this standardized model for each of four scenarios. Table SBR.56 provides an estimated mass balance of nutrients for the 4,000-sow farrow-to-wean operation modeled for the SBR technology.

5.8. Extrapolation to Other Farm Types and Sizes (Tables SBR.57-SBR.58)

Table SBR.57 summarizes the per unit incremental costs ($ / 1,000 lbs. SSLW) of retrofitting the SBR technology onto each of the 25 size of farm / type of operation combinations. This table uses the representative farm size for a permitted North Carolina farm within a size / type combination. Incremental costs are shown for both pit-recharge and flush systems and Table SBR.57's costs assume nitrogen-based land application to forages. Table SBR.58 is analogous to Table SBR.57, but uses representative farm sizes for Smithfield Foods/Premium Standard Farms (SF/PSF) owned farms only. Incremental costs are again shown for both pit-recharge and flush systems. As in Table SBR.57, the costs in Table SBR.58 assume that a nitrogen-based land application to forages is chosen. Tables SBR.57 and SBR.58 illustrate that predicted incremental costs decrease as the size of the farm increases. These economies of scale are present across all five types of operations, and are the most significant when moving from the smallest size category (0-500,000 lbs. SSLW) to the next smallest size category (500,000-1,000,000 lbs. SSLW). Within their farm size categories, wean-to-feeder operations are clearly the most expensive types of farms on which to construct and operate the SBR technology (on a $ / 1,000 lbs. SSLW / year basis). It is also apparent in Tables SBR.57 and SBR.58 that retrofits of farms with flush systems of manure removal are predicted to be more costly than those with pit-recharge systems for any size of farm/type of operation category.

6. Summary

The sequencing batch reactor (SBR) technology was installed on the R.C. Hunt farm and treated an average of 27,687 gallons per day of effluent from six open-gutter flush finishing barns. Performance evaluation occurred between January 20 and September 2, 2004. Two operating protocols were evaluated; a 24-hour cycle and a 12-hour cycle twice per day. The cycles each consist of periods of aeration and mixing and periods of no aeration and settling in the primary SBR tank. An average of 7,374 gallons per day of thickened liquid (containing settled solids) and 20,313 gallons per day of clarified liquid were drawn from the SBR tank after treatment. The primary treatment tank had a liquid volume of 285,810 gallons. Two 7.5-HP aerators and two 30-HP mixers were used at a time to mix and aerate the SBR primary treatment tank during the aeration phase of the cycle. Both liquids were pumped from the SBR to an existing lagoon at the farm. A device to dewater the solids in the thickened liquid was tested at the site but not included in the evaluation. The SBR treatment was effective at reducing COD, TKN, and P concentrations in the clarified liquid. The initial investment predicted for installation of the SBR system on a standardized 4,320-head finishing farm is $511,093. The annual operating costs for the system are predicted at $40,706 and total annualized cost of the system is predicted at $221.43 per 1,000 pounds Steady State Live Weight per year over a 10-year amortization period. A considerable range of predicted costs ($103 to $845 per 1,000 pounds SSLW per year) occurs across different sizes and types of farms reflecting economies of size and scale in construction of the system and reflecting differences in COD loading per 1,000 pounds SSLW across different types of farms.

References

Cavanaugh and Associates. Data provided and/or personal communication with Jason Wilson. September-December, 2004.

Classen, John J. and Sarah K. Liehr. "Alternative Natural Technologies Sequencing Batch Reactor Performance Verification." April, 2005

Eno, Steve. "Somat Dewatering Pilot Test Report." April, 2005.

Goldsmith, C. Douglas. President. Alternative Natural Technolgies, Inc. Personal Communication. September, 2004- March, 2005.

Tables SBR.1 through SBR.3: Flow Rates, Mass Balances, and Performance Data for the SBR Technology as Operated at R.C. Hunt Farm

Table SBR.1. Flow Rates and Retention Times for the SBR Technology (Classen)

	All Samples	1-24 Hour Cycle	2-12 Hour Cycles
# of samples	41	26	15
Range of sampling dates (mm/dd/yy)	01/22/04-09/02/04	01/22/04-06/24/04	06/29/04-09/02/04
Average biosolids removed (wasted) per day (gpd)	7,374	7,593	6,994
Average clarified liquid effluent removed per day (gpd)	20,313	17,335	25,475
Total volume treated per day (gpd)	27,687	24,928	32,469
Hydraulic retention time (days)	10	11	8
Solids retention time (days)	26.8	23	28

Table SBR.2. SBR Technology Performance Data[1]: 1-24 Hour Treatment Cycle Per Day (Classen)

COD influent	8,471 mg / L
COD clarified liquid effluent	2,035 mg / L
Reduction in COD	75.98 %
TKN influent	955 mg / L
TKN clarified liquid effluent	187 mg / L
Reduction in TKN	80.41 %
P influent	121 mg / L
P clarified liquid effluent	80 mg / L
Reduction in P	33.42 %

1. Based on the average of 30 samples taken between the dates of 1/20/04 and 6/24/04

Table SBR.3. SBR Technology Performance Data[1]: 2-12 Hour Treatment Cycles Per Day (Classen)

COD influent	6,576 mg / L
COD clarified liquid effluent	1,307 mg / L
Reduction in COD	80.13 %
TKN influent	772 mg / L
TKN clarified liquid effluent	219 mg / L
Reduction in TKN	71.58 %
P influent	125 mg / L
P clarified liquid effluent	69 mg / L
Reduction in P	44.37 %

1. Based on the average of 15 samples taken between the dates of 6/29/04 and 9/2/04

Table SBR.4: Actual Electricity Costs of the SBR Technology as Operated at R.C. Hunt Farm

Table SBR.4. Actual Electricity Costs of the SBR Technology as Operated at R.C. Hunt Farm (Cavanaugh)

Month	Kilowatt-Hours	Electricity Cost
December '03	46,440	$4,386.53*
January '04	47,560	$4,512.68*
February '04	21,980	$2,238.89
March '04	21,500	$2,195.47
April '04	23,840	$2,301.39
May '04	26,840	$2,493.90
June '04	25,900	$2,413.33
July '04	28,220	$2,534.81
August '04	31,060	$2,740.82
September '04	12,720	$1,618.25
Averages	**28,606**	**$2,743.61**

* See Appendix A

Tables SBR.5 through SBR.8: Invoiced Construction Costs at R.C. Hunt Farm

Table SBR.5. Invoiced Construction Costs of SBR Equalization Tank (Cavanaugh)

Component	Cost
81,660-gallon concrete tank	$22,284.28
Excavation and subgrade	$3,950.67
Subdrain	$2,472.10
2 7.5-HP mixers and float assemblies	$10,900.00
Pumps	$7,925.00
Electrical (labor and materials)	$7,494.38
Plumbing (labor and materials)	$2,565.89
Concrete, pump, rebar and labor	$6,631.11
57 stone	$2,243.75
Miscellaneous parts (wire ropes and clips, turn buckles, etc.)	$267.96
Control panel	$5,713.00
Precast meter boxes and manholes	$654.72
Sand	$17.62
Rip rap	$37.58
ABC stone	$214.57
Construction staking	$111.05
Total Cost of Equalization Tank	**$73,483.68**

Table SBR.6. Invoiced Construction Costs of SBR Primary Treatment Tank (Cavanaugh)

Component	Cost
285,810-gallon concrete tank	$77,994.97
Excavation and subgrade	$13,827.33
Subdrain	$8,652.35
4 30-HP aerators and float assemblies	$62,100.00
Pumps	$7,925.00
Electrical (labor and materials)	$26,230.31
Plumbing (labor and materials)	$8,960.61
Concrete, pump, rebar and labor	$23,208.89
57 stone	$7,853.16
Miscellaneous parts (wire ropes and clips, turn buckles, etc.)	$938.33
Control panel and soft-start addition	$13,673.00
Control platform (labor and materials)	$1,156.63
Precast meter boxes and manholes	$2,293.13
Sand	$61.71
Rip rap	$131.62
ABC stone	$751.51
Construction staking	$388.95
Total Cost of Primary Treatment Tank	**$257,267.50**

Table SBR.7. Invoiced Miscellaneous Construction Costs of SBR Technology (Cavanuagh)

Component	Cost
Waste evacuation modifications (gravity lines and piping)	$26,667.00
Operations building	$4,815.00
Control system	$40,000.00
3-phase installation to site	$10,000.00
Construction bond	$7,142.00
ANT consulting fees and miscellaneous expenses	$22,168.68
Mullen & Company consulting fees	$20,000.00
Total Miscellaneous Costs	**$130,792.68**

Table SBR.8. Summary of Invoiced Construction Costs for the SBR Technology (Cavanaugh)

Unit Process	Cost	% of Total Cost
Waste evacuation modifications	$26,667.00	5.78 %
Equalization tank	$73,483.68	15.92 %
Primary treatment tank	$257,267.50	55.74 %
Operations building	$4,815.00	1.04 %
Control system	$40,000.00	8.67 %
3-phase installation to site	$10,000.00	2.17 %
Construction bond	$7,142.00	1.55 %
Consulting fees	$42,168.68	9.13 %
Total Invoiced Cost of SBR Technology	**$461,543.86**	**100.00 %**

Table SBR.9 through SBR.10: Modified Invoiced Construction Costs for the SBR Technology as Constructed at R.C. Hunt Farm

Table SBR.9. Summary of Modified Costs for the SBR Technology

Unit Process	System Component	Invoiced Cost	Modified Cost	Reason for Modification
Equalization tank	Concrete, pump, rebar, and labor	$6,631.11	$5,631.11	Invoiced cost includes research-related vaults
Primary treatment tank	Concrete, pump, rebar, and labor	$23,208.89	$22,208.89	Invoiced cost includes research-related vaults
Equalization tank	Precast meter boxes and manholes	$654.72	$0.00	Entire cost research-related
Primary treatment tank	Precast meter boxes and manholes	$2,293.13	$0.00	Entire cost research-related
Control system	Control system	$40,000.00	$25,000.00	Could be installed at a lower cost without research-related components

Table SBR.10. Summary of Modified Invoiced Construction Costs for the SBR Technology

Unit Process	Cost	% of Total Cost
Waste evacuation modifications	$26,667.00	6.04 %
Equalization tank	$71,828.96	16.27 %
Primary treatment tank	$253,974.37	57.51 %
Operations building	$4,815.00	1.09 %
Control system	$25,000.00	5.66 %
3-phase installation to site	$10,000.00	2.26 %
Construction bond	$7,142.00	1.62 %
Consulting fees	$42,168.68	9.55 %
Total Modified Cost of SBR Technology	**$441,596.01**	**100.00 %**

Tables SBR.11 through SBR.12: Modeling and Tank Size Assumptions for Standardized Cost Models

Table SBR.11. Modeling and Operating Assumptions for Standardized Cost Models

Equalization tank volume (maximum of 2 days retention time)	modeled to hold 2 days of flush volume from the houses
Equalization tank depth (including freeboard)	12 feet
Equalization tank freeboard	2 feet
Equalization tank mixing horsepower	1 HP per 10,000 gallons of volume
Equalization tank mixing time	24 hours / day
Primary treatment tank retention time	based on COD loading amounts (see Table SBR.12)
Primary treatment tank depth (including freeboard)	12 feet
Primary treatment tank freeboard	2 feet
Primary treatment tank aerating horsepower	1 HP per 36 pounds of COD loaded
Primary treatment tank aerating time	11 hours / day

Table SBR.12. Predicted COD Amounts and Corresponding Tank Volumes for Smithfield Foods/Premium Standard Farms Representative Farm Type / Farm Size Combinations—SBR Technology

	Farm Size (1,000 pounds SSLW)				
	0-500	**500-1000**	**1000-1500**	**1500-2000**	**> 2000**
Farm Type					
Farrow-wean					
Rep. # of sows	650	1,700	2,400	4,000	7,000
COD (lbs. / day)	636	1,664	2,349	3,915	6,851
Tank volume (gallons)	96,046	251,196	354,629	591,048	1,034,335
Farrow-feeder					
Rep. # of sows	675	1,200	2,000	3,419	5,500
COD (lbs. / day)	1,140	2,026	3,377	5,774	9,288
Tank volume (gallons)	172,103	305,963	509,939	871,739	1,402,329
Farrow-finish					
Rep. # of sows	N/A	500	1,000	1,200	2,000
COD (lbs. / day)	N/A	2,888	5,777	6,932	11,553
Tank volume (gallons)	N/A	436,086	872,171	1,046,606	1,744,342
Wean-feeder					
Rep. head capacity	2,808	N/A	N/A	N/A	N/A
COD (lbs. / day)	688	N/A	N/A	N/A	N/A
Tank volume (gallons)	103,805	N/A	N/A	N/A	N/A
Feeder-finish					
Rep. head capacity	1,240	5,100	8,800	12,246	17,136
COD (lbs. / day)	845	3,475	5,996	8,343	11,675
Tank volume (gallons)	127,554	524,619	905,224	1,259,702	1,762,720

Tables SBR.13 through SBR.20: Costs and Returns Estimates Based on Actual Cost and Performance Data for SBR On-Farm System: 3,568-Head Feeder to Finish Operation with Flush System

Table SBR.13. SBR Technology Assumptions and Total Annualized Costs—Actual Costs and Performance Data

Number of Animals	**3,568**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Flush**				
Annualized Cost ($ / Year)					
Total Annualized Cost			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**139,346.91**	**$**	**138,827.87**
	If Phosphorus-Based Application	**$**	**138,247.71**	**$**	**138,530.44**
Per Unit Cost ($ / 1,000 lbs. of SSLW)					
Total Annualized Cost per Unit			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**289.29**	**$**	**288.22**
	If Phosphorus-Based Application	**$**	**287.01**	**$**	**287.60**

Note: Daily volume discharged from barns is 27,687 gallons / day including recharge liquid.
SSLW equals 481,680 pounds.

Table SBR.14. SBR Technology Manure Evacuation Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Gravity Lines and Piping	$ 26,667.00	$ 3,974.17
Contractor & Engineering Services & Overhead	$ 11,493.48	$ 1,712.87
Total Construction Cost	$ 38,160.48	$ 5,687.04
Maintenance Cost		$ 533.34
Property Taxes		$ 135.47
Total Operating Costs		$ 668.81
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 6,355.85**

Table SBR.15. SBR Technology Equalization Tank Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Sollenberger Tank (81,660 gallons)	$ 22,284.28	$ 3,321.01
Excavation and Subgrade	$ 3,950.67	$ 588.77
Sub Drain	$ 2,472.10	$ 368.42
2 7.5-HP Mixers and Float Assemblies	$ 10,900.00	$ 3,927.80
Pumps	$ 7,925.00	$ 2,855.76
Electrical (labor and materials)	$ 7,494.38	$ 1,116.88
Plumbing (flow meters, valves, fittings, misc.)	$ 2,565.89	$ 382.39
Concrete, Pump, Rebar, and Labor	$ 5,631.11	$ 839.20
57 Stone	$ 2,243.75	$ 334.38
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 267.96	$ 39.93
Motor Control Panel and Shipping	$ 5,713.00	$ 851.41
ABC Stone, Rip Rap, and Sand	$ 269.77	$ 40.20
Construction Staking	$ 111.05	$ 16.55
Contractor & Engineering Services & Overhead	$ 30,958.28	$ 4,613.70
Total Construction Cost	$ 102,787.24	$ 19,296.41
Electric Power Cost		$ 8,494.25
Maintenance Cost		$ 2,001.33
Property Taxes		$ 364.89
Total Operating Cost		$ 10,860.48
TOTAL ANNUALIZED COST OF EQUALIZATION TANK		**$ 30,156.89**

Table SBR.16. SBR Technology Primary Treatment Tank Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Sollenberger Tank (285,810 gallons)	$ 77,994.97	$ 11,623.55
Excavation and Subgrade	$ 13,827.33	$ 2,060.68
Sub Drain	$ 8,652.35	$ 1,289.46
4 30-HP Aerators and Float Assemblies	$ 63,200.00	$ 22,774.03
Pumps	$ 7,925.00	$ 2,855.76
Electrical (labor and materials)	$ 26,230.31	$ 3,909.09
Plumbing (flow meters, valves, fittings, misc.)	$ 8,980.61	$ 1,338.31
Concrete, Pump, Rebar, and Labor	$ 22,208.89	$ 3,309.78
57 Stone	$ 7,853.16	$ 1,170.35
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 938.33	$ 139.84
Motor Control Panel and Soft-Start Addition	$ 13,673.00	$ 2,037.68
Pressure-Treated Control Platform (labor and materials)	$ 1,156.63	$ 172.37
ABC Stone, Rip Rap, and Sand	$ 944.84	$ 140.81
Construction Staking	$ 388.95	$ 57.97
Contractor & Engineering Services & Overhead	$ 109,462.95	$ 16,313.21
Total Construction Cost	$ 363,437.32	$ 69,192.95
Electric Power Cost		$ 18,175.21
Maintenance Cost		$ 7,213.24
Property Taxes		$ 1,290.20
Total Operating Cost		$ 26,678.65
TOTAL ANNUALIZED COST OF PRIMARY TREATMENT TANK		**$ 95,871.59**

Table SBR.17. SBR Technology Operations Building Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Building	$ 4,815.00	$ 717.58
Contractor & Engineering Services & Overhead	$ 2,075.27	$ 309.28
Total Construction Cost	$ 6,890.27	$ 1,026.85
Maintenance Cost		$ 96.30
Property Taxes		$ 24.46
Total Operating Cost		$ 120.76
TOTAL ANNUALIZED COST OF OPERATIONS BUILDING		**$ 1,147.61**

Table SBR.18. SBR Technology Control System Costs—Actual Costs and Performance Data

Component		Total Cost		Annualized Cost
Control System	$	25,000.00	$	3,725.74
3-Phase Installation	$	10,000.00	$	1,490.29
Contractor & Engineering Services & Overhead	$	15,085.00	$	2,248.11
Total Construction Cost	$	50,085.00	$	7,464.14
Maintenance Cost			$	700.00
Property Taxes			$	177.80
Total Operating Cost			$	877.80
TOTAL ANNUALIZED COST OF CONTROL SYSTEM			**$**	**8,341.94**

TOTAL CONSTRUCTION COST OF SBR TECHNOLOGY	**$**	**561,360.31**
TOTAL OPERATING COST OF SBR TECHNOLOGY	**$**	**39,206.49**
TOTAL ANNUALIZED COSTS OF SBR TECHNOLOGY WITHOUT LAND APPLICATION	**$**	**141,873.88**

Table SBR.19. SBR Technology Predicted Liquid Application Costs for Four Land Application Scenarios—Actual Costs and Performance Data

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	9,835.59	$	6,876.35
If Phosphorus-Based Application	$	11,483.68	$	7,484.12
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		19.93		64.59
If Phosphorus-Based Application		37.29		101.93
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,195.70		-
If Phosphorus-Based Application	$	2,237.27		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	8,639.90	$	8,261.60
If Phosphorus-Based Application	$	7,784.96	$	9,618.44
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(1,385.25)
If Phosphorus-Based Application		-	$	(2,134.32)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	1,461.45		-

Note: 3,685,303 gallons / year of effluent land applied at R.C. Hunt Farm

Table SBR.20. Summary and Mass Balance of Generated and Land Applied Nutrients—Actual Costs and Performance Data

Nutrient Balance	Nitrogen (lbs/ year)	Phosphorus (lbs / year)	Potassium* (lbs / year)
Generated At Barn	72,216.32	20,694.40	35,501.60
Removed in Primary Treatment Tank	57,513.08	6,992.64	-
Applied to Land in Lagoon Effluent	11,570.38	1,846.34	21,694.45
Nutrients Unaccounted for	3,132.87	11,855.43	13,807.15

* No data on percentage of potassium removed in SBR primary treatment tank

Tables SBR.21 through SBR.29: Costs and Returns Estimates Based on Standardized Cost and Performance Data for SBR Technology: 4,320-Head Feeder to Finish Operation with Flush System

Table SBR.21. SBR Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Number of Animals	**4,320**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Flush**				
Annualized Cost ($ / Year)					
Total Annualized Cost			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**132,530.40**	**$**	**131,026.95**
	If Phosphorus-Based Application	**$**	**129,666.29**	**$**	**130,328.94**
Per Unit Cost ($ / 1,000 lbs. of SSLW)					
Total Annualized Cost per Unit			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**227.25**	**$**	**224.67**
	If Phosphorus-Based Application	**$**	**222.34**	**$**	**223.47**

Note: Daily volume discharged from barns is 33,505 gallons / day including recharge liquid.
SSLW equals 583,200 pounds.

Table SBR.22. SBR Technology Manure Evacuation Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component	Total Cost	Annualized Cost
Gravity Lines and Piping	$ 9,110.00	$ 1,357.66
Contractor & Engineering Services & Overhead	$ 3,926.41	$ 585.15
Total Construction Cost	$ 13,036.41	$ 1,942.81
Maintenance Cost		$ 182.20
Property Taxes		$ 46.28
Total Operating Costs		$ 228.48
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 2,171.29**

Table SBR.23. SBR Technology Equalization Tank Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component	Total Cost	Annualized Cost
Sollenberger Tank	$ 32,699.76	$ 4,873.23
Excavation and Subgrade	$ 1,566.35	$ 233.43
Sub Drain	$ 1,590.04	$ 236.96
Mixers and Float Assemblies	$ 5,450.00	$ 1,963.90
Pumps	$ 7,925.00	$ 2,855.76
Electrical (labor and materials)	$ 4,820.33	$ 718.37
Plumbing (flow meters, valves, fittings, misc.)	$ 1,650.36	$ 245.95
Concrete, Pump, Rebar, and Labor	$ 4,267.27	$ 635.95
57 Stone	$ 1,443.16	$ 215.07
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 172.35	$ 25.69
Motor Control Panel and Shipping	$ 5,713.00	$ 851.41
ABC Stone, Rip Rap, and Sand	$ 173.51	$ 25.86
Contractor & Engineering Services & Overhead	$ 29,080.05	$ 4,333.79
Total Construction Cost	$ 96,551.18	$ 17,215.36
Electric Power Cost		$ 4,702.12
Maintenance Cost		$ 1,750.67
Property Taxes		$ 342.76
Total Operating Cost		$ 6,795.55
TOTAL ANNUALIZED COST OF EQUALIZATION TANK		**$ 24,010.91**

Table SBR.24. SBR Technology Primary Treatment Tank Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component	Total Cost	Annualized Cost
Sollenberger Tank	$ 78,479.41	$ 11,695.75
Excavation and Subgrade	$ 7,743.67	$ 1,154.03
Sub Drain	$ 10,379.82	$ 1,546.90
Aerators and Float Assemblies	$ 47,400.00	$ 17,080.52
Pumps	$ 7,925.00	$ 2,855.76
Electrical (labor and materials)	$ 31,467.28	$ 4,689.55
Plumbing (flow meters, valves, fittings, misc.)	$ 10,773.62	$ 1,605.59
Concrete, Pump, Rebar, and Labor	$ 32,050.83	$ 4,776.52
57 Stone	$ 9,380.55	$ 1,397.98
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 1,125.67	$ 167.76
Motor Control Panel and Soft-Start Addition	$ 13,673.00	$ 2,037.68
Pressure-Treated Control Platform (labor and materials)	$ 1,156.63	$ 172.37
ABC Stone, Rip Rap, and Sand	$ 1,133.48	$ 168.92
Contractor & Engineering Services & Overhead	$ 108,908.94	$ 16,230.64
Total Construction Cost	$ 361,597.90	$ 65,579.98
Electric Power Cost		$ 24,866.13
Maintenance Cost		$ 6,713.53
Property Taxes		$ 1,283.67
Total Operating Cost		$ 32,863.34
TOTAL ANNUALIZED COST OF PRIMARY TREATMENT TANK		**$ 98,443.31**

Table SBR.25. SBR Technology Operations Building Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component	Total Cost	Annualized Cost
Building	$ 4,815.00	$ 717.58
Contractor & Engineering Services & Overhead	$ 2,075.27	$ 309.28
Total Construction Cost	$ 6,890.27	$ 1,026.85
Maintenance Cost		$ 96.30
Property Taxes		$ 24.46
Total Operating Cost		$ 120.76
TOTAL ANNUALIZED COST OF OPERATIONS BUILDING		**$ 1,147.61**

Table SBR.26. SBR Technology Control System Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component		Total Cost		Annualized Cost
Control System	$	25,000.00	$	3,725.74
3-Phase Installation	$	10,000.00	$	1,490.29
Contractor & Engineering Services & Overhead	$	15,085.00	$	2,248.11
Total Construction Cost	$	50,085.00	$	7,464.14
Maintenance Cost			$	700.00
Property Taxes			$	177.80
Total Operating Cost			$	877.80
TOTAL ANNUALIZED COST OF CONTROL SYSTEM			**$**	**8,341.94**

Table SBR.27. SBR Technology Return to Barns Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component		Total Cost		Annualized Cost
Plumbing/Piping	$	1,300.00	$	193.74
Pumps	$	600.00	$	216.21
Contractor & Engineering Services & Overhead	$	818.90	$	122.04
Total Construction Cost	$	2,718.90	$	531.99
Electric Power Cost			$	195.23
Maintenance Cost			$	56.00
Property Tax			$	9.65
Total Operating Cost			$	260.88
TOTAL ANNUALIZED COST OF RETURN TO BARNS			**$**	**792.87**

TOTAL CONSTRUCTION COST OF SBR TECHNOLOGY	**$**	**530,879.66**
TOTAL OPERATING COST OF SBR TECHNOLOGY	**$**	**41,146.81**
TOTAL ANNUALIZED COSTS OF SBR TECHNOLOGY WITHOUT LAND APPLICATION	**$**	**134,907.94**

Table SBR.28. SBR Technology Predicted Liquid Application Costs for Four Land Application Scenarios— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	11,165.64	$	7,089.53
If Phosphorus-Based Application	$	11,843.44	$	7,535.98
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		16.26		52.69
If Phosphorus-Based Application		34.50		94.30
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	975.45		-
If Phosphorus-Based Application	$	2,069.76		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	10,190.19	$	8,231.56
If Phosphorus-Based Application	$	8,238.24	$	9,472.06
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(1,142.02)
If Phosphorus-Based Application		-	$	(1,936.08)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	1,535.45		-

Note: 4,446,995 gallons / year of effluent modeled to be land applied

Table SBR.29. Summary and Mass Balance of Generated and Land Applied Nutrients— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Nutrient Balance	**Nitrogen (lbs/ year)**	**Phosphorus (lbs / year)**	**Potassium* (lbs / year)**
Generated At Barn	87,436.80	25,056.00	42,984.00
Removed in Primary Treatment Tank	70,307.93	8,373.72	-
Applied to Land in Lagoon Effluent	9,439.06	1,708.09	11,139.72
Nutrients Unaccounted for	7,689.81	14,974.19	31,844.28

* No data on percentage of potassium removed in SBR primary treatment tank

Tables SBR.30 through SBR.38: Costs and Returns Estimates Based on Standardized Cost and Performance Data for SBR Technology: 4,320-Head Feeder to Finish Operation with Pit-Recharge System

Table SBR.30. SBR Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Number of Animals	**4,320**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Pit-Recharge**				
Annualized Cost ($ / Year)					
Total Annualized Cost			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**129,140.40**	**$**	**127,636.95**
	If Phosphorus-Based Application	**$**	**126,276.29**	**$**	**126,938.94**
Per Unit Cost ($ / 1,000 lbs. of SSLW)					
Total Annualized Cost per Unit			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**221.43**	**$**	**218.86**
	If Phosphorus-Based Application	**$**	**216.52**	**$**	**217.66**

Note: Daily volume discharged from barns is 28,361 gallons / day including recharge liquid.
SSLW equals 583,200 pounds.

Table SBR.31. SBR Technology Manure Evacuation Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Gravity Lines and Piping	$ 4,550.00	$ 678.83
Contractor & Engineering Services & Overhead	$ 1,963.21	$ 292.58
Total Construction Cost	$ 6,518.21	$ 971.40
Maintenance Cost		$ 91.10
Property Taxes		$ 23.14
Total Operating Costs		$ 114.24
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 1,085.64**

Table SBR.32. SBR Technology Equalization Tank Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Sollenberger Tank	$ 28,339.79	$ 4,223.46
Excavation and Subgrade	$ 1,374.81	$ 204.89
Sub Drain	$ 1,345.93	$ 200.58
Mixers and Float Assemblies	$ 5,450.00	$ 1,963.90
Pumps	$ 7,925.00	$ 2,855.76
Electrical (labor and materials)	$ 4,080.29	$ 608.08
Plumbing (flow meters, valves, fittings, misc.)	$ 1,396.99	$ 208.19
Concrete, Pump, Rebar, and Labor	$ 3,480.93	$ 518.76
57 Stone	$ 1,221.60	$ 182.05
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 145.89	$ 21.74
Motor Control Panel and Shipping	$ 5,713.00	$ 851.41
ABC Stone, Rip Rap, and Sand	$ 146.88	$ 21.89
Contractor & Engineering Services & Overhead	$ 26,127.69	$ 3,893.80
Total Construction Cost	$ 86,748.79	$ 15,754.52
Electric Power Cost		$ 4,670.62
Maintenance Cost		$ 1,613.67
Property Taxes		$ 307.96
Total Operating Cost		$ 6,592.25
TOTAL ANNUALIZED COST OF EQUALIZATION TANK		**$ 22,346.77**

Table SBR.33. SBR Technology Primary Treatment Tank Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Sollenberger Tank	$ 78,479.41	$ 11,695.75
Excavation and Subgrade	$ 7,580.24	$ 1,129.68
Sub Drain	$ 10,137.99	$ 1,510.86
Aerators and Float Assemblies	$ 47,400.00	$ 17,080.52
Pumps	$ 7,925.00	$ 2,855.76
Electrical (labor and materials)	$ 30,734.16	$ 4,580.30
Plumbing (flow meters, valves, fittings, misc.)	$ 10,522.62	$ 1,568.15
Concrete, Pump, Rebar, and Labor	$ 31,289.61	$ 4,663.07
57 Stone	$ 9,162.01	$ 1,365.41
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 1,099.44	$ 163.85
Motor Control Panel and Soft-Start Addition	$ 13,673.00	$ 2,037.68
Pressure-Treated Control Platform (labor and materials)	$ 1,156.63	$ 172.37
ABC Stone, Rip Rap, and Sand	$ 1,107.07	$ 164.99
Contractor & Engineering Services & Overhead	$ 107,865.15	$ 16,075.09
Total Construction Cost	$ 358,132.33	$ 65,063.51
Electric Power Cost		$ 24,845.74
Maintenance Cost		$ 6,655.09
Property Taxes		$ 1,271.37
Total Operating Cost		$ 32,782.20
TOTAL ANNUALIZED COST OF PRIMARY TREATMENT TANK		**$ 97,845.71**

Table SBR.34. SBR Technology Operations Building Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Building	$ 4,815.00	$ 717.58
Contractor & Engineering Services & Overhead	$ 2,075.27	$ 309.28
Total Construction Cost	$ 6,890.27	$ 1,026.85
Maintenance Cost		$ 96.30
Property Taxes		$ 24.46
Total Operating Cost		$ 120.76
TOTAL ANNUALIZED COST OF OPERATIONS BUILDING		**$ 1,147.61**

Table SBR.35. SBR Technology Control System Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Control System	$ 25,000.00	$ 3,725.74
3-Phase Installation	$ 10,000.00	$ 1,490.29
Contractor & Engineering Services & Overhead	$ 15,085.00	$ 2,248.11
Total Construction Cost	$ 50,085.00	$ 7,464.14
Maintenance Cost		$ 700.00
Property Taxes		$ 177.80
Total Operating Cost		$ 877.80
TOTAL ANNUALIZED COST OF CONTROL SYSTEM		**$ 8,341.94**

Table SBR.36. SBR Technology Return to Barns Costs— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Plumbing/Piping	$ 1,300.00	$ 193.74
Pumps	$ 600.00	$ 216.21
Contractor & Engineering Services & Overhead	$ 818.90	$ 122.04
Total Construction Cost	$ 2,718.90	$ 531.99
Electric Power Cost		$ 152.62
Maintenance Cost		$ 56.00
Property Tax		$ 9.65
Total Operating Cost		$ 218.27
TOTAL ANNUALIZED COST OF RETURN TO BARNS		**$ 750.26**

TOTAL CONSTRUCTION COST OF SBR TECHNOLOGY	**$ 511,093.49**
TOTAL OPERATING COST OF SBR TECHNOLOGY	**$ 40,705.53**
TOTAL ANNUALIZED COSTS OF SBR TECHNOLOGY WITHOUT LAND APPLICATION	**$ 131,517.94**

Table SBR.37. SBR Technology Predicted Liquid Application Costs for Four Land Application Scenarios— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	11,165.64	$	7,089.53
If Phosphorus-Based Application	$	11,843.44	$	7,535.98
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		16.26		52.69
If Phosphorus-Based Application		34.50		94.30
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	975.45		-
If Phosphorus-Based Application	$	2,069.76		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	10,190.19	$	8,231.56
If Phosphorus-Based Application	$	8,238.24	$	9,472.06
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(1,142.02)
If Phosphorus-Based Application		-	$	(1,936.08)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	1,535.45		-

Note: 4,446,995 gallons / year of effluent modeled to be land applied

Table SBR.38. Summary and Mass Balance of Generated and Land Applied Nutrients— Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Nutrient Balance	**Nitrogen (lbs/ year)**	**Phosphorus (lbs / year)**	**Potassium* (lbs / year)**
Generated At Barn	87,436.80	25,056.00	42,984.00
Removed in Primary Treatment Tank	70,307.93	8,373.72	-
Applied to Land in Lagoon Effluent	9,439.06	1,708.09	11,139.72
Nutrients Unaccounted for	7,689.81	14,974.19	31,844.28

* No data on percentage of potassium removed in SBR primary treatment tank

Tables SBR.39 through SBR.47: Costs and Returns Estimates Based on Standardized Cost and Performance Data for SBR Technology: 8,800-Head Feeder to Finish Operation with Flush System

Table SBR.39. SBR Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Number of Animals	**8,800**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Flush**				
Annualized Cost ($ / Year)					
Total Annualized Cost			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**262,734.35**	**$**	**261,614.29**
	If Phosphorus-Based Application	**$**	**258,700.66**	**$**	**260,686.07**
Per Unit Cost ($ / 1,000 lbs. of SSLW)					
Total Annualized Cost per Unit			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**221.16**	**$**	**220.21**
	If Phosphorus-Based Application	**$**	**217.76**	**$**	**219.43**

Note: Daily volume discharged from barns is 68,251 gallons / day including recharge liquid.
SSLW equals 1,188,000 pounds.

Table SBR.40. SBR Technology Manure Evacuation Costs— Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Component	Total Cost	Annualized Cost
Gravity Lines and Piping	$ 18,220.00	$ 2,715.32
Contractor & Engineering Services & Overhead	$ 7,852.82	$ 1,170.30
Total Construction Cost	$ 26,072.82	$ 3,885.62
Maintenance Cost		$ 364.40
Property Taxes		$ 92.56
Total Operating Costs		$ 456.96
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 4,342.58**

Table SBR.41. SBR Technology Equalization Tank Costs— Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Component	Total Cost	Annualized Cost
Sollenberger Tank	$ 45,779.66	$ 6,822.52
Excavation and Subgrade	$ 2,801.41	$ 417.49
Sub Drain	$ 3,238.96	$ 482.70
Mixers and Float Assemblies	$ 10,900.00	$ 3,927.80
Pumps	$ 7,925.00	$ 2,855.76
Electrical (labor and materials)	$ 9,819.18	$ 1,463.35
Plumbing (flow meters, valves, fittings, misc.)	$ 3,361.84	$ 501.01
Concrete, Pump, Rebar, and Labor	$ 9,545.67	$ 1,422.59
57 Stone	$ 2,939.77	$ 438.11
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 351.08	$ 52.32
Motor Control Panel and Shipping	$ 5,713.00	$ 851.41
ABC Stone, Rip Rap, and Sand	$ 353.45	$ 52.68
Contractor & Engineering Services & Overhead	$ 44,276.21	$ 6,598.46
Total Construction Cost	$ 147,005.25	$ 25,886.20
Electric Power Cost		$ 9,411.84
Maintenance Cost		$ 2,619.33
Property Taxes		$ 521.87
Total Operating Cost		$ 12,553.03
TOTAL ANNUALIZED COST OF EQUALIZATION TANK		**$ 38,439.23**

Table SBR.42. SBR Technology Primary Treatment Tank Costs— Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Component	Total Cost	Annualized Cost
Sollenberger Tank	$ 161,318.79	$ 24,041.26
Excavation and Subgrade	$ 15,746.88	$ 2,346.75
Sub Drain	$ 21,144.08	$ 3,151.09
Aerators and Float Assemblies	$ 110,600.00	$ 39,854.55
Pumps	$ 15,850.00	$ 5,711.52
Electrical (labor and materials)	$ 64,100.01	$ 9,552.79
Plumbing (flow meters, valves, fittings, misc.)	$ 21,946.26	$ 3,270.64
Concrete, Pump, Rebar, and Labor	$ 66,311.65	$ 9,882.39
57 Stone	$ 19,108.54	$ 2,847.74
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 2,293.03	$ 341.73
Motor Control Panel and Soft-Start Addition	$ 27,346.00	$ 4,075.36
Pressure-Treated Control Platform (labor and materials)	$ 2,313.26	$ 344.74
ABC Stone, Rip Rap, and Sand	$ 2,308.94	$ 344.10
Contractor & Engineering Services & Overhead	$ 228,596.99	$ 34,067.69
Total Construction Cost	$ 758,984.43	$ 139,832.36
Electric Power Cost		$ 57,981.61
Maintenance Cost		$ 14,401.25
Property Taxes		$ 2,694.39
Total Operating Cost		$ 75,077.26
TOTAL ANNUALIZED COST OF PRIMARY TREATMENT TANK		**$ 214,909.61**

Table SBR.43. SBR Technology Operations Building Costs— Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Component	Total Cost	Annualized Cost
Building	$ 4,815.00	$ 717.58
Contractor & Engineering Services & Overhead	$ 2,075.27	$ 309.28
Total Construction Cost	$ 6,890.27	$ 1,026.85
Maintenance Cost		$ 96.30
Property Taxes		$ 24.46
Total Operating Cost		$ 120.76
TOTAL ANNUALIZED COST OF OPERATIONS BUILDING		**$ 1,147.61**

Table SBR.44. SBR Technology Control System Costs— Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Component		Total Cost		Annualized Cost
Control System	$	30,000.00	$	4,470.88
3-Phase Installation	$	10,000.00	$	1,490.29
Contractor & Engineering Services & Overhead	$	17,240.00	$	2,569.27
Total Construction Cost	$	57,240.00	$	8,530.45
Maintenance Cost			$	800.00
Property Taxes			$	203.20
Total Operating Cost			$	1,003.20
TOTAL ANNUALIZED COST OF CONTROL SYSTEM			**$**	**9,533.65**

Table SBR.45. SBR Technology Return to Barns Costs— Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Component		Total Cost		Annualized Cost
Plumbing/Piping	$	2,600.00	$	387.48
Pumps	$	1,200.00	$	432.32
Contractor & Engineering Services & Overhead	$	1,637.80	$	244.08
Total Construction Cost	$	5,437.80	$	1,063.98
Electric Power Cost			$	795.37
Maintenance Cost			$	112.00
Property Tax			$	19.30
Total Operating Cost			$	926.68
TOTAL ANNUALIZED COST OF RETURN TO BARNS			**$**	**1,990.65**

TOTAL CONSTRUCTION COST OF SBR TECHNOLOGY	**$**	**1,001,630.56**
TOTAL OPERATING COST OF SBR TECHNOLOGY	**$**	**90,137.89**
TOTAL ANNUALIZED COSTS OF SBR TECHNOLOGY WITHOUT LAND APPLICATION	**$**	**270,363.34**

Table SBR.46. SBR Technology Predicted Liquid Application Costs for Four Land Application Scenarios— Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	12,941.37	$	8,460.98
If Phosphorus-Based Application	$	17,175.37	$	10,100.09
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		32.82		106.36
If Phosphorus-Based Application		69.64		190.35
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,969.09		-
If Phosphorus-Based Application	$	4,178.12		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	10,972.28	$	10,766.32
If Phosphorus-Based Application	$	9,897.71	$	14,008.37
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(2,305.35)
If Phosphorus-Based Application		-	$	(3,908.28)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	3,099.53		-

Note: 8,976,943 gallons / year of effluent modeled to be land applied

Table SBR.47. Summary and Mass Balance of Generated and Land Applied Nutrients— Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Nutrient Balance	**Nitrogen (lbs/ year)**	**Phosphorus (lbs / year)**	**Potassium* (lbs / year)**
Generated At Barn	178,112.00	51,040.00	87,560.00
Removed in Primary Treatment Tank	143,219.86	17,057.57	-
Applied to Land in Lagoon Effluent	19,054.19	3,448.04	22,487.24
Nutrients Unaccounted for	15,837.95	30,534.39	65,072.76

* No data on percentage of potassium removed in SBR primary treatment tank

Tables SBR.48 through SBR.56: Costs and Returns Estimates Based on Standardized Cost and Performance Data for SBR Technology: 4,000-Sow Farrow to Wean Operation with Flush System

Table SBR.48. SBR Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Number of Animals	**4,000**				
Type of Operation	**Farrow-Wean**				
Barn Cleaning System	**Flush**				
Annualized Cost ($ / Year)					
Total Annualized Cost			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**216,667.30**	**$**	**215,479.80**
	If Phosphorus-Based Application	**$**	**208,792.38**	**$**	**213,692.86**
Per Unit Cost ($ / 1,000 lbs. of SSLW)					
Total Annualized Cost per Unit			Forages		Row Crops
	If Nitrogen-Based Application	**$**	**125.10**	**$**	**124.41**
	If Phosphorus-Based Application	**$**	**120.55**	**$**	**123.38**

Note: Daily volume discharged from barns is 158,582 gallons / day including recharge liquid.
SSLW equals 1,732,000 pounds

Table SBR.49. SBR Technology Manure Evacuation Costs— Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Component	Total Cost	Annualized Cost
Gravity Lines and Piping	$ 12,754.00	$ 1,900.72
Contractor & Engineering Services & Overhead	$ 5,496.97	$ 819.21
Total Construction Cost	$ 18,250.97	$ 2,719.93
Maintenance Cost		$ 255.08
Property Taxes		$ 64.79
Total Operating Costs		$ 319.87
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 3,039.80**

Table SBR.50. SBR Technology Equalization Tank Costs— Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Component	Total Cost	Annualized Cost
Sollenberger Tank	$ 67,579.49	$ 10,071.34
Excavation and Subgrade	$ 5,823.64	$ 867.89
Sub Drain	$ 7,525.80	$ 1,121.57
Mixers and Float Assemblies	$ 27,250.00	$ 9,819.50
Pumps	$ 7,925.00	$ 2,855.76
Electrical (labor and materials)	$ 22,815.11	$ 3,400.12
Plumbing (flow meters, valves, fittings, misc.)	$ 7,811.33	$ 1,164.12
Concrete, Pump, Rebar, and Labor	$ 23,161.70	$ 3,451.78
57 Stone	$ 6,830.64	$ 1,017.97
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 815.75	$ 121.57
Motor Control Panel and Shipping	$ 5,713.00	$ 851.41
ABC Stone, Rip Rap, and Sand	$ 821.26	$ 122.39
Contractor & Engineering Services & Overhead	$ 79,335.34	$ 11,823.31
Total Construction Cost	$ 263,408.07	$ 46,688.72
Electric Power Cost		$ 23,455.84
Maintenance Cost		$ 4,736.70
Property Taxes		$ 935.10
Total Operating Cost		$ 29,127.64
TOTAL ANNUALIZED COST OF EQUALIZATION TANK		**$ 75,816.36**

Table SBR.51. SBR Technology Primary Treatment Tank Costs— Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Component	Total Cost	Annualized Cost
Sollenberger Tank	$ 117,719.12	$ 17,543.62
Excavation and Subgrade	$ 9,032.90	$ 1,346.17
Sub Drain	$ 11,337.41	$ 1,689.61
Aerators and Float Assemblies	$ 63,200.00	$ 22,774.03
Pumps	$ 15,850.00	$ 5,711.52
Electrical (labor and materials)	$ 34,370.29	$ 5,122.19
Plumbing (flow meters, valves, fittings, misc.)	$ 11,767.54	$ 1,753.71
Concrete, Pump, Rebar, and Labor	$ 35,393.28	$ 5,274.64
57 Stone	$ 10,245.96	$ 1,526.95
Miscellaneous Parts (wire rope/clips, turnbuckles, etc.)	$ 1,229.52	$ 183.23
Motor Control Panel and Soft-Start Addition	$ 27,346.00	$ 4,075.36
Pressure-Treated Control Platform (labor and materials)	$ 2,313.26	$ 344.74
ABC Stone, Rip Rap, and Sand	$ 1,238.05	$ 184.51
Contractor & Engineering Services & Overhead	$ 146,989.67	$ 21,905.80
Total Construction Cost	$ 488,033.00	$ 89,436.08
Electric Power Cost		$ 33,606.56
Maintenance Cost		$ 9,192.37
Property Taxes		$ 1,732.52
Total Operating Cost		$ 44,531.44
TOTAL ANNUALIZED COST OF PRIMARY TREATMENT TANK		**$ 133,967.52**

Table SBR.52. SBR Technology Operations Building Costs— Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Component	Total Cost	Annualized Cost
Building	$ 4,815.00	$ 717.58
Contractor & Engineering Services & Overhead	$ 2,075.27	$ 309.28
Total Construction Cost	$ 6,890.27	$ 1,026.85
Maintenance Cost		$ 96.30
Property Taxes		$ 24.46
Total Operating Cost		$ 120.76
TOTAL ANNUALIZED COST OF OPERATIONS BUILDING		**$ 1,147.61**

Table SBR.53. SBR Technology Control System Costs— Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Component	Total Cost		Annualized Cost	
Control System	$	30,000.00	$	4,470.88
3-Phase Installation	$	10,000.00	$	1,490.29
Contractor & Engineering Services & Overhead	$	17,240.00	$	2,569.27
Total Construction Cost	$	57,240.00	$	8,530.45
Maintenance Cost			$	800.00
Property Taxes			$	203.20
Total Operating Cost			$	1,003.20
TOTAL ANNUALIZED COST OF CONTROL SYSTEM			**$**	**9,533.65**

Table SBR.54. SBR Technology Return to Barns Costs— Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Component	Total Cost		Annualized Cost	
Plumbing/Piping	$	2,600.00	$	387.48
Pumps	$	1,200.00	$	432.32
Contractor & Engineering Services & Overhead	$	1,637.80	$	244.08
Total Construction Cost	$	5,437.80	$	1,063.98
Electric Power Cost			$	2,150.04
Maintenance Cost			$	112.00
Property Tax			$	19.30
Total Operating Cost			$	2,281.35
TOTAL ANNUALIZED COST OF RETURN TO BARNS			**$**	**3,345.32**

TOTAL CONSTRUCTION COST OF SBR TECHNOLOGY	**$**	**839,260.11**
TOTAL OPERATING COST OF SBR TECHNOLOGY	**$**	**77,384.26**
TOTAL ANNUALIZED COSTS OF SBR TECHNOLOGY WITHOUT LAND APPLICATION	**$**	**226,850.27**

Table SBR.55. SBR Technology Predicted Liquid Application Costs for Four Land Application Scenarios— Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Annual Cost of Applying Lagoon Effluent	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 14,344.14	$ 9,193.16
If Phosphorus-Based Application	$ 21,394.73	$ 12,012.41
Acres Needed For Assimilation	**Forages**	**Row Crops**
If Nitrogen-Based Application	39.48	127.95
If Phosphorus-Based Application	94.61	258.62
Opportunity Cost of Land	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 2,368.62	-
If Phosphorus-Based Application	$ 5,676.44	-
Irrigation Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 11,975.52	$ 11,998.04
If Phosphorus-Based Application	$ 11,077.03	$ 17,232.12
Savings From Not Having To Buy Fertilizer	**Forages**	**Row Crops**
If Nitrogen-Based Application	-	$ (2,804.87)
If Phosphorus-Based Application	-	$ (5,219.71)
Extra Fertilizer Purchase Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	-	-
If Phosphorus-Based Application	$ 4,641.26	-

Note: 12,196,173 gallons / year of effluent modeled to be land applied

Table SBR.56. Summary and Mass Balance of Generated and Land Applied Nutrients— Standardized Quantities and Prices (4,000-Sow Farrow-Wean)

Nutrient Balance	**Nitrogen (lbs/ year)**	**Phosphorus (lbs / year)**	**Potassium* (lbs / year)**
Generated At Barn	117,000.00	37,040.00	77,000.00
Removed in Primary Treatment Tank	94,079.70	12,378.77	-
Applied to Land in Lagoon Effluent	22,920.30	4,684.55	30,551.41
Nutrients Unaccounted for	0.00	19,976.68	46,448.59

* No data on percentage of potassium removed in SBR primary treatment tank

Tables SBR.57 and SBR.58: Predicted Costs of Retrofitting Various Representative Farm Sizes and Farm Types with the SBR Technology: DWQ Permitted Farms and SF/PSF Owned Farms

Table SBR.57. Predicted Costs ($ / 1,000 Pounds of Steady-State Live Weight (SSLW) per Year) of Retrofitting DWQ Permitted Representative Farm Type / Farm Size Combinations—SBR Technology

	Farm Size (1,000 pounds SSLW)				
	0-500	**500-1000**	**1000-1500**	**1500-2000**	**> 2000**
Farm Type					
Farrow-wean					
Rep. # of sows	752	1,540	2,400	4,000	6,000
Pit-recharge system	$219.72	$164.37	$125.49	$123.37	$105.23
Flush system	$219.12	$161.87	$123.92	$125.02	$106.17
Farrow-feeder					
Rep. # of sows	500	1,200	2,000	3,600	5,500
Pit-recharge system	$270.63	$180.19	$181.06	$154.92	$145.11
Flush system	$288.90	$206.83	$202.89	$176.46	$166.40
Farrow-finish					
Rep. # of sows	150	500	1,000	1,200	2,000
Pit-recharge system	$333.62	$222.53	$190.76	$171.91	$169.44
Flush system	$336.62	$225.48	$198.14	$184.79	$177.14
Wean-feeder					
Rep. head capacity	3,840	20,000	N/A	N/A	N/A
Pit-recharge system	$613.35	$342.18	N/A	N/A	N/A
Flush system	$664.32	$425.19	N/A	N/A	N/A
Feeder-finish					
Rep. head capacity	2,448	5,280	8,800	12,240	17,136
Pit-recharge system	$292.69	$215.17	$215.35	$207.14	$194.25
Flush system	$298.41	$229.87	$221.16	$211.91	$202.15

Table SBR.58. Predicted Costs ($ / 1,000 Pounds of Steady-State Live Weight (SSLW) per Year) of Retrofitting Smithfield Foods/Premium Standard Farms Representative Farm Type / Farm Size Combinations—SBR Technology

	Farm Size (1,000 pounds SSLW)				
	0-500	**500-1000**	**1000-1500**	**1500-2000**	**> 2000**
Farm Type					
Farrow-wean					
Rep. # of sows	650	1,700	2,400	4,000	7,000
Pit-recharge system	$246.97	$151.70	$125.49	$123.37	$102.69
Flush system	$246.59	$149.97	$123.92	$125.02	$103.38
Farrow-feeder					
Rep. # of sows	675	1,200	2,000	3,419	5,500
Pit-recharge system	$260.73	$180.19	$181.06	$157.29	$145.11
Flush system	$297.28	$206.83	$202.89	$179.50	$166.40
Farrow-finish					
Rep. # of sows	N/A	500	1,000	1,200	2,000
Pit-recharge system	N/A	$222.53	$190.76	$171.91	$169.44
Flush system	N/A	$225.48	$198.14	$184.79	$177.14
Wean-feeder					
Rep. head capacity	2,808	N/A	N/A	N/A	N/A
Pit-recharge system	$788.49	N/A	N/A	N/A	N/A
Flush system	$844.75	N/A	N/A	N/A	N/A
Feeder-finish					
Rep. head capacity	1,240	5,100	8,800	12,246	17,136
Pit-recharge system	$409.39	$220.63	$215.35	$207.05	$194.25
Flush system	$420.39	$235.77	$221.16	$211.83	$202.15

Appendix A: Comments Provided by the Technology Providers

MEMO TO: Dr. Kelly Zering and Adrian Atkinson, NCSU
FROM: Tom Smith, CEO and C. Doug Goldsmith, President, ANT, Inc.
DATE: December 11, 2005
Revised: January 13, 2006

Please find attached a few comments and questions regarding the economic analysis. A revised table has been developed for the SBR construction costs as presented below. The following table and comments are for inclusion in the Summary of Results-Technology Providers Comments.

CONSTRUCTION COSTS

Table SBR 8. Summary of Invoiced Construction Costs for the SBR Technology (Cavanaugh)

Unit Process	Actual Cost	Est. New Farm *	Est. for Existing Farm*
Waste evacuation mod.	$26,667.00	$5,300	$9,200
Equalization tank	$73,483.68	56,800	65,500
Primary treatment tank	$257,267.50	174,000	190,000
Operations building	$4,815.00	0	5,000
Control system	$40,000.00	22,000	22,000
3-phase installation to site	$10,000.00	0	0
Construction bond	$7,142.00	0	0
Consulting fees	$42,168.68	20,000	25,000
Total Invoiced Cost of SBR	**$461,543.86**	**$278,100**	**$316,800**
% of Research Project Cost		**60.2**	**68.6**

***Actual Cost Adjusted for expenditures not required for a normal hog farm operation.**

- Research related expenditures
- Construction cost required by "Farmer/State of North Carolina Agreement"
- Environmental- NCDENR required for backup system
- Expenditures related to "farm upgrades" to comply with NCDENR farm operations
- Design requirements by "estimated engineering models" during permit process
- Purchase of concrete prefab tanks in volume of five or more results in reduced costs of 15%

OVERHEAD

ANT, Inc. disagrees with the overhead cost projections. With subsequent engineering and design efforts the overhead should be dramatically reduced due to the cookie cutter effect and would be less than 20 percent. We believe the overhead for the SBR should be equal to or less than the lagoon.

ELECTRICAL COSTS (Table SBR 4.)

Electrical Invoices: The December 2003 and January 2004 costs of $8899.21 ($4386.53 + $4512.63) were for the period from August through December 2003. Wilson Electric did not make an official "cut on" reading and a negotiated 5 month estimate usage was necessary for the start-up phase of August through December. August and September power mainly from construction related events. This would result in an average electrical cost of $2416 (Feb-Aug 2004) during the testing period. For the normalized operating months this is approximately 85% of the average cost calculated on Table SBR 4.

The SBR aerators were somewhat oversized in hp and the use of only two during the entire time of operation would have resulted in decreased costs. Similarly, there were two mixers in the EQ tank and only one was used during the study.

OPERATING EFFICIENCIES

Receiving the flow from a total farm would result in enhanced efficiency due to a more consistent COD loading and would significantly reduce costs versus receiving a partial flow with variable COD as was done during the study.

RESULTS SUMMARY

Summary Table. Average influent concentrations, mass loading, and percent removal under normal loading conditions at all BSRTs studied.

Parameter	Concentration (mg/L)	Mass Loading Rate (kg/d)	Average % Removal*
Mass Balance Removals			
Total Kjeldahl Nitrogen (TKN)	862	79.8	83.0
Total Ammoniacal Nitrogen (TAN)	637	58.6	96.8
Chemical Oxygen Demand (COD)	7310	687	63.7
Suspended COD (SS-COD)	5400	506	60.4
Treated Water Quality (for water reuse)			
Total Kjeldahl Nitrogen (TKN)	862	79.8	90.0
Total Ammoniacal Nitrogen (TAN)	637	58.6	96.8
Chemical Oxygen Demand (COD)	7310	687	84.0
Suspended COD (SS-COD)	5400	506	89.7
Total Phosphorus (TP)	118	11.0	36.5
Ortho-Phosphate-P (o-PO4)	96	8.82	34.6
Copper (Cu)	2.46	0.242	76.1
Zinc (Zn)	3.94	0.362	81.4

*enhanced removal rates are achievable when the SBR is operated at a BSRT >30 days as per Section 5.3 of the NCSU evaluation report

SBR DESIGN/CONCEPT

ANT'S concept (engineering/biological design) was to collect, measure, treat and control 100% of the swine waste from a flush or pull-plug waste system. During the research study the SBR was operated under various BSRT (biological solids retention time) to allow for the design and modeling of future treatment systems and to provide data for the farm matrix model required for the economic analysis. As such the system was not always operated under optimum conditions. Optimum treatment was obtained at a BSRT greater than 30 days. While the averages reported by the primary investigator were good, the optimum operational values were far better. COD removal was 90%, TKN removal was 95% and ammonia nitrogen removal was 99%. Please see Figures 42, 43 and 46 of NCSU report.

The ultimate objective is to convert the contaminated water to potable water to the extent possible for reuse as drinking and flush water in the barns. All untreated swine waste solids are metabolized by the SBR technology and converted to carbon dioxide, water and nitrogen gas resulting the generation of biological solids (biosolids) comprised of microbial mass. The equivalent of these generated biosolids was removed daily and represents only 25-30% of the original amount of the raw solids received for treatment, i.e., 70-75% solids reduction. Biosolids generated by the SBR technology may be dewatered for ease of handling and shipping. The demonstration at the Hunt Farm was determined to be the equivalent of 3,568 head and this yielded 385 ww tons/year for beneficial reuse as a fertilizer on or off-site. The treatment process achieved significant reduction to the targeted parameters of COD and nitrogen and effective sorption of phosphorus and metals by the biosolids. The *process* (methodology developed by ANT, Inc.) was managed by software and in-system sensors and required minimum labor/supervision to achieve predetermined environmental standards. This highly automated process achieved high volume throughput via its 24/7 operating schedule. Very low operating cost relative to the environmental results and processed volume were achieved. More importantly, the environmental liability associated with the present lagoon system (to which no value has been assigned) will be removed.

ADDITIONS OR CHANGES THAT IMPROVE THE ECONOMICS AND/OR EFFICACY OF THE SBR

- The addition of a primary solids removal tank (clarifier) would result in a clarified waste similar to the surface liquid of the lagoon as analyzed at each sampling during the study. This would allow a system designed for the treatment of raw waste to treat at least ***four times*** **the number of head.** The harvested primary solids could be composted on-site or otherwise treated and disposed. Therefore, farms that need the solids for fertilizer the SBR investment and treatment costs would be 25% allowing for versatility in implementation options.

- The addition of an effluent mix and settlement tank will allow for nearly complete phosphorus removal with the addition of chemical flocculants such as alum. (p. 30 NCSU report)

- Pathogen comparisons during the study were done on the clear water effluent of the SBR and the lagoon clear surface water. Little difference in pathogen content would be expected since gravity settling is the main mechanism of bacterial removal in both systems. The addition of a chlorination system or equivalent would be required to sanitize the water for drinking.

- Barn hygiene is improved (treated water vs. lagoon for flushing) resulting in potential productivity improvement and $ savings.

- The addition of a biosolids dewatering unit can provide a viable organic fertilizer product for use on-site or off-site ($).

SUMMARY

- Excellent contaminant reduction in all categories.
- It is possible to eliminate lagoons and eliminate or minimize spray field operations resulting in lower operating and overhead cost.
- In the “closed loop” approach treated wastewater can be used as drinking water after chlorination (pathogen elimination) and flush waster.

- Fresh water removal from the aquifer is greatly reduced.
- No chemical usage in the SBR treatment process during the study.
- No mechanical handling and minimal labor required during entire "closed loop" treatment process.
- The residual, biosolids (high quality fertilizer) is low volume (minimum handling), easy to store and use for land application for on or off- site use.
- The average flow to the SBR was 27,687 gallons or 230,909 pounds/day. The dewatered biosolids would be the only out of system residual to be handled (low labor cost) at about 440 pounds/day. This represents only 0.2% of the total input volume. ***The SBR closed loop process could result in the recycle of 99.8% of the total waste volume.*** The 0.2% of biosolids is available for use or sale.