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Cost and Returns Analysis of Manure Management Systems Evaluated in 2004 under the North Carolina Attorney General Agreements with Smithfield Foods, Premium Standard Farms, and Front Line Farmers

TECHNOLOGY REPORT: RECIP

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

Prepared for:
C. M. (Mike) Williams
Animal and Poultry Waste Management Center
North Carolina State University
Campus Box 7609
Room 134 Scott Hall
2711 Founder's Drive
Raleigh, NC 27695-7608

Prepared by:
Task 1 Team
Department of Agricultural and Resource Economics
North Carolina State University

Technical Point of Contact:
Dr. Kelly Zering (Task 1 Team Leader)
North Carolina State University
Department of Agricultural
and Resource Economics
3313 Nelson Hall
Campus Box 8109
Raleigh, NC 27695-8109
Tel: 919-515-6089
Fax: 919-515-6268
Email: kelly_zering@ncsu.edu

Administrative Point of Contact:
Dr. Michael Wohlgenant
(Project Coordinator)
North Carolina State University
Department of Agricultural
and Resource Economics
3310 Nelson Hall
Campus Box 8109
Raleigh, NC 27695-8109
Tel: 919-515-4673
Fax: 919-515-6268
Email:michael_wohlgenant@ncsu.edu

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Summary of Results

Retrofit Cost per 1,000 pounds Steady State Live Weight per year: $143.21
Standardized Feeder-to-Finish Farm with 4,320 head (Tables RC.29- RC.38)
10-Year Amortization, Pit-Recharge, N limited Irrigation onto Forages

Includes:	Manure Evacuation:	$ 4.66 / 1,000 lbs. SSLW / Yr.
	Controls:	$ 4.08 / 1,000 lbs. SSLW / Yr.
	Holding Pond:	$ 6.41 / 1,000 lbs. SSLW / Yr.
	Clarifier:	$ 16.52 / 1,000 lbs. SSLW / Yr.
	Day Tank:	$ 10.38 / 1,000 lbs. SSLW / Yr.
	ReCip Cells:	$ 85.67 / 1,000 lbs. SSLW / Yr.
	Royalty Fees:	$ 8.88 / 1,000 lbs. SSLW / Yr.
	Increased Land Application Cost:	$ 6.61 / 1,000 lbs. SSLW / Yr.

Range:	Across Farm Sizes and Types (Pit-Recharge): / 1,000 lbs. SSLW / Yr.	$111.58 To $411.40
	Across Farm Sizes and Types (Flush): / 1,000 lbs. SSLW / Yr.	$133.75 To $793.00

Confidence in Estimates:

Medium to Medium-Low
Based on 14 months evaluation, real commercial setting data for electricity use and price, construction and operating performance and expense. Standardized model assumes performance beyond demonstrated loading rates and includes an untested component (holding pond).

Costs by Category:

Direct Construction:	$ 80.70 / 1,000 lbs. SSLW / Yr.
Contractor Overhead:	$ 33.00 / 1,000 lbs. SSLW / Yr.
Total Operating:	$ 22.90 / 1,000 lbs. SSLW / Yr.
Increased Land Application Cost:	$ 6.61 / 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	$65.42	$77.20
Baseline Cost Projection (10-year economic life, 8 % interest rate)	0.1490	$96.02	**$113.71***
High-Cost Projection (7-year economic life, 10 % interest rate)	0.2054	$133.45	$158.36

* 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)	$21.09
Baseline Cost of Electricity ($0.08 / kWh)	**$22.90***
High-Cost Electricity ($0.10 / kWh)	$24.70

* 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 $113.71 is the actual predicted 2004 construction and overhead cost for the RECIP system 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 RECIP system are recalculated using higher and lower prices for electricity. The 25% increase or decrease in electricity price has a slight effect on the predicted annual operating cost per unit reflecting limited use of electricity by the RECIP system.

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 ReCip system produces only separated slurry and liquid effluent. While systems for de-watering the slurry have been proposed, none was demonstrated so further separation performance and cost data are not available. Breakeven analysis was not conducted for this technology.

1. Overview of the ReCip Technology

1.1 Farm Overview

The ReCip liquid treatment system was evaluated on the Corbett # 2 farm near Rose Hill, NC in Duplin County. This finishing farm consists of two barns with 910 hogs per barn capacity. The barns have fully-slatted floors and incorporate a natural ventilation system. The ReCip system was designed to treat manure from 1,820 hogs or 246,000 pounds SSLW if the farm is operating at full capacity. The manure was originally treated by two anaerobic lagoons which were later converted to holding ponds for treated effluent (Worley-Davis). The ReCip technology was in operation from December 2002 until January 2004. Although Corbett Farm #2 has a maximum capacity of 1,820 feeder-to-finish pigs, the ReCip technology treated manure generated from an average of about 1,350 hogs during its evaluation period (Rice a, b).

The manure is evacuated from barns using a flush system. Each building has two 800-gallon flush tanks which flush four times during a 24-hour period. The total of recycled water used in a day with the ReCip system was approximated at 12,800 gallons. Previous to the ReCip system installation the buildings were flushed more frequently, but the flush frequency was reduced to optimize the nutrient concentration in the waste. The average total daily volume flushed from the facility was estimated at 19,976 gallons / day (Rice a).

1.2 Technology Overview

The Reciprocating Water Technology (ReCip) is distributed by BioConcepts, Inc. which is a licensed agent for Tennessee Valley Authority's (TVA) ReCip technology in North Carolina. The manure is evacuated from barns via flush system. The flush liquid and accumulated manure travel via gravity to a two-stage 12,000-gallon liftstation/solids separator. The purpose of the first 6,000-gallon chamber of the separator is to separate solids using several dual baffles. Separated solids (slurry) were pumped to the former lagoon and later land applied. Separated liquids are further treated by two Zabell filters to remove suspended solids before entering the second 6,000-gallon chamber of the separator by overflow. From the second chamber (lift station), the separated liquids are pumped to the ReCip system cells.

The ReCip system consists of two adjacent earthen cells which are lined with synthetic liner and filled with several types of aggregates that serve as a media for bacteria. The size of aggregate varies from larger grade gravel at the bottom to smaller grade pea gravel at the top. The ReCip cells are constructed with a 1/3 slope. The liquid remains subsurface throughout the entire treatment process in the cells. There is a sludge collection area in cell #1 designed to collect any solids not captured by the solids

separator and filtration process. If necessary, the area can be emptied by a sludge pump. There are four pump chambers in each cell housing 1.5-HP pumps. These pumps are used to move water between adjacent cells.

The ReCip treatment technology relies on a process called reciprocation which is defined by BioConcepts, Inc. as an alternate draining and filling of the two cells on a defined and recurrent basis. When one cell is nearly full, the other cell is nearly empty. The sequential drain and fill technique is designed to create an environment suitable for growth of bacteria utilized in the nitrification-denitrification process. The liquid continues being moved back and forth between the cells for the duration of its six-day average hydraulic retention time. The gravel media occupy 445 cubic yards so the available liquid volume is 297 cubic yards or approximately 60,000 gallons. Thus, the effective hydraulic retention time is 60,000 gallons per cell divided by 19,976 gallons per day equals approximately 3 days per cell. The total volume of the cells includes 1 foot of freeboard. Any emergency overflow of the cells would flow into the daytank by gravity. As new liquid is pumped from the clarifier to the first cell, the treated liquid flows by gravity from the Recip cells to the day tank.

The day tank was designed as a 12,000-gallon earthen cell that serves as storage for treated liquid to be used for flush tank recharge, for treated liquid to be used for cleaning of the clarifier (separator), and as a reservoir before the excess treated liquid is sent to the second former lagoon where it accumulates before being land applied. The model presented in this document includes the day tank. According to the technology provider the day tank could be eliminated from the system if the original lagoon served as a storage pond.

A diagram of ReCip technology is shown in Appendix RC.A.

2. ReCip System Design and Invoiced Construction Costs

The ReCip retrofit technology consists of the following main components:

1) Manure Evacuation
2) Solids Separator (Clarifier)/Liftstation
3) ReCip Cells
4) Day Tank
5) Land Application of Separated Liquids and Solids (Slurry)

The construction cost records for this technology were obtained from Cavanaugh and Associates (Tables RC.1-RC.7). Tables RC.1-RC.6 have two cost columns. The first details the actual costs of the ReCip technology as documented on invoices. Total construction costs, however, included contractor's profit and overhead in each item (10.0 % overhead + 10.0 % profit = 20 % total overhead and profit). To be consistent with the economic analyses performed on other technologies, contractor's overhead and profit was

taken out of ReCip's itemized invoiced construction costs and is shown under miscellaneous items in Table RC.6 as a separate item. The second column of Tables RC.1-RC.6 shows the adjusted invoice costs (80 % of the original invoiced cost) of the technology after removing contractor's overhead and profit. The manure evacuation route was modified by installing two splitter boxes which diverted the original flow to the lagoon to the solids separator (clarifier). The settling tank was cast in place and cost $32,843.75 including baffles and hatches (see Table RC.1). For flush system operations, it is assumed that the flushed liquid needs to enter the first chamber of the tank all at once to provide optimal barn cleaning and therefore the maximum handling capacity of the tank is 6,000 gallons per flush. The construction cost of the two ReCip cells is identical except that the first cell contains a sludge collection area which adds another $1,605.76 to the cost (see Tables RC.2 and RC.3). The day tank was cast in place and cost $22,894.62 (see Table RC.4). Table RC.5 reports the cost of piping and allocates the total electrical cost of the technology ($24,998) among its unit processes. Table RC.6 reports miscellaneous costs associated with the ReCip technology, while Table RC.7 summarizes the total cost of the technology as allocated to unit processes. As listed in Table RC.7, the construction cost of the ReCip system is equal to $328,908.74. Table RC.8 shows a modified estimate of ReCip's construction costs of $242,489.50. The $86,419.24 reduction in total construction costs between Tables RC.7 and RC.8 includes $75,419.24 in excluded contractor's overhead and profit and eliminated payments of $9,000 to BioConcepts and $2,000 to The Rose Group.

Table RC.9 shows the electricity usage to power the system. Invoiced power bills for the timeframe in which the ReCip system was fully operational show the ReCip technology's average monthly electricity costs were $284.83 for December 2002 through August 2003.

3. Overview of Cost Modeling

Invoiced construction costs of the ReCip technology as it was built on Corbett Farm Unit #2 are reported by unit process in Tables RC.1-RC.6 and summarized in Tables RC.7 and RC.8. In the next step, the data reported in Tables RC.1-RC.6 were modified to account for missing components, outdated prices and unnecessary expenses. Tables RC.10-RC.18 represent modified complete construction and operating cost incurred at the experimental site with average operating capacity of 1,350 finishers. The numbers in these tables reflect the ReCip technology as it was operated under Corbett #2 farm conditions. Contractor overhead and profit and other construction related fees were replaced with standard assumptions (Appendix I, Table I.1).

Table RC.19 provides estimated summary costs (total annual and per unit costs) for the ReCip technology assuming that the farm was filled to its maximum capacity of 1,820 finishers.[1] The numbers in Table RC.19 assume that treatment costs and performance are

[1] At the time of design, the technology provider assumed that the farm operates at its full capacity (1,820 finishers). This implies that the ReCip system was oversized for the farm's operating capacity of 1,350 finishers. The results presented in Table RC.19 adjust for over-sizing. Under the scenario with 1,820 finishers presented in Table RC.19, the treatment capacity and effectiveness of the system and operating expenses are assumed to remain the same. The cost of land application increased due to increased volume of manure from 1,820 animals.

unchanged with the higher loading rate. The costs per unit ($ / 1,000 lbs. SSLW) in Table RC.19 (modified costs with 1,820 head) are lower than those in Table RC.10 (modified actual costs with 1,350 head).
In the next step, estimates of costs that would occur on standard (representative) North Carolina farms were calculated. These costs were calculated using the standard parameter and cost assumptions. ReCip cells were sized assuming a six day effective hydraulic retention time (equivalent to the actual ReCip system serving 1,820 pigs).

As reported in Tables RC.2 and RC.3, the technology provider incurred significant cost for excavation and dewatering and transportation of liner (fill) material from an off-farm location. According to the technology provider, the high cost for excavation of earthen cells was due to high water table and low quality of on-site fill material (material was imported from a distant off-farm location). If built on a representative NC farm site, technology providers assume that about 50 % of the cell volume would be excavated and the excavated soil used to build up the remaining portion of the cell. Based on this assumption, our standardized model assumes that 50 % of the cell volume is excavated and no additional liner (fill) material must be imported from off-farm locations. These are different assumptions than our standard excavation assumption of 70 % excavated and no imported fill material. The assumption of 50 % excavation versus 70 % reduces the predicted standardized construction cost of the cells by less than $5,000 or 35 %.

If the manure discharged from the facility can not be handled by a single separator, the model assumes installation of another unit. The solids separator (clarifier) unit process contributes significantly to the total cost of the ReCip technology. The solids separator (clarifier) installed on the ReCip site cost $32,843.75 (Table RC.1) and can treat up to 30,000 gallons per day with two hour retention time. The solids separator is necessary for the operation of ReCip technology, however, the primary technology demonstrated at Corbett Farm #2 is the ReCip cells. According to the technology provider, ReCip cells could be operated with any solids separator that provides similar separation efficiency.

Standardized costs are presented in Tables RC.20-RC.28 for a 4,320-head feeder-to-finish facility using a flush system of manure removal. Tables RC.29-RC.38 present the costs associated with a standard North Carolina feeder-to-finish operation with a capacity of 4,320 pigs using a pit-recharge system of manure removal. ReCip system design for a facility equipped with pit recharge system includes another component (holding pond) that serves as a buffer (equalization tank) between barns and clarifier. The holding pond is designed as an earthen structure that is able to hold one day's volume of emptied pit contents at the maximum daily rate of pit emptying. A representative NC 8,800-head feeder-to-finish facility with a flush manure removal system is detailed in Tables RC.39-RC.47. The final standard NC farm described in this report is a 4,000-sow farrow-to-wean operation using a flush system of manure removal. Tables RC.48-RC.56 list the estimated costs associated with using the ReCip technology at the 4,000 sow facility. Tables RC.57 and RC.58 extrapolate costs to other representative farm sizes and types for all DWQ permitted farms and for Smithfield Foods/Premium Standard Farms owned operations only, respectively.

3.1 Modified Actual Cost for ReCip Technology at Corbett Farm #2 (Tables RC.10-RC.19)

Table RC.10 provides the assumptions for the cost estimate calculation and 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).[2] A plastic liner was used at Farm #2 for cell lining (clay liner was used under the plastic liner to create a base). Annualized costs for the whole farm and per 1,000 lbs. of SSLW (incremental retrofit cost) are reported. In Table RC.10, incremental costs of the retrofit for each of the four land application scenarios range from $350.92 (phosphorus-based application to row crops) to $400.73 (phosphorus-based application to forages) per 1,000 pounds SSLW per year, with an average of $370.96. Tables RC.11-RC.15 summarize costs of individual unit processes of the ReCip technology including manure evacuation (RC.11), controls (RC.12), clarifier (RC.13), day tank (RC.14), and ReCip cells (RC.15). Table RC.10 reports the total costs associated with the unit processes listed above. Total construction costs are reported as $362,210.24, while operating costs are estimated as $5,903.91. The total annualized cost of the ReCip technology before land application is estimated to be $62,901.34 for the 1,350-head feeder-to-finish facility at Corbett Farm #2. Tables RC.16 (lagoon effluent) and RC.17 (slurry) report land application costs associated with the ReCip technology. Used in conjunction with the numbers reported at the end of Table RC.10, the total annualized and incremental cost estimates can be calculated. These numbers are reported in at the top of Table RC.10 for each of the four scenarios of land application. Table RC.18 details the mass balance of nutrients associated with the ReCip technology. This table is necessary to derive the numbers found in Tables RC.16 and RC.17. Table RC.19 is similar to Table RC.10 and summarizes the total annualized and per unit costs associated with the ReCip technology as constructed at Farm #2. While total construction and operating costs are the same as reported in Table RC.10, in Table RC.19 these costs are distributed over 1,820 pigs in inventory instead of the 1,350 pigs represented in Table RC.10. As a result, per unit costs for each of the four land application scenarios are reduced by about 26 % (as SSLW is increased about 35 % from 182,250 lbs. to 245,700 lbs.). In addition, the modeled electric power usage is lower than the actual invoiced electric power usage in Table RC.9. This is due to the fact that ReCip motors seem to have relatively low efficiency of 58 % or operated longer than what the protocol indicates. In order to be consistent with other technology, our standard assumption was used (88 % efficiency) in all ReCip models.[3] This assumption reduces predicted electricity consumption and cost by (1 – (58/88) = 0.34) about 34 %.

[2] For more on land application, see Appendix B of the Summary document.

[3] The ReCip technology team provided actual metered electricity usage and information for the motors that was not provided for all technologies. We have used this information, scheduled motor usage, and the actual power bill to calculate ReCip cell motor efficiency (56 %). The standard assumption for efficiency (88 %) was used to be consistent with other technologies where separate meters and detailed information on electric power usage is not available.

3.2 Standardized Costs for ReCip Technology at a 4,320-Head Feeder-to-Finish Farm (Flush System) (Tables RC.20-RC.28)

Tables RC.20- RC.28 provide estimates of the cost of constructing and operating the ReCip technology on a standard (representative) North Carolina 4,320-head feeder-to-finish facility using a flush system for manure removal. Table RC.20 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for the standardized retrofit with ReCip technology. The standardized incremental costs range from $158.71 (nitrogen-based application to row crops) to $241.06 (phosphorus-based application to forages) per 1,000 pounds SSLW for each of the four land application scenarios, with an average of $183.86. Phosphorus-based land application is more costly than nitrogen-based land application for the ReCip technology on a standardized farm. For this standardized farm, land application to forages is also more costly than land application to row crops. Tables RC.21-RC.25 are analogous to Tables RC.11-RC.15. They report standardized costs for the same unit processes listed in the above section (in the same order). Within certain unit processes (e.g., waste evacuation), there might be differences in grouping individual components between the actual and standardized models. For example, the splitter boxes used at Farm #2 were included under manure evacuation/plumbing cost for the representative NC farm and are not listed individually. Table RC.20 also summarizes the total costs associated with the standardized ReCip technology for a 4,320-head finishing facility with a flush system (summing the unit processes reported in Tables RC.21-RC.25). Total construction costs are estimated at $505,379.42, while total operating costs are reported as $15,318.43. Total annualized costs before land application are estimated at $93,076.40 for this representative farm size and type. Tables RC.26 (lagoon effluent) and RC.27 (slurry) summarize the land application costs associated with the standardized model for each of four scenarios. Table RC.28 provides an estimated mass balance of nutrients for this representative NC farm.

3.3 Standardized Costs for ReCip Technology at a 4,320-Head Feeder-to-Finish Farm (Pit-Recharge System) (Tables RC.29-RC.38)

Tables RC.29- RC.38 provide estimates of the cost of constructing and operating the ReCip technology on a standard (representative) 4,320-head feeder-to-finish farm in North Carolina with a pit-recharge system for manure removal. The type of manure removal system used is the only difference between the farm modeled in Tables RC.29-RC.38 versus the one modeled in Tables RC.20-RC.28. Using the ReCip technology with a pit-recharge system introduces another unit process. A holding pond (equalization pond) must be used in conjunction with the ReCip technology if operated with a pit-recharge manure removal system. Table RC.29 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for the standardized ReCip technology. The standardized incremental costs range from $134.67 (nitrogen-based application to row crops) to $221.50 (phosphorus-based application to forages) for each of the four land application scenarios, with an average incremental cost of $161.53 per 1,000 pounds SSLW. As for the flush system with 4,320 pigs, phosphorus-based applications are more costly than

nitrogen-based applications and applications to forages are more costly than application to row crops.

Using a pit-recharge system of manure removal is about 12 % less costly than using a flush system for the ReCip technology on a standardized 4,320-head finishing farm. Although there are additional costs associated with the inclusion of a holding pond for pit-recharge systems, these costs are more than offset by the savings associated with smaller ReCip cells due to lower daily liquid volume loaded. For this size and type of farm, the assumed holding pond had an annualized cost of $3,739.16 (Table RC.32). The ReCip cells had a total annualized cost of $49,961.45 in this pit-recharge model (Table RC.35), as compared to $58,377.39 for an identical farm using a flush system (Table RC.25). This annual cost savings of $8,415.94 associated with smaller ReCip cells more than offsets the $3,739.16 in annual cost to construct the holding pond. Thus, the pit-recharge system is more economically efficient than the flush system for this type and size of farm using the ReCip technology. Implicit in these models is the assumption that smaller Recip cells loaded with the same quantity of manure but a smaller volume of liquid will produce the same level of treatment in the same period of hydraulic retention. Operational and environmental performance of the holding pond (equalization cell) also remains to be determined.

Tables RC.30-RC.35 list the costs of individual unit processes in this standardized model. The set of unit processes and components are identical to those in Tables RC.21-RC.25, but for the inclusion of a table detailing the holding pond costs (Table RC.32). Changes in recycled liquid volume in the pit-recharge system versus the flush system cause some cost estimates to change between the two sets of tables. Table RC.29 summarizes the total costs associated with the standardized ReCip technology for a 4,320-head finishing facility with a pit-recharge system (summing the unit processes detailed in Tables RC.30-RC.35). Total construction costs are estimated at $434,197.89, while total operating costs are reported as $13,352.63. Total annualized costs before land application are estimated at $79,665.97 for this representative farm size and type. Tables RC.36 (lagoon effluent) and RC.37 (slurry) summarize the land application costs associated with this standardized model for each of four scenarios. Table RC.38 provides an estimated mass balance of nutrients for the representative farm modeled in these tables.

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

Tables RC.39- RC.47 provide estimates of the cost of constructing and operating the ReCip technology on a standard (representative) 8,800-head feeder-to-finish farm in North Carolina with a flush system for manure removal and a plastic liner. Table RC.39 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for the standardized ReCip technology. The standardized incremental costs for the 8,800-head finishing facility range from $136.05 (nitrogen-based application of row crops) to $168.52 (phosphorus-based application of forages) across the four scenarios, with an average incremental cost of $146.60 per 1,000 pounds SSLW. For this size and type of farm, row

crops are slightly less costly to land apply than forages and nitrogen-based applications are less costly than phosphorus-based applications. Compared to the 4,320-head finishing facility using a flush system, the average incremental costs of this 8,800-head farm are about 20 % less costly. Based on this finding, the model suggests that economies of scale are present for the ReCip technology. Specifically, the controls are a fixed cost across farm size. The clarifier and day tank also exhibited economies of scale to lesser degrees. Tables RC.40-RC.44 list the costs of individual unit processes in this standardized model. The set of unit processes and components are identical to those in Tables RC.21-RC.25. Table RC.39 summarizes the total costs associated with the standardized ReCip technology for an 8,800-head finishing facility using a flush system. Total construction costs are estimated at $902,182.81, while total operating costs are reported as $27,067.02. Total annualized costs before land application are estimated at $164,888.20 for this representative farm size and type. While these total construction costs are higher than in the standardized 4,320-head model, the per unit capacity costs are 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. Tables RC.45 (lagoon effluent) and RC.46 (slurry) summarize the land application costs associated with this standardized model for each of four scenarios. Table RC.47 provides an estimated mass balance of nutrients for the representative farm modeled in these tables.

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

Tables RC.48- RC.56 provide estimates of the construction and operating costs of retrofitting the ReCip technology onto a standard (representative) 4,000-sow North Carolina farrow-to-wean farm using a flush system for manure removal. This representative farm has 1,732,000 pounds of SSLW: the largest of any standard farm modeled for the ReCip technology. Table RC.48 also provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for the standardized ReCip technology. The standardized incremental costs range from $200.30 (phosphorus-based application to row crops) to $218.64 (phosphorus-based application to forages) / 1,000 lbs. SSLW / year across the four land application scenarios, with an average per unit cost of $206.08. Tables RC.49-RC.53 report the costs of individual unit processes in this standardized model. The set of unit processes and components are identical to those listed in Tables RC.21-RC.25 and RC.40-RC.44. Table RC.48 summarizes the total costs of the standardized ReCip technology for a 4,000-sow farrow-to-wean operation (summing the unit processes described in Tables RC.49-RC.53). Total construction costs are estimated at $1,907,027.02, while total operating costs are reported as $57,859.81. Total annualized costs before land application are estimated at $349,383.60 for this representative farm size and type. Tables RC.54 (lagoon effluent) and RC.55 (slurry) summarize the land application costs associated with this standardized model for each of four scenarios. Table RC.56 provides an estimated mass balance of nutrients for the 4,000-sow farrow-to-wean operation modeled for the ReCip technology.

3.6 Extrapolation to Other Farm Types and Sizes (Tables RC.57-RC.58)

Table RC.57 summarizes the per unit costs ($ / 1,000 lbs. SSLW) of the ReCip technology for each of the 25 farm size / farm type 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 costs in Table RC.57 assume nitrogen-based land application to forages is utilized. Table RC.58 is analogous to Table RC.57, but uses representative farm sizes for Smithfield Foods/Premium Standard Farms (SF/PSF) owned operations only. Incremental costs are again shown for both pit-recharge and flush systems. To calculate the costs reported in Table RC.58, the representative SF/PSF farm size is used for each size / type combination. As in Table RC.57, the costs in Table RC.58 assume that nitrogen-based land application to forages is chosen. In Tables RC.57 and RC.58, incremental costs decrease as the size of the farm increases as the ReCip technology demonstrates economies of scale for all types of operations. For the ReCip technology, feeder-to-finish operations are generally the least expensive within a given size category. The solids separator (clarifier) and ReCip cells are the specific unit processes that contribute most significantly to the economies of type demonstrated by feeder-to-finish operations. In Tables RC.57 and RC.58, pit-recharge systems are generally less costly than flush systems for a given size / type combination. As explained earlier in the report (Section III.C), pit-recharge systems will involve an additional holding pond cost, but require smaller ReCip cells. Usually, as indicated by the numbers in Tables RC.57 and RC.58, the reduction in the cost of the ReCip cells will outweigh the added cost of the holding pond. This will lead to a lower overall cost of the ReCip technology when constructed and operated with a pit-recharge system of manure removal. Only on some farms within the smallest size category (0-500,000 lbs. SSLW) are flush systems less costly than pit-recharge systems for the ReCip technology. Again, implicit in these models is the assumption that smaller Recip cells loaded with the same quantity of manure but a smaller volume of liquid will produce the same level of treatment in the same period of hydraulic retention.

4. Summary and Conclusions

The ReCip system was installed and operated on an existing feeder pig to finish farm with capacity for 1,820 pigs. The system operated between December, 2002 and January, 2004. The primary functions of the system include solids separation and the repeated filling and emptying of two reciprocating earthen cells filled with various types of gravel. Separated solids were placed in an existing anaerobic lagoon. Treated liquid was placed in another existing anaerobic lagoon. The farm has a flush system and even with a reduced flushing schedule, the ReCip system was designed to handle the larger daily effluent volume associated with flush systems. It was reported that the farm had an

average inventory of 1,350 head during the evaluation so the system had a lower daily manure loading than originally planned. Approximately 20 % of nitrogen and phosphorus in the barn effluent was removed in the separated solids. About 60 % of the nitrogen and 15 % of the phosphorus was removed in the reciprocating cells. About 1 % of nitrogen and phosphorus was land applied in liquid effluent. The remainder of nitrogen and phosphorus are unaccounted for.

The actual system cost $328,908.74 to install. Electric bills averaged $284.83 per month between December, 2002 and August, 2003. The cost and returns model for the actual system treating 1,350 head (182,250 pounds SSLW) produced retrofit cost estimates of $351 to $401 per 1,000 pounds SSLW per year.

Assuming the actual system could treat manure from 1,820 head (245,700 pounds SSLW or 35 % more than the actual inventory) with no additional cost or loss of performance, the cost and returns model produced retrofit cost estimates of $261 to $294 per 1,000 pounds SSLW per year.

Costs in the standardized models were adjusted. Electricity usage was reduced by 34 % since the metered usage was that much higher than the predicted usage based on motor size and scheduled use. Percent of earthen cells excavated was set at 50 % instead of the standard 70 % assumption. Construction costs were reduced by 20 % to remove contractor and design charges before the standard 43.1% charge for contractor overhead and profit was applied. Separated solids and excess liquid effluent were assumed to be land applied using the standard operations in the cost and returns model. Based on these and other assumptions, the model predicted retrofit costs ranging from $111.58 per 1,000 pounds SSLW per year on the largest finishing farm with a pit-recharge system to $793.00 per 1,000 pounds SSLW per year on a small wean-to-feeder farm with a flush system.

Acreage required for liquid effluent irrigation fell substantially while the acreage required for separated solids application added 76 (nitrogen limited on forage) to 666 (phosphorus limited on row crops) acres of required land for effluent application. As with other technologies, the model can be adjusted and costs reduced if an alternative outlet for solids can be identified at a lower cost to the farmer.

The standardized models for farms with pit recharge systems assumed a holding pond or equalization pond prior to solids separation. This feature was not evaluated at the Corbett # 2 site.

References

(Rice a) Rice, Mark. PI for ReCip Technology. Reply to ARE request for information. March 2004.

(Rice b) Rice, Mark. Solids-Separation-Reciprocating Wetland. Final Report (Draft) to APWMC. April 2004.

Worley-Davis, Lynn. Research Assistant. Animal and Poultry Waste Management Center. North Carolina State University. ReCip System, USA Project Information. 2002.

Tables RC.1 through RC.9: Invoiced and Adjusted Costs and Electrical Usage for the Actual ReCip System: 1,350-Head Feeder to Finish (Average Inventory)

Table RC.1. Invoiced Settling Tank/Clarifier Construction Costs

Component	Actual Invoice Cost	Adjusted Invoice Cost
Hatches and baffles	$16,187.88	$12,950.30
Stone base	$627.25	$501.80
Excavation and dewatering	$3,860.00	$3,088.00
Zabell filters	$1,114.56	$891.65
Pumps	$2,123.00	$1,698.40
Sludge pump	$3,720.07	$2,976.06
Pipes, valves, and fittings (sludge pump)	$2,745.42	$2,196.34
Concrete slab for sludge pump	$289.50	$231.60
Pipes, valves, and fittings (clarifier)	$2,176.07	$1,740.86
Total Cost of Settling Tank/Clarifier	**$32,843.75**	**$26,275.01**

Table RC.2. Invoiced ReCip Cell # 1 Construction Costs

Component	Actual Invoice Cost	Adjusted Invoice Cost
Excavation and dewatering	$3,763.50	$3,010.80
Cut	$1,113.42	$890.74
On-site fill	$1,559.25	$1,247.40
Off-site fill	$7,929.80	$6,343.84
Fine grading and compaction	$2,108.53	$1,686.82
Liner installation	$20,265.00	$16,212.00
Pipes, valves, and fittings	$4,535.50	$3,628.40
Stilling wells	$1,158.00	$926.40
Pumps	$4,246.00	$3,396.80
Furnish and install gravel (No. 4)	$28,483.52	$22,786.82
Furnish and install gravel (No. 78)	$11,734.40	$9,387.52
Furnish and install Cobble	$14,204.80	$11,363.84
Furnish and install Rip Rap	$1,605.76	$1,284.61
Overflow box	$965.00	$772.00
Plants	$2,500.00	$2,000.00
Total Cost of ReCip Cell # 1	**$106,172.48**	**$84,937.99**

Table RC.3. Invoiced ReCip Cell # 2 Construction Costs

Component	Actual Invoice Cost	Adjusted Invoice Cost
Excavation and dewatering	$3,763.50	$3,010.80
Cut	$1,113.42	$890.74
On-site fill	$1,559.25	$1,247.40
Off-site fill	$7,929.80	$6,343.84
Fine grading and compaction	$2,108.53	$1,686.82
Liner installation	$20,265.00	$16,212.00
Pipes, valves, and fittings	$4,535.50	$3,628.40
Stilling wells	$1,158.00	$926.40
Pumps	$4,246.00	$3,396.80
Furnish and install gravel (No. 4)	$28,483.52	$22,786.82
Furnish and install gravel (No. 78)	$11,734.40	$9,387.52
Furnish and install Cobble	$14,204.80	$11,363.84
Overflow box	$965.00	$772.00
Plants	$2,500.00	$2,000.00
Total Cost of ReCip Cell # 2	**$104,566.72**	**$83,653.38**

Table RC.4. Invoiced Day Tank Construction Costs

Component	Actual Invoice Cost	Adjusted Invoice Cost
Excavation and dewatering	$2,653.75	$2,123.00
Stone base	$699.62	$559.70
Pumps	$2,123.00	$1,698.40
Labor and materials	$10,856.25	$8,685.00
Pipes, valves, and fittings	$5,307.50	$4,246.00
Railing	$1,254.00	$1,003.20
Total Cost of Day Tank	**$22,894.62**	**$18,315.30**

Table RC.5. Invoiced Miscellaneous Piping and Electrical Construction Costs

Component	Actual Invoice Cost	Adjusted Invoice Cost
Piping costs		
Splitter boxes (settling tank/clarifier)	$2,856.40	$2,285.12
12” PVC gravity pipe to settling tank	$2,904.57	$2,323.66
Pipes, valves, and fittings (day tank)	$3,377.50	$2,702.00
Electrical costs		
Control and power panels	$8,834.00	$7,067.20
Power feeder	$3,426.00	$2,740.80
Wiring to flush tanks	$3,452.00	$2,761.60
Wiring to clarifier and sludge pump	$2,989.00	$2,391.20
Day tank wiring	$2,593.00	$2,074.40
Wiring to cells #1 and #2	$3,704.00	$2,963.20
Total Cost of Piping and Electrical	**$34,136.47**	**$27,309.18**

Table RC.6. Invoiced Miscellaneous Construction Costs

Component	Actual Invoice Cost	Adjusted Invoice Cost
Mobilization	$10,862.20	$10,682.20
Performance and payment bonds	$5,371.00	$5,371.00
BioConcepts fees	$9,000.00	$0.00
The Rose Group fees	$2,000.00	$0.00
Extra pump for ReCip cells	$1,061.50	$849.20
Total Cost of Miscellaneous Charges	**$28,294.70**	**$16,902.40**

Table RC.7. Summary of Actual Invoiced Construction Costs for the ReCip Technology

Project Component	Cost	% of Total Cost
Settling tank/clarifier	$32,843.75	9.99 %
ReCip cell # 1	$106,172.48	32.28 %
ReCip cell # 2	$104,566.72	31.79 %
Day tank	$22,894.62	6.96 %
Miscellaneous piping and electrical	$34,136.47	10.38 %
Miscellaneous charges	$28,294.70	8.60 %
Total Actual Invoice Cost of ReCip Technology	**$328,908.74**	**100.00 %**

Table RC.8. Summary of Modified/Adjusted Invoiced Construction Costs for the ReCip Technology

Project Component	Cost	% of Total Cost
Settling tank/clarifier	$26,275.01	10.21 %
ReCip cell # 1	$84,937.99	33.00 %
ReCip cell # 2	$83,653.38	32.50 %
Day tank	$18,315.30	7.11 %
Miscellaneous piping and electrical	$27,309.18	10.61 %
Miscellaneous charges	$16,902.40	6.57 %
Total Modified/Adjusted Cost of ReCip Technology	**$257,393.26**	**100.00 %**

Table RC.9. Monthly Operating Costs (Power Usage) for the ReCip Technology

Month	Operating Cost
December ‘02	$142.13
January ‘03	$204.27
February ‘03	$363.05
March ‘03	$362.39
April ‘03	$387.74
May ‘03	$279.58
June ‘03	$285.18
July ‘03	$271.29
August ‘03	$267.86
Total Operating Cost	**$2,563.49**
Average Monthly Operating Cost	**$284.83**

Tables RC.10 through RC.18: Predicted Cost and Returns and Mass Balance for the Actual ReCip System: 1,350-Head Feeder to Finish (Average Inventory) and (Table 19) 1820-Head Capacity with Flush System

Table RC.10. ReCip Technology Assumptions and Total Annualized Costs—Actual Costs and Performance Data

Number of Animals	**1,350**
Type of Operation	**Feeder-Finish**
Barn Cleaning System	**Flush System**
Liner Material	**Plastic**

Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 66,362.50**	**$ 67,081.54**
	If Phosphorus-Based Application	**$ 73,033.78**	**$ 63,954.41**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 364.13**	**$ 368.07**
	If Phosphorus-Based Application	**$ 400.73**	**$ 350.92**

Note: Daily volume discharged from barns is 19,976 gallons / day including recharge liquid.
SSLW equals 182,250 pounds.

TOTAL CONSTRUCTION COST	**$ 362,210.24**
TOTAL CONTRACTOR AND ENGINEERING SERVICES AND OVERHEAD	**$ 107,587.43**
TOTAL OPERATING COST INCLUDING ROYALTIES	**$ 5,903.91**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION	**$ 62,901.34**

Table RC.11. ReCip Technology Manure Evacuation Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Splitter Boxes	$ 2,285.12	$ 340.55
Gravity Pipe to Clarifier	$ 2,323.66	$ 346.29
Electrical Wiring for Flush Tanks/Pits	$ 2,783.81	$ 414.87
Contractor & Engineering Services & Overhead	$ 3,186.20	$ 474.84
Total Construction Cost	$ 10,578.79	$ 1,576.55
Maintenance Cost		$ 147.85
Property Taxes		$ 37.55
Total Operating Costs		$ 185.41
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 1,761.96**

Table RC.12. ReCip Technology Controls Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Control Panel	$ 10,207.30	$ 1,521.19
Electrical Installation	$ 1,159.92	$ 172.86
Contractor & Engineering Services & Overhead	$ 4,899.27	$ 730.14
Total Construction Cost	$ 16,266.49	$ 2,424.19
Maintenance Cost		$ 227.34
Property Taxes		$ 57.75
Electric Power Cost		$ 292.20
Total Operating Cost		$ 577.29
TOTAL ANNUALIZED COST OF CONTROLS		**$ 3,001.48**

Table RC.13. ReCip Technology Clarifier Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Hatches and Baffles	$ 12,950.30	$ 1,929.98
Stone Base	$ 501.80	$ 74.78
Excavation and Dewatering	$ 3,088.00	$ 460.20
Zabell Filters	$ 891.65	$ 132.88
Pumps	$ 1,698.40	$ 612.02
Pipes, Valves, and Fittings (Sludge Pump)	$ 2,196.34	$ 327.32
Sludge Pump	$ 2,976.06	$ 1,072.42
Concrete Slab for Sludge Pump	$ 231.60	$ 34.52
Pipes, Valves, and Fittings (Clarifier)	$ 1,740.86	$ 259.44
Electrical Installation	$ 2,319.84	$ 345.72
Storage for Solids	$ 10,000.00	$ 1,490.29
Contractor & Engineering Services & Overhead	$ 16,634.38	$ 2,479.01
Total Construction Cost	$ 55,229.22	$ 9,218.58
Maintenance Cost		$ 712.13
Electric Power Cost		$ 103.97
Total Operating Cost		$ 816.10
TOTAL ANNUALIZED COST OF CLARIFIER		**$ 10,034.69**

Table RC.14. ReCip Technology Day Tank Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Excavation and Dewatering	$ 2,123.00	$ 316.39
Stone Base	$ 559.70	$ 83.41
Pumps	$ 1,698.40	$ 659.04
Labor and Materials	$ 8,685.00	$ 1,294.32
Pipes, Valves, and Fittings	$ 4,246.00	$ 632.78
Railing	$ 1,003.60	$ 149.57
Piping to Flush Tanks	$ 3,377.50	$ 503.35
Electrical Installation	$ 2,087.86	$ 311.15
Contractor & Engineering Services & Overhead	$ 10,249.63	$ 1,527.50
Total Construction Cost	$ 34,030.69	$ 5,477.50
Electric Power Cost		$ 131.72
Maintenance Cost		$ 352.87
Property Taxes		$ 120.81
Total Operating Cost		$ 605.40
TOTAL ANNUALIZED COST OF DAY TANK		**$ 6,082.90**

Table RC.15. ReCip Technology ReCip Cells Costs—Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Geological Investigation	$ 879.96	$ 131.14
Excavation and Dewatering	$ 6,021.60	$ 897.40
Cut	$ 1,781.47	$ 265.49
On-Site Fill	$ 2,494.80	$ 371.80
Off-Site Fill	$ 12,687.68	$ 1,890.84
Fine Grading and Compaction	$ 3,373.66	$ 502.77
Furnish and Install Liner	$ 32,424.00	$ 4,832.13
Furnish and Install Rip Rap	$ 1,284.61	$ 191.44
Pipes, Valves, and Fittings	$ 7,256.80	$ 1,081.48
Stilling Wells	$ 1,852.80	$ 276.12
Pumps	$ 6,793.60	$ 2,636.14
Furnish and Install No. 4	$ 45,573.63	$ 6,791.82
Overflow Box	$ 1,544.00	$ 230.10
Furnish and Install No. 78	$ 18,775.04	$ 2,798.03
Furnish and Install Cobble	$ 22,727.68	$ 3,387.09
Electrical Installation	$ 3,015.79	$ 449.44
Plants	$ 5,000.00	$ 745.15
Contractor & Engineering Services & Overhead	$ 72,617.95	$ 10,822.22
Total Construction Cost	$ 246,105.06	$ 38,300.61
Electric Power Cost		$ 2,232.97
Maintenance Cost		$ 613.07
Property Taxes		$ 873.67
Total Operating Cost		$ 3,719.71
TOTAL ANNUALIZED COST OF RECIP CELLS		**$ 42,020.32**

Table RC.16. ReCip Technology Liquid Land Application Costs for Four Scenarios—Actual Costs and Performance Data

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	4,861.61	$	4,738.70
If Phosphorus-Based Application	$	2,825.71	$	1,257.50
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		1.66		1.66
If Phosphorus-Based Application		2.78		7.59
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	99.79	$	99.79
If Phosphorus-Based Application	$	166.64	$	455.52
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	4,761.82	$	4,761.82
If Phosphorus-Based Application	$	2,659.07	$	1,332.28
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(23.12)
If Phosphorus-Based Application		-	$	(74.78)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	195.22		-

Note: 904,725 gallons / year of effluent land applied at Corbett Farm #2

Table RC.17. ReCip Technology Solids Application Costs for Four Land Application Scenarios—Actual Costs and Performance Data

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	7,479.97	$	5,248.88
If Phosphorus-Based Application	$	15,567.29	$	5,802.50
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		16.06		52.07
If Phosphorus-Based Application		51.30		137.06
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	963.87		-
If Phosphorus-Based Application	$	3,078.22		-
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	5,427.46	$	6,058.92
If Phosphorus-Based Application	$	6,045.72	$	7,490.70
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(810.04)
If Phosphorus-Based Application		-	$	(1,688.20)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,088.63		-
If Phosphorus-Based Application	$	6,443.54		-

Note: 534,011 gallons / year of slurry land applied at Corbett Farm #2

Table RC.18. ReCip Technology Summary and Mass Balance of Generated and Land Applied Nutrients—Actual Costs and Performance Data

Nutrient Balance	Nitrogen (lbs. / year)	Phosphorus (lbs. / year)
Generated At Barn	36,836.80	10,556.00
Removed in Separated Solids	7,772.56	2,172.42
Unaccounted for Before Entering ReCip Cells	4,678.27	5,278.00
Entering ReCip Cells	24,385.96	3,105.58
Removed by ReCip Technology	21,386.49	1,555.89
Entering Storage Pond and Day Tank	2,999.47	1,549.68
Land Applied in Lagoon Effluent	266.18	137.52

Table RC.19. ReCip Technology Assumptions and Total Annualized Costs—Actual Costs and Performance Data (Corbett Farm #2 filled to capacity)

Number of Animals	**1,820**
Type of Operation	**Feeder-Finish**
Barn Cleaning System	**Flush System**
Liner Material	**Plastic**

Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 65,827.67**	**$ 66,913.17**
	If Phosphorus-Based Application	**$ 72,307.09**	**$ 64,230.17**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 267.90**	**$ 272.34**
	If Phosphorus-Based Application	**$ 294.29**	**$ 261.42**

Note: Daily volume discharged from barns is 19,976 gallons / day including recharge liquid.
SSLW equals 245,700 pounds.

TOTAL CONSTRUCTION COST	**$ 362,210.24**
TOTAL CONTRACTOR AND ENGINEERING SERVICES AND OVERHEAD	**$ 107,587.43**
TOTAL OPERATING COST INCLUDING ROYALTIES	**$ 5,895.47**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION	**$ 62,892.90**

Tables RC.20 through RC.28: Predicted Costs and Returns and Mass Balance Based on Standardized Costs and Performance Data for a 4,320-Head Feeder to Finish Farm with Flush System

Table RC.20. ReCip Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Number of Animals	**4,320**
Type of Operation	**Feeder-Finish**
Barn Cleaning System	**Flush System**
Liner Material	**Plastic**

Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 97,242.22**	**$ 92,560.20**
	If Phosphorus-Based Application	**$ 140,586.70**	**$ 98,523.78**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 166.74**	**$ 158.71**
	If Phosphorus-Based Application	**$ 241.06**	**$ 168.94**

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

Royalty Payments	**Total Cost**	**Annualized Cost**
SYSTEM ROYALTY FEES	**$ 40,430.35**	**$ 6,025.31**

TOTAL CONSTRUCTION COST	**$ 505,379.42**
TOTAL CONTRACTOR AND ENGINEERING SERVICES AND OVERHEAD	**$ 150,352.81**
TOTAL ANNUAL OPERATING COST INCLUDING ROYALTIES	**$ 15,378.43**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION	**$ 93,076.40**

Table RC.21. ReCip Technology Manure Evacuation Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Waste Evacuation/Plumbing Cost	$ 9,110.00	$ 1,357.66
Electrical Wiring for Flush Tanks/Pits	$ 6,852.00	$ 1,021.15
Contractor & Engineering Services & Overhead	$ 6,879.62	$ 1,025.27
Total Construction Cost	$ 22,841.62	$ 3,404.08
Maintenance Cost		$ 319.24
Property Taxes		$ 81.09
Total Operating Costs		$ 400.33
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 3,804.40**

Table RC.22. ReCip Technology Controls Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Control Panel	$ 7,067.20	$ 1,053.22
Power Connection	$ 1,713.00	$ 255.29
Contractor & Engineering Services & Overhead	$ 3,784.27	$ 563.97
Total Construction Cost	$ 12,564.47	$ 1,872.48
Maintenance Cost		$ 175.60
Property Taxes		$ 44.60
Electric Power Cost		$ 292.20
Total Operating Cost		$ 512.41
TOTAL ANNUALIZED COST OF CONTROLS		**$ 2,384.88**

Table RC.23. ReCip Technology Clarifier Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Hatches and Baffles	$ 25,900.61	$ 3,859.95
Stone Base	$ 1,003.60	$ 149.57
Excavation and Dewatering	$ 647.62	$ 96.51
Zabell Filters	$ 1,783.30	$ 265.76
Pumps (Liquids)	$ 3,396.80	$ 1,224.03
Sludge Pump	$ 5,952.11	$ 2,144.83
Pipes, Valves, and Fittings (Sludge Pump)	$ 4,392.67	$ 654.64
Concrete Slab for Sludge Pump	$ 463.20	$ 69.03
Pipes, Valves, and Fittings (Clarifier)	$ 3,481.71	$ 518.88
Electrical Installation	$ 4,782.40	$ 712.72
Storage for Solids	$ 10,000.00	$ 1,490.29
Contractor & Engineering Services & Overhead	$ 26,637.53	$ 3,969.78
Total Construction Cost	$ 88,441.55	$ 15,156.00
Maintenance Cost		$ 1,483.52
Electric Power Cost		$ 174.39
Total Operating Cost		$ 1,657.91
TOTAL ANNUALIZED COST OF CLARIFIER		**$ 16,813.91**

Table RC.24. ReCip Technology Day Tank Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Excavation	$ 675.70	$ 100.70
Stone Base	$ 555.63	$ 82.80
Pumps	$ 1,698.40	$ 659.04
Labor and Materials	$ 8,685.00	$ 1,294.32
Pipes, Valves, and Fittings	$ 4,246.00	$ 632.78
Railing	$ 999.55	$ 148.96
Piping to Flush Tanks	$ 3,000.00	$ 447.09
Electrical Installation	$ 2,074.40	$ 309.15
Contractor & Engineering Services & Overhead	$ 9,453.84	$ 1,408.90
Total Construction Cost	$ 31,388.51	$ 5,083.74
Electric Power Cost		$ 184.01
Maintenance Cost		$ 291.32
Property Taxes		$ 111.43
Total Operating Cost		$ 586.76
TOTAL ANNUALIZED COST OF DAY TANK		**$ 5,670.49**

Table RC.25. ReCip Technology ReCip Cells Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Geological Investigation	$ 870.35	$ 129.71
Excavation and Dewatering	$ 6,860.91	$ 1,022.48
On-Site Fill	$ 6,860.91	$ 1,022.48
Fine Grading and Compaction	$ 4,751.20	$ 708.07
Furnish and Install Liner	$ 45,663.34	$ 6,805.18
Furnish and Install Rip Rap	$ 1,817.02	$ 270.79
Pipes, Valves, and Fittings	$ 12,834.33	$ 1,912.69
Stilling Wells	$ 2,964.48	$ 441.79
Pumps	$ 11,888.80	$ 1,771.78
Furnish and Install No. 4	$ 79,797.84	$ 11,892.23
Overflow Box	$ 1,544.00	$ 230.10
Furnish and Install No. 78	$ 31,013.32	$ 4,621.90
Furnish and Install Cobble	$ 28,313.44	$ 4,219.54
Electrical Installation	$ 5,185.60	$ 772.81
Plants	$ 6,180.18	$ 921.03
Contractor & Engineering Services & Overhead	$ 103,597.55	$ 15,439.09
Total Construction Cost	$ 350,143.27	$ 52,181.67
Electric Power Cost		$ 3,907.70
Maintenance Cost		$ 1,045.01
Property Taxes		$ 1,243.01
Total Operating Cost		$ 6,195.72
TOTAL ANNUALIZED COST OF RECIP CELLS		**$ 58,377.39**

Table RC.26. ReCip Technology Liquid Land Application Costs for Four Scenarios—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	6,012.18	$	4,184.66
If Phosphorus-Based Application	$	10,248.58	$	8,360.40
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		6.53		9.58
If Phosphorus-Based Application		33.15		90.63
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	391.69		-
If Phosphorus-Based Application	$	1,989.26		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	5,620.49	$	4,333.68
If Phosphorus-Based Application	$	5,716.95	$	9,143.75
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(1,008.47)
If Phosphorus-Based Application		-	$	(1,375.76)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	2,542.37		-

Note: 3,551,322 gallons / year of effluent modeled to be land applied

Table RC.27. ReCip Technology Solids Application Costs for Four Land Application Scenarios—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	11,696.82	$	6,269.67
If Phosphorus-Based Application	$	54,346.80	$	9,201.96
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		38.13		123.58
If Phosphorus-Based Application		225.51		602.48
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	2,287.87		-
If Phosphorus-Based Application	$	13,530.66		-
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	6,824.94	$	8,192.41
If Phosphorus-Based Application	$	9,759.18	$	15,212.15
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(1,922.74)
If Phosphorus-Based Application		-	$	(6,010.19)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	2,584.01		-
If Phosphorus-Based Application	$	31,056.97		-

Note: 895,673 gallons / year of slurry modeled to be land applied

Table RC.28. ReCip Technology Summary and Mass Balance of Generated and Land Applied Nutrients—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush System)

Nutrient Balance	Nitrogen (lbs. / year)	Phosphorus (lbs. / year)
Generated At Barn	87,436.80	46,400.00
Removed in Separated Solids	18,449.16	9,549.12
Unaccounted for Before Entering ReCip Cells	11,104.47	23,200.00
Entering ReCip Cells	57,883.16	13,650.88
Removed by ReCip Technology	50,763.53	6,839.09
Entering Storage Pond and Day Tank	7,119.63	6,811.79
Land Applied in Lagoon Effluent	1,715.85	1,641.66

Tables RC.29 through RC.38: Predicted Costs and Returns and Mass Balance Based on Standardized Costs and Performance Data for a 4,320-Head Feeder to Finish Farm with Pit-Recharge

Table RC.29. ReCip Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge System)

Number of Animals	**4,320**
Type of Operation	**Feeder-Finish**
Barn Cleaning System	**Pit-Recharge System**
Liner Material	**Plastic**

Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
(Discounted over 10 years)	If Nitrogen-Based Application	**$ 83,519.21**	**$ 78,541.83**
	If Phosphorus-Based Application	**$ 129,175.86**	**$ 85,564.98**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost		Forages	Row Crops
(Discounted over 10 years)	If Nitrogen-Based Application	**$ 143.21**	**$ 134.67**
	If Phosphorus-Based Application	**$ 221.50**	**$ 146.72**

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

Royalty Payments	**Total Cost**	**Annualized Cost**
SYSTEM ROYALTY FEES	**$ 34,735.83**	**$ 5,176.66**

TOTAL CONSTRUCTION COST	**$ 434,197.89**
TOTAL CONTRACTOR AND ENGINEERING SERVICES AND OVERHEAD	**$ 129,158.25**
TOTAL ANNUAL OPERATING COST INCLUDING ROYALTIES	**$ 13,352.63**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION	**$ 79,665.97**

Table RC.30. ReCip Technology Manure Evacuation Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge System)

Component	Total Cost	Annualized Cost
Waste Evacuation/Plumbing Cost	$ 4,555.00	$ 678.83
Electrical Wiring for Flush Tanks/Pits	$ 6,852.00	$ 1,021.15
Contractor & Engineering Services & Overhead	$ 4,916.42	$ 732.69
Total Construction Cost	$ 16,323.42	$ 2,432.67
Maintenance Cost		$ 228.14
Property Taxes		$ 57.95
Total Operating Costs		*$ 286.09*
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 2,718.76**

Table RC.31. ReCip Technology Controls Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge System)

Component	Total Cost	Annualized Cost
Control Panel	$ 7,067.20	$ 1,053.22
Power Connection	$ 1,713.00	$ 255.29
Contractor & Engineering Services & Overhead	$ 3,784.27	$ 563.97
Total Construction Cost	$ 12,564.47	$ 1,872.48
Maintenance Cost		$ 175.60
Property Taxes		$ 44.60
Electric Power Cost		$ 292.20
Total Operating Cost		$ 512.41
TOTAL ANNUALIZED COST OF CONTROLS		**$ 2,384.88**

Table RC.32. ReCip Technology Holding Pond Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge System)

Component	Total Cost	Annualized Cost
Excavation	$ 5,184.62	$ 772.66
Plastic Liner	$ 8,389.33	$ 1,250.26
Geological Investigation	$ 274.20	$ 40.86
Pumps	$ 1,000.00	$ 360.35
Contractor & Engineering Services & Overhead	$ 6,399.56	$ 953.72
Total Construction Cost	$ 21,247.71	$ 3,377.85
Electric Power Cost		$ 118.09
Maintenance Cost		$ 167.79
Property Taxes		$ 75.43
Total Operating Cost		$ 361.31
TOTAL ANNUALIZED COST OF HOLDING POND		**$ 3,739.16**

Table RC.33. ReCip Technology Clarifier Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge System)

Component	Total Cost	Annualized Cost
Hatches and Baffles	$ 12,950.30	$ 1,929.98
Stone Base	$ 501.80	$ 74.78
Excavation and Dewatering	$ 323.99	$ 48.28
Zabell Filters	$ 891.65	$ 132.88
Pumps (Liquids)	$ 1,698.40	$ 612.02
Sludge Pump	$ 2,976.06	$ 1,072.42
Pipes, Valves, and Fittings (Sludge Pump)	$ 2,196.34	$ 327.32
Concrete Slab for Sludge Pump	$ 231.60	$ 34.52
Pipes, Valves, and Fittings (Clarifier)	$ 1,740.86	$ 259.44
Electrical Installation	$ 2,391.20	$ 356.36
Storage for Solids	$ 10,000.00	$ 1,490.29
Contractor & Engineering Services & Overhead	$ 15,473.84	$ 2,306.06
Total Construction Cost	$ 51,376.03	$ 8,644.35
Maintenance Cost		$ 841.76
Electric Power Cost		$ 147.61
Total Operating Cost		$ 989.38
TOTAL ANNUALIZED COST OF CLARIFIER		**$ 9,633.72**

Table RC.34. ReCip Technology Day Tank Costs—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge System)

Component	Total Cost	Annualized Cost
Excavation	$ 1,137.41	$ 169.51
Stone Base	$ 936.04	$ 139.50
Pumps	$ 1,698.40	$ 659.04
Labor and Materials	$ 8,685.00	$ 1,294.32
Pipes, Valves, and Fittings	$ 4,246.00	$ 632.78
Railing	$ 1,297.35	$ 193.34
Piping to Flush Tanks	$ 3,000.00	$ 447.09
Electrical Installation	$ 2,074.40	$ 309.15
Contractor & Engineering Services & Overhead	$ 9,945.15	$ 1,482.12
Total Construction Cost	$ 33,019.75	$ 5,326.84
Electric Power Cost		$ 309.99
Maintenance Cost		$ 297.28
Property Taxes		$ 117.22
Total Operating Cost		$ 724.48
TOTAL ANNUALIZED COST OF DAY TANK		**$ 6,051.33**

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

Component	Total Cost	Annualized Cost
Geological Investigation	$ 792.86	$ 118.16
Excavation and Dewatering	$ 5,862.42	$ 873.67
On-Site Fill	$ 5,862.42	$ 873.67
Fine Grading and Compaction	$ 4,170.61	$ 621.54
Furnish and Install Liner	$ 40,083.36	$ 5,973.60
Furnish and Install Rip Rap	$ 1,621.20	$ 241.61
Pipes, Valves, and Fittings	$ 10,392.93	$ 1,548.85
Stilling Wells	$ 2,593.92	$ 386.57
Pumps	$ 10,190.40	$ 1,518.67
Furnish and Install No. 4	$ 67,884.30	$ 10,116.76
Overflow Box	$ 1,544.00	$ 230.10
Furnish and Install No. 78	$ 26,941.65	$ 4,015.10
Furnish and Install Cobble	$ 23,274.11	$ 3,468.53
Electrical Installation	$ 4,444.80	$ 662.41
Plants	$ 5,368.52	$ 800.07
Contractor & Engineering Services & Overhead	$ 88,639.02	$ 13,209.83
Total Construction Cost	$ 299,666.51	$ 44,659.15
Electric Power Cost		$ 3,349.46
Maintenance Cost		$ 889.03
Property Taxes		$ 1,063.82
Total Operating Cost		$ 5,302.31
TOTAL ANNUALIZED COST OF RECIP CELLS		**$ 49,961.45**

Table RC.36. ReCip Technology Liquid Land Application Costs for Four Scenarios—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge System)

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	6,071.96	$	3,919.65
If Phosphorus-Based Application	$	12,565.06	$	9,078.26
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		6.78		11.88
If Phosphorus-Based Application		41.14		112.45
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	406.86		-
If Phosphorus-Based Application	$	2,468.28		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	5,665.10	$	4,104.56
If Phosphorus-Based Application	$	6,942.22	$	10,050.24
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(184.90)
If Phosphorus-Based Application		-	$	(971.98)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	3,154.57		-

Note: 3,688,830 gallons / year of effluent modeled to be land applied

Table RC.37. ReCip Technology Solids Application Costs for Four Land Application Scenarios—Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge System)

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	11,324.46	$	5,926.73
If Phosphorus-Based Application	$	54,029.92	$	8,935.73
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		38.13		123.58
If Phosphorus-Based Application		225.51		602.48
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	2,287.87		-
If Phosphorus-Based Application	$	13,530.66		-
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	6,452.58	$	7,849.47
If Phosphorus-Based Application	$	9,442.30	$	14,945.92
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(1,922.74)
If Phosphorus-Based Application		-	$	(6,010.19)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	2,584.01		-
If Phosphorus-Based Application	$	31,056.97		-

Note: 758,165 gallons / year of slurry modeled to be land applied

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

Nutrient Balance	Nitrogen (lbs. / year)	Phosphorus (lbs. / year)
Generated At Barn	87,436.80	46,400.00
Removed in Separated Solids	18,449.16	9,549.12
Unaccounted for Before Entering ReCip Cells	11,104.47	23,200.00
Entering ReCip Cells	57,883.16	13,650.88
Removed by ReCip Technology	50,763.53	6,839.09
Entering Storage Pond and Day Tank	7,119.63	6,811.79
Land Applied in Lagoon Effluent	2,129.03	2,036.97

Tables RC.39 through RC.47: Predicted Costs and Returns and Mass Balance Based on Standardized Costs and Performance Data for an 8,800-Head Feeder to Finish Farm with Flush System

Table RC.39. ReCip Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Number of Animals	**8,800**
Type of Operation	**Feeder-Finish**
Barn Cleaning System	**Flush System**
Liner Material	**Plastic**

Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 171,472.08**	**$ 161,621.15**
	If Phosphorus-Based Application	**$ 200,196.53**	**$ 163,340.95**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 144.34**	**$ 136.05**
	If Phosphorus-Based Application	**$ 168.52**	**$ 137.49**

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

Royalty Payments	**Total Cost**	**Annualized Cost**
SYSTEM ROYALTY FEES	**$ 72,174.62**	**$ 10,756.15**

TOTAL CONSTRUCTION COST	**$ 902,182.81**
TOTAL CONTRACTOR AND ENGINEERING SERVICES AND OVERHEAD	**$ 268,271.77**
TOTAL ANNUAL OPERATING COST INCLUDING ROYALTIES	**$ 27,067.02**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION	**$ 164,888.20**

Table RC.40. ReCip Technology Manure Evacuation Costs—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Waste Evacuation/Plumbing Cost	$ 18,220.00	$ 2,715.32
Electrical Wiring for Flush Tanks/Pits	$ 13,704.00	$ 2,042.30
Contractor & Engineering Services & Overhead	$ 13,759.24	$ 2,050.53
Total Construction Cost	$ 45,683.24	$ 6,808.15
Maintenance Cost		$ 638.48
Property Taxes		$ 162.18
Total Operating Costs		$ 800.66
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 7,608.81**

Table RC.41. ReCip Technology Controls Costs—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Control Panel	$ 7,067.20	$ 1,053.22
Power Connection	$ 1,713.00	$ 255.29
Contractor & Engineering Services & Overhead	$ 3,784.27	$ 563.97
Total Construction Cost	$ 12,564.47	$ 1,872.48
Maintenance Cost		$ 175.60
Property Taxes		$ 44.60
Electric Power Cost		$ 292.20
Total Operating Cost		$ 512.41
TOTAL ANNUALIZED COST OF CONTROLS		**$ 2,384.88**

Table RC.42. ReCip Technology Clarifier Costs—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Hatches and Baffles	$ 38,850.91	$ 5,789.93
Stone Base	$ 1,505.40	$ 224.35
Excavation and Dewatering	$ 970.88	$ 144.69
Zabell Filters	$ 2,674.94	$ 398.65
Pumps (Liquids)	$ 5,095.20	$ 1,836.05
Sludge Pump	$ 8,928.17	$ 3,217.25
Pipes, Valves, and Fittings (Sludge Pump)	$ 6,589.01	$ 981.96
Concrete Slab for Sludge Pump	$ 694.80	$ 103.55
Pipes, Valves, and Fittings (Clarifier)	$ 5,222.57	$ 778.32
Electrical Installation	$ 7,173.60	$ 1,069.08
Storage for Solids	$ 10,000.00	$ 1,490.29
Contractor & Engineering Services & Overhead	$ 37,801.06	$ 5,633.47
Total Construction Cost	$ 125,506.54	$ 21,667.58
Maintenance Cost		$ 2,125.29
Electric Power Cost		$ 355.23
Total Operating Cost		$ 2,480.52
TOTAL ANNUALIZED COST OF CLARIFIER		**$ 24,148.10**

Table RC.43. ReCip Technology Day Tank Costs—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Excavation	$ 1,374.75	$ 204.88
Stone Base	$ 1,131.83	$ 168.68
Pumps	$ 1,698.40	$ 659.04
Labor and Materials	$ 8,685.00	$ 1,294.32
Pipes, Valves, and Fittings	$ 4,246.00	$ 632.78
Railing	$ 1,426.60	$ 212.61
Piping to Flush Tanks	$ 3,000.00	$ 447.09
Electrical Installation	$ 2,074.40	$ 309.15
Contractor & Engineering Services & Overhead	$ 10,187.54	$ 1,518.24
Total Construction Cost	$ 33,824.52	$ 5,446.78
Electric Power Cost		$ 374.83
Maintenance Cost		$ 299.86
Property Taxes		$ 120.08
Total Operating Cost		$ 794.77
TOTAL ANNUALIZED COST OF DAY TANK		**$ 6,241.54**

Table RC.44. ReCip Technology ReCip Cells Costs—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Component	Total Cost	Annualized Cost
Geological Investigation	$ 1,344.35	$ 200.35
Excavation and Dewatering	$ 13,448.37	$ 2,004.20
On-Site Fill	$ 13,448.37	$ 2,004.20
Fine Grading and Compaction	$ 8,478.74	$ 1,263.58
Furnish and Install Liner	$ 81,488.50	$ 12,144.19
Furnish and Install Rip Rap	$ 2,860.89	$ 426.36
Pipes, Valves, and Fittings	$ 30,191.08	$ 4,499.36
Stilling Wells	$ 5,187.84	$ 773.14
Pumps	$ 22,079.20	$ 3,290.45
Furnish and Install No. 4	$ 159,621.70	$ 23,788.34
Overflow Box	$ 1,544.00	$ 230.10
Furnish and Install No. 78	$ 57,553.26	$ 8,577.13
Furnish and Install Cobble	$ 63,516.94	$ 9,465.90
Electrical Installation	$ 9,630.40	$ 1,435.21
Plants	$ 11,470.74	$ 1,709.48
Contractor & Engineering Services & Overhead	$ 202,739.66	$ 30,214.19
Total Construction Cost	$ 684,604.03	$ 102,026.19
Electric Power Cost		$ 7,257.16
Maintenance Cost		$ 2,035.03
Property Taxes		$ 2,430.34
Total Operating Cost		$ 11,722.53
TOTAL ANNUALIZED COST OF RECIP CELLS		**$ 113,748.22**

Table RC.45. ReCip Technology Liquid Land Application Costs for Four Scenarios—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	7,577.71	$	5,739.12
If Phosphorus-Based Application	$	11,134.93	$	9,000.24
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		13.15		19.51
If Phosphorus-Based Application		33.15		90.63
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	788.87		-
If Phosphorus-Based Application	$	1,989.26		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	6,788.83	$	6,042.67
If Phosphorus-Based Application	$	6,861.32	$	9,916.68
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(303.56)
If Phosphorus-Based Application		-	$	(916.44)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	2,284.36		-

Note: 7,152,423 gallons / year of effluent modeled to be land applied

Table RC.46. ReCip Technology Solids Application Costs for Four Land Application Scenarios—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	19,576.53	$	8,203.86
If Phosphorus-Based Application	$	53,011.44	$	9,229.86
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		77.67		251.75
If Phosphorus-Based Application		225.51		602.48
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	4,660.48		-
If Phosphorus-Based Application	$	13,530.66		-
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	9,652.32	$	12,120.56
If Phosphorus-Based Application	$	11,752.87	$	16,957.17
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(3,916.70)
If Phosphorus-Based Application		-	$	(7,727.31)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	5,263.73		-
If Phosphorus-Based Application	$	27,727.92		-

Note: 1,824,519 gallons / year of slurry modeled to be land applied

Table RC.47. ReCip Technology Summary and Mass Balance of Generated and Land Applied Nutrients—Standardized Quantities and Prices (8,800-Head Feeder-Finish with Flush System)

Nutrient Balance	Nitrogen (lbs. / year)	Phosphorus (lbs. / year)
Generated At Barn	178,112.00	46,400.00
Removed in Separated Solids	37,581.63	9,549.12
Unaccounted for Before Entering ReCip Cells	22,620.22	23,200.00
Entering ReCip Cells	117,910.14	13,650.88
Removed by ReCip Technology	103,407.20	6,839.09
Entering Storage Pond and Day Tank	14,502.95	6,811.79
Land Applied in Lagoon Effluent	3,495.26	1,641.66

Tables RC.48 through RC.56: Predicted Costs and Returns and Mass Balance Based on Standardized Costs and Performance Data for a 4,000-Sow Farrow to Wean Farm with Flush System

Table RC.48. ReCip Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Number of Animals	**4,000**
Type of Operation	**Farrow-Wean**
Barn Cleaning System	**Flush System**
Liner Material	**Plastic**

Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 353,360.97**	**$ 348,730.37**
	If Phosphorus-Based Application	**$ 378,688.13**	**$ 346,915.75**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 204.02**	**$ 201.35**
	If Phosphorus-Based Application	**$ 218.64**	**$ 200.30**

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

Royalty Payments	**Total Cost**	**Annualized Cost**
SYSTEM ROYALTY FEES	**$ 152,562.16**	**$ 22,736.26**

TOTAL CONSTRUCTION COST	**$ 1,907,027.02**
TOTAL CONTRACTOR AND ENGINEERING SERVICES AND OVERHEAD	**$ 566,960.73**
TOTAL ANNUAL OPERATING COST INCLUDING ROYALTIES	**$ 57,859.81**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION	**$ 349,383.60**

Table RC.49. ReCip Technology Manure Evacuation Costs—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Component	Total Cost	Annualized Cost
Waste Evacuation/Plumbing Cost	$ 12,754.00	$ 1,900.72
Electrical Wiring for Flush Tanks/Pits	$ 9,592.80	$ 1,429.61
Contractor & Engineering Services & Overhead	$ 9,631.47	$ 1,435.37
Total Construction Cost	$ 31,978.27	$ 4,765.71
Maintenance Cost		$ 446.94
Property Taxes		$ 113.52
Total Operating Costs		$ 560.46
TOTAL ANNUALIZED COST OF MANURE EVACUATION		**$ 5,326.16**

Table RC.50. ReCip Technology Controls Costs—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Component	Total Cost	Annualized Cost
Control Panel	$ 7,067.20	$ 1,053.22
Power Connection	$ 1,713.00	$ 255.29
Contractor & Engineering Services & Overhead	$ 3,784.27	$ 563.97
Total Construction Cost	$ 12,564.47	$ 1,872.48
Maintenance Cost		$ 175.60
Property Taxes		$ 44.60
Electric Power Cost		$ 292.20
Total Operating Cost		$ 512.41
TOTAL ANNUALIZED COST OF CONTROLS		**$ 2,384.88**

Table RC.51. ReCip Technology Clarifier Costs—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Component	Total Cost	Annualized Cost
Hatches and Baffles	$ 90,652.13	$ 13,509.84
Stone Base	$ 3,512.60	$ 523.48
Excavation and Dewatering	$ 2,260.31	$ 336.85
Zabell Filters	$ 6,241.54	$ 930.17
Pumps (Liquids)	$ 11,888.80	$ 4,284.11
Sludge Pump	$ 20,832.39	$ 7,506.92
Pipes, Valves, and Fittings (Sludge Pump)	$ 15,374.35	$ 2,291.23
Concrete Slab for Sludge Pump	$ 1,621.20	$ 241.61
Pipes, Valves, and Fittings (Clarifier)	$ 12,185.99	$ 1,816.07
Electrical Installation	$ 16,738.40	$ 2,494.52
Storage for Solids	$ 10,000.00	$ 1,490.29
Contractor & Engineering Services & Overhead	$ 82,453.62	$ 12,288.02
Total Construction Cost	**$ 273,761.34**	**$ 47,713.12**
Maintenance Cost		$ 4,692.33
Electric Power Cost		$ 825.39
Total Operating Cost		$ 5,517.72
TOTAL ANNUALIZED COST OF CLARIFIER		**$ 53,230.84**

Table RC.52. ReCip Technology Day Tank Costs—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Component	Total Cost	Annualized Cost
Excavation	$ 3,701.16	$ 551.58
Stone Base	$ 3,059.55	$ 455.96
Pumps	$ 1,698.40	$ 659.04
Labor and Materials	$ 8,685.00	$ 1,294.32
Pipes, Valves, and Fittings	$ 4,246.00	$ 632.78
Railing	$ 2,345.53	$ 349.55
Piping to Flush Tanks	$ 3,000.00	$ 447.09
Electrical Installation	$ 2,074.40	$ 309.15
Contractor & Engineering Services & Overhead	$ 12,417.13	$ 1,850.52
Total Construction Cost	$ 41,227.17	$ 6,549.99
Electric Power Cost		$ 1,013.24
Maintenance Cost		$ 318.24
Property Taxes		$ 146.36
Total Operating Cost		$ 1,477.83
TOTAL ANNUALIZED COST OF DAY TANK		**$ 8,027.82**

Table RC.53. ReCip Technology ReCip Cells Costs—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Component	Total Cost	Annualized Cost
Geological Investigation	$ 2,419.05	$ 360.51
Excavation and Dewatering	$ 21,514.03	$ 3,206.22
On-Site Fill	$ 21,514.03	$ 3,206.22
Fine Grading and Compaction	$ 17,549.85	$ 2,615.44
Furnish and Install Liner	$ 168,670.09	$ 25,136.82
Furnish and Install Rip Rap	$ 4,685.03	$ 698.21
Pipes, Valves, and Fittings	$ 78,075.92	$ 11,635.61
Stilling Wells	$ 11,487.36	$ 1,711.96
Pumps	$ 50,952.00	$ 7,593.35
Furnish and Install No. 4	$ 365,071.19	$ 54,406.37
Overflow Box	$ 1,544.00	$ 230.10
Furnish and Install No. 78	$ 123,476.89	$ 18,401.70
Furnish and Install Cobble	$ 158,750.57	$ 23,658.52
Electrical Installation	$ 22,224.00	$ 3,312.03
Plants	$ 24,612.18	$ 3,667.94
Contractor & Engineering Services & Overhead	$ 458,674.24	$ 68,355.99
Total Construction Cost	$ 1,547,495.78	$ 230,622.50
Electric Power Cost		$ 16,747.29
Maintenance Cost		$ 4,814.23
Property Taxes		$ 5,493.61
Total Operating Cost		$ 27,055.13
TOTAL ANNUALIZED COST OF RECIP CELLS		**$ 257,677.63**

Table RC.54. ReCip Technology Liquid Land Application Costs for Four Scenarios—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	7,927.42	$	6,953.04
If Phosphorus-Based Application	$	8,945.18	$	8,005.45
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		14.63		14.63
If Phosphorus-Based Application		16.09		43.99
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	877.59		-
If Phosphorus-Based Application	$	965.58		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	7,049.83	$	7,049.83
If Phosphorus-Based Application	$	6,786.39	$	8,406.74
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(96.79)
If Phosphorus-Based Application		-	$	(401.30)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		-
If Phosphorus-Based Application	$	1,193.22		-

Note: 7,956,859 gallons / year of effluent modeled to be land applied

Table RC.55. ReCip Technology Solids Application Costs for Four Land Application Scenarios—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	20,577.05	$	12,957.36
If Phosphorus-Based Application	$	59,811.97	$	14,696.52
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		51.02		165.37
If Phosphorus-Based Application		225.51		602.48
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	3,061.43		-
If Phosphorus-Based Application	$	13,530.66		-
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	14,057.93	$	15,530.20
If Phosphorus-Based Application	$	16,309.73	$	21,260.55
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(2,572.84)
If Phosphorus-Based Application		-	$	(6,570.03)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	3,457.69		-
If Phosphorus-Based Application	$	29,971.58		-

Note: 4,239,315 gallons / year of slurry modeled to be land applied

Table RC.56. ReCip Technology Summary and Mass Balance of Generated and Land Applied Nutrients—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Flush System)

Nutrient Balance	Nitrogen (lbs. / year)	Phosphorus (lbs. / year)
Generated At Barn	117,000.00	46,400.00
Removed in Separated Solids	24,687.00	9,549.12
Unaccounted for Before Entering ReCip Cells	14,859.00	23,200.00
Entering ReCip Cells	77,454.00	13,650.88
Removed by ReCip Technology	67,927.16	6,839.09
Entering Storage Pond and Day Tank	9,526.84	6,811.79
Land Applied in Lagoon Effluent	1,114.46	796.85

Tables RC.57 and RC.58: Predicted Costs and Returns Extrapolated to Various Representative Farm Sizes and Farm Types Based on Standardized Costs and Performance Data for Flush and Pit-Recharge Systems

Table RC.57. $ / 1,000 Pounds of Steady-State Live Weight (SSLW) for DWQ Permitted Representative Type of Operation / Size of Farm Combinations—ReCip Technology

	Size of Farm (1,000 pounds SSLW)				
	0-500	**500-1000**	**1000-1500**	**1500-2000**	**> 2000**
Type of Operation					
Farrow-wean					
Rep. # of sows	752	1,540	2,400	4,000	6,000
Pit-recharge system	$245.83	$200.44	$188.33	$176.05	$167.95
Flush system	$240.47	$225.23	$209.70	$204.02	$198.28
Farrow-feeder					
Rep. # of sows	500	1,200	2,000	3,600	5,500
Pit-recharge system	$271.94	$201.70	$194.61	$181.01	$174.28
Flush system	$339.61	$283.29	$272.72	$258.68	$253.76
Farrow-finish					
Rep. # of sows	150	500	1,000	1,200	2,000
Pit-recharge system	$245.13	$158.62	$143.37	$139.69	$133.10
Flush system	$267.37	$196.64	$183.50	$182.85	$176.33
Wean-feeder					
Rep. head capacity	3,840	20,000	N/A	N/A	N/A
Pit-recharge system	$343.23	$163.34	N/A	N/A	N/A
Flush system	$773.47	$596.54	N/A	N/A	N/A
Feeder-finish					
Rep. head capacity	2,448	5,280	8,800	12,240	17,136
Pit-recharge system	$176.86	$138.02	$119.69	$118.03	$111.58
Flush system	$183.59	$156.01	$144.34	$139.33	$133.75

Table RC.58. $ / 1,000 Pounds of Steady-State Live Weight (SSLW) for Smithfield Foods/Premium Standard Farms Representative Type of Operation / Size of Farm Combinations—ReCip Technology

	Size of Farm (1,000 pounds SSLW)				
	0-500	**500-1000**	**1000-1500**	**1500-2000**	**> 2000**
Type of Operation					
Farrow-wean					
Rep. # of sows	650	1,700	2,400	4,000	7,000
Pit-recharge system	$261.28	$196.24	$188.33	$176.05	$169.78
Flush system	$251.08	$218.89	$209.70	$204.02	$197.70
Farrow-feeder					
Rep. # of sows	675	1,200	2,000	3,419	5,500
Pit-recharge system	$239.25	$201.70	$194.61	$182.84	$174.28
Flush system	$310.32	$283.29	$272.72	$261.39	$253.76
Farrow-finish					
Rep. # of sows	N/A	500	1,000	1,200	2,000
Pit-recharge system	N/A	$158.62	$143.37	$139.69	$133.10
Flush system	N/A	$196.64	$183.50	$182.85	$176.33
Wean-feeder					
Rep. head capacity	2,808	N/A	N/A	N/A	N/A
Pit-recharge system	$411.40	N/A	N/A	N/A	N/A
Flush system	$793.00	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	$255.53	$139.90	$119.69	$118.01	$111.58
Flush system	$249.38	$158.31	$144.34	$139.31	$133.75

Appendix RC.A RECIP SYSTEM DRAWING