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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: BELT SYSTEMS (LAKE WHEELER AND VAN KEMPEN-KOGER)

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
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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1. Introduction

A prospective cost analysis is developed here for retrofit installation and use of under-floor belts for manure removal in four types of feeder to finish barns that are common in North Carolina. In addition to our standard excretion and land application assumptions, three studies were used to develop this analysis. Reports on evaluations of two North Carolina State University **pilot-scale** belt systems for manure removal from swine barns are used to establish solids-liquids and nutrient separation efficiency. These reports are also used to raise other issues that may have very substantial effects on costs and performance of full-scale commercial systems but have yet to be proven in such settings.. This analysis also relies heavily on an analysis prepared by Elmer Environmental, a professional engineering firm, to develop initial designs and cost estimates for retrofitting full-scale commercial swine finishing barns with under-floor belts.

The pilot scale belt system located at the NCSU Agricultural Research Station on Lake Wheeler Road, formerly known as the Gannet-Fleming Belt System is referred to as the 'Lake Wheeler Belt System' throughout this document. The pilot scale belt system located at Grinnells Labs is part of the Re-Cycle technology. It is being referred to as the 'Van Kempen-Koger Belt System' in this report.

IT IS IMPORTANT TO KEEP IN MIND THAT NO FULL-SCALE COMMERCIAL SWINE BUILDING OF THE TYPES USED IN NORTH CAROLINA HAS BEEN RETROFITTED WITH A BELT SYSTEM. Therefore, these cost estimates are very preliminary and many questions remain about the practical installation, operation, and maintenance of such belt systems and their effects on productivity and the environment in a commercial setting. Proposals have been made to equip a new building with a belt system at an NCSU / NCDA&CS agricultural research station.

2. Technology Description of the Lake Wheeler Belt System

The experimental facility for this belt system for swine manure removal from barns was located at North Carolina State University's Lake Wheeler Road Field Laboratory in Raleigh, North Carolina. The system is intended to maintain separation of swine manure solids (feces and spilled feed) and liquid (urine and spilled water) streams. The Lake Wheeler experimental facility consisted of five pens containing a total of fifteen feeder to finish pigs. It was designed to resemble a small-scale swine finishing facility. In the pilot-scale facility, the floors were tribar with space between bars to allow for manure to drop onto the belt below. The belt itself has a convex shape allowing liquid to gravity flow into gutters that are positioned on either side of the belt. From the gutters, this liquid flows to an enclosed collection tank for additional processing. The manure solids remain on the belt and are carried to a hopper at one end of the belt. Solids are periodically conveyed by an auger to outside storage.

The Lake Wheeler belt system became operational on October 7, 2002. Its evaluation period ran from January 13, 2003 to January 7, 2004. During this timeframe, belt solids and liquids were collected, measured, and analyzed for three consecutive rotations of pigs. The Lake Wheeler belt system was intended for use with complementary technologies. Alternative utilization of manure solids evaluated under the Agreement included the Black Soldier Fly biomass conversion project. Other technologies that can be used to recover by-products from the manure solids but were not evaluated under the Agreement include high-temperature charring, lime stabilization, and vermicomposting. An ammonia stripping process can be used to recover ammonia from the separated liquid.

In the Lake Wheeler experimental facility, separated liquids were drained from the barn and collected in a one-stage lagoon before being land applied at a later date. Separated solids were delivered to the Black Soldier Fly technology providers in close proximity to the experimental site at Lake Wheeler Road Field Laboratory. In a commercial facility, both separated liquids and solids would need to be stored and storage-related costs would be incurred. In the cost tables that follow, no costs have been allocated to the storage of either separated liquids or solids.

2.1 Lake Wheeler Experimental Facility Nutrient Content and Manure Characteristics

Tables BELTS.1-BELTS.3 are derived from the report by Rice et al. and summarize the nutrient content and quantity of manure produced at the Lake Wheeler experimental facility. Table BELTS.1 reports by rotation the amount of manure solids (in lbs / pig / day) and liquid (in gal. / pig / day) produced at the facility. Table BELTS.2 characterizes the manure solids. Nearly all of the total phosphorus (91 %) is contained in the solids. Conversely, less than half (41 %) of TKN is found in the solids. For each of the three rotations, approximately 67 % of the manure solids mass was moisture. Table BELTS.3 characterizes the liquid from the Lake Wheeler belt. It contained the majority of the TKN (59 %) and a small fraction of the total phosphorus (9 %) collected by the Lake Wheeler belt system (Rice, et al.).

2.2. Invoiced Costs of Lake Wheeler Belt System

Table BELTS.4 shows the actual invoiced costs associated with the Lake Wheeler pilot scale belt system. Table BELTS.5 lists the components that comprise the $54,000 expense for belt construction and design. Included are the cost of the belt itself, plus costs for support structures, motors, augers, and gear reducers. Also included are the labor costs borne by the Lake Wheeler belt system technology providers. Table BELTS.6 shows the construction parameters associated with the Lake Wheeler belt system, as it was constructed at the experimental facility. Tables BELTS.4 and BELTS.5 represent the actual costs realized at the Lake Wheeler facility for this pilot scale belt system. They do not represent the costs associated with retrofitting this technology to an existing farm operation.

3. Technology Description of the Van Kempen-Koger Belt System

The van Kempen-Koger belt system was tested in an experimental facility at Grinnells Lab on the campus of North Carolina State University in Raleigh, North Carolina. The technology is a belt-based manure harvesting system intended to separate the solid and liquid portions of swine manure so that they can be treated more effectively by other technologies. The system also partially dries the manure solids on the belt using ventilation air. It is proposed that the manure solids will be treated at a centralized gasification/steam reforming facility where thermal decomposition will produce a medium-steam Btu gas and a mineral ash. Likewise separated liquid is proposed to be directed to an enclosed vessel and ultimately processed in a sequencing batch reactor. In the reactor, nitrogen will be returned to the atmosphere while the treated effluent can be used as irrigation water. The economic analyses in this section deal only with the van Kempen-Koger belt system, not with any complementary technologies.

The van Kempen-Koger belt runs beneath the slatted portion of the partially-slatted pen. The slightly-sloped orientation of the belt allows urine and spilled water to drain into a sloped gutter where it travels by gravity to a covered storage container. The manure solids can be dried to 50-80 % dry matter (DM) during their 24-hour residence time on the belt (Koger(b)). Separated and partially dried solids are collected at the end of the first belt by a second belt. This transverse belt system transports the solids to an outside storage bin.

3.1. Grinnells Experimental Facility Nutrient Content and Manure Characteristics

Table BELTS.7 summarizes the amount of manure produced at the Grinnells Lab experimental facility. The data were collected from five trials involving grower pigs conducted between August, 2001 and April, 2003. Average daily outputs per pig for both solids and liquid are given in Table BELTS.7. Solids output in Table BELTS.7 is reported in units of dry matter (DM). For the five trials, the moisture content of the manure solids ranged from 46 % to 57 % with an average moisture content of 51 % (Koger(b)). The separated liquids contained 0.69 % of N and 0.02 % of P. The nutrient concentration of separated solids on a dry matter (DM) basis was 3.89 % N and 1.88 % P (van Kempen).

3.2. Invoiced Costs of Van Kempen-Koger Belt System

Some components for the van Kempen-Koger belt system were either donated to the project or available "on site" at Grinnells Lab. As such, the actual cost of assembling the experimental belt system was less than the cost of constructing the system with entirely purchased components. Table BELTS.8 details the components that were actually purchased for inclusion in the van Kempen-Koger belt system. Table BELTS.9 summarizes the components that were donated to the project or readily available at the lab. Table BELTS.10 shows the replacement cost of assembling the van Kempen-Koger belt system at the experimental facility. By replacement

cost, it is meant that all necessary components would be purchased and included in the cost of the project. The total in Table BELTS.10 includes all of the itemized costs detailed in Tables BELTS.8 and BELTS.9. Again, the costs in Tables BELTS.8-BELTS.10 reflect invoiced costs associated with the Grinnells Lab facility. They do not represent the costs of retrofitting the pilot-scale technology onto an existing pig farm.
Appendix BELTS.A provides a more detailed description of the materials used in constructing the van Kempen-Koger experimental belt system. Some of the itemized components in Tables BELTS.8 and BELTS.9 are described more completely in Appendix BELTS.A. Appendix BELTS.B provides pictures and drawings of the experimental belt system and its components. It clarifies terms used in Tables BELTS.8- BELTS.10 and illustrates the role of specific components in the overall technology.

4. Rough Design and Cost Study of Retrofitting Belt System Technology to Existing Barns

Katie Elmer of Elmer Environmental, LLC was contracted to provide rough design and cost estimates for retrofitting 4 typical barn types with under floor belts for manure removal. She was provided with a set of guidelines that reflected the types of belts used in the pilot scale evaluations. In order to construct a prospective cost model for retrofitting a belt system to existing barns, four common types of finishing barns were chosen to define the design constraints of existing facilities. These finishing barns are the four predominant types used by the North Carolina Murphy-Brown LLC company.

Type I is a 1,224-head finishing barn with natural ventilation, partially slatted floors, and a flush system for manure removal. Type II is an 800-head finishing barn with natural ventilation, fully slatted floors, and a pit-recharge system for manure removal. Type III is an 800-head finishing barn with tunnel ventilation, fully slatted floors, and either flush or pit-recharge systems of manure removal. Finally, Type IV can be characterized as an 880-head finishing barn with tunnel ventilation, fully slatted floors, and either flush or pit-recharge systems of manure removal (Elmer). See Table BELTS.11 for additional barn specifications and manure characteristics associated with the four types (I-IV) of finishing barns used in this cost model. Type I barns (partially slatted floors) have 2 pits / barn whereas the remaining types (II-IV) have 4 pits / barn (fully slatted floors). Additional pits require additional belts. Table BELTS.12 details the specifications of the belt system for each of the four finishing barns used in the cost model. Used in conjunction, Tables BELTS.11 and BELTS.12 allow for the cost of belt construction materials to be calculated for each barn type. In addition to the costs of materials, there are costs associated with retrofitting the belt system technology to an existing facility. These costs are assumed equal across all types of barns, as retrofitting expenditures are modeled as independent of existing pit specifications. Retrofitting costs can be defined as facility modifications necessary to accommodate a new technology or process. It is estimated that there will be a break in production of approximately two weeks per barn in order to install the belt and replace the slats and penning. The costs associated with the belt's installation are the final component of the belt system technology's construction costs. Total construction costs are equal to the sum of material costs, retrofitting costs, and installation costs. Operating costs for the belt system technology include maintenance costs, property taxes, and electricity costs. Annualized construction costs plus operating costs are added to arrive at a total annualized cost for the technology.

5. A Prospective Cost Analysis of Retrofitting Feeder to Finish Farms with a Belt System

Tables BELTS.13 through BELTS.33 were constructed using an economic model incorporating *standardized quantities and prices* for the belt system technology. Two representative feeder-to-finish farm sizes were analyzed in the standardized belt system model: a 4,320-head facility and an 8,800-head facility. Specifically, Tables BELTS.13- BELTS.25 describe the standardized 4,320-head finishing facility, while Tables 26-33 present the standardized 8,800-head finishing facility. Two belt materials were included in the cost analysis (4-mm, 2 ply poly/PVC proposed by Elmer Environmental and 1.2-mm, HDPE proposed by Theo van Kempen). The cost of the 4-mm belt includes delivery fees and was estimated by Elmer Environmental to cost $4.80 per square foot. Currently, there is not a manufacturer in the U.S. that makes 1.2-mm belt of desired specifications at 2.4-m width. Theo van Kempen contacted DRC Polymer Products in Great Britain and they provided a quote for high density polyethylene, 1.2-mm belt at approximately $0.30 per square foot. The model was also estimated with alternative price assumptions for the 1.2-mm belt material to address higher price uncertainty due to the fact that there is no U.S. manufacturer. A delivery charge of $500 per barn is assumed. The results of the comparison for the 4-mm belt and 1.2-mm belt are shown in Tables BELTS.24, BELTS.25 and BELTS.33.

Table BELTS.13 provides the incremental annualized costs ($ / 1,000 lbs. SSLW) associated with Type I barns (as described above). These annualized costs are given for each of four land application scenarios. In Table BELTS.14, these costs are detailed and categorized by material costs, retrofitting costs, installation costs, and operating costs. Table BELTS.14 also provides a summary of total construction cost per barn, total operating cost per barn, total annualized cost per barn, and total incremental annualized cost per barn ($ / 1,000 lbs. SSLW). These total annualized costs exclude land application costs but include the construction and operating costs associated with the actual belt system technology. The costs summarized at the bottom of Table BELTS.14 are added to land application costs (that differ based on application scenario) to derive the total annualized costs listed in Table BELTS.13 for Type I barns. Identical cost analyses are performed for each of the four types of finishing barn. Tables BELTS.15 and BELTS.16 pertain to Type II barns. Tables BELTS.17 and BELTS.18 detail the costs associated with Type III barns, while the Type IV barn costs are listed in Tables BELTS.19 and BELTS.20. Table BELTS.21 summarizes the costs associated with land application of liquids for each of four land application scenarios. Table BELTS.22 details the costs of land applying solids for the same four scenarios. Tables BELTS.21 and BELTS.22 are the same for each of the four types of barn. Table BELTS.23 shows a mass balance of nutrients generated and land applied when using the belt system technology at a standardized 4,320-head finishing facility. Again, the mass balance of nutrients will be the same across each of the four types of finishing barns. Tables BELTS.24 and BELTS.25 compare costs for 4-mm and 1.2-mm belt materials. The cost of the belt is significantly lower when 1.2-mm material is used (Table BELTS.24). The annualized cost per 1,000 lbs of SSLW for retrofitting the belt system is approximately $20 lower ($69 vs. $89 / 1000 lbs. SSLW / year) when 1.2-mm material is used.

Tables BELTS.26- BELTS.29 report the incremental annualized costs of the belt system for each of the four types of finishing barns when modeling a standardized 8,800-head facility. There are no itemized cost tables for the 8,800-head facility, as there are for the 4,320-head facility in Tables BELTS.14, BELTS.16, BELTS.18, and BELTS.20. Estimated construction and operating costs will be the same for the belt system technology in the 4,300-head and 8,800-head facilities on a $ / 1,000 lbs. SSLW basis. The numbers in Tables BELTS.14, BELTS.16, BELTS.18, and BELTS.20 are identical to the cost numbers for an 8,800-head facility when using barn types I, II, III, and IV respectively. Land application costs differ for different sized facilities. Because of this, the total incremental annualized costs of retrofititng the 8,800-head facility will not be the same as for the 4,320-head facility (even though the costs will be the same for constructing and operating the belt). Tables BELTS.30 (liquids) and BELTS.31 (solids) summarize the costs associated with land applying separated manure solids and liquid from the belt system technology for each of four scenarios. Table BELTS.32 gives a mass balance of generated and land applied nutrients associated with a standardized 8,800-head finishing facility. Table BELTS.33 makes a comparison of cost ($/1,000 lbs of SSLW) for two belt materials (4-mm and 1.2-mm) for 8,800 head finishing operation. The cost for the 1.2-mm material is significantly lower.

6. Summary and Conclusion

Pilot scale belt systems for manure removal and separation were built and operated in two distinct experiments: the Lake Wheeler belt (Rice, et al.) and the van Kempen - Koger belt (Koger(b)). A rough design and prospective cost model for retrofitting 4 types of finishing barns was developed by Elmer Environmental. Separation performance data from the pilot scale projects and retrofit cost data from the Elmer model were used to construct the economic model used in this analysis. Standard excretion volume and composition assumptions and land application assumptions were used to model the cost of land applying all solids and liquids. Small storage facilities were assumed to allow holding of materials between land applications. Approximated annual incremental costs to retrofit and operate the belt system ranged from $89.30 to $95.94 per 1,000 pounds SSLW per year across the 4 types of finishing barns on a 4,320-head capacity feeder-to-finish farm.

The retrofit cost was reduced by about $20 / 1,000 lbs. SSLW / year when 1.2-mm HDPE material was assumed for the belt in place of 4-mm 2 ply poly/pvc assumed in the estimation. The van Kempen - Koger pilot scale belt was 1.2-mm HDPE. Further evaluation in commercial conditions is required to understand the expected maintenance requirements, the expected useful life of various belt materials, and the resulting cost per 1,000 lbs. SSLW per year.

A limiting assumption in this analysis is that all solids and liquids are land applied. If an alternative outlet for manure solids is developed, and if the cost of accessing it is less than that of land application, the net cost of the belt system would be reduced. Cost estimates include the cost of land applying the liquid and solids collected. The standardized annual incremental cost ranges from $89 to $261 per 1,000 pounds SSLW per year with costs varying across barn type, costs increasing with farm size, and costs increasing sharply from nitrogen limited to phosphorus limited land application rates. Excluding costs of land application of solids and liquids reduces costs to $56.38 to $62.93 / 1,000 lbs. SSLW / year for the standardized belt system on a 4,320-head feeder-to-finish farm.

The pilot scale experiments provided some data indicating that feed conversion and/or growth rate were superior for the pigs in the experimental facilities as compared to pigs in commercial facilities. If these productivity gains can be shown in commercial settings with retrofitted belt systems, the net cost of the belt system could be substantially reduced. For example, a 1 % reduction in feed required in the feeder-to-finish phase of production might save $8.21 (0.01 x 205 x 2.6 x 2.6 x $0.08 x 1,000/135) per 1,000 lbs. SSLW per year.

To repeat, IT IS IMPORTANT TO KEEP IN MIND THAT NO FULL-SCALE COMMERCIAL SWINE BUILDING OF THE TYPES USED IN NORTH CAROLINA HAS BEEN RETROFITTED WITH A BELT SYSTEM. Therefore, these cost estimates are very preliminary and many questions remain about the practical installation, operation, and maintenance of such belt systems and their effects on productivity and the environment in a commercial setting. Proposals have been made to equip a new building with a belt system at an NCSU / NCDA&CS agricultural research station.

References

(AREa) Agricultural and Resource Economics Department. North Carolina State University. Request for information to Lake Wheeler Belt System Team. December, 2002.

(AREb) Agricultural and Resource Economics Department. North Carolina State University. Request for information to van Kempen-Koger Belt System Team. December, 2002.

(EE) Elmer Environmetal. Belt System Project Report. May 2004.

(Koger(a)) Koger, J, T. van Kempen, and P. Burnette. Re-Cycle: An Integrated System to Substantially Eliminate the Environmental Impact of Swine Waste—Report to the Economic Team." February, 2004.

(Koger(b)) Koger, J. B., B. A. Kasper, R. P. Burnette, M. H. J. G. van Kempen and T. A. T. G. van Kempen. Swine Waste Management through Belt-Based Housing Design. AG/SF/PSF/Frontline Agreement Project Report. April, 2004.

Rice, M, F. Humenik and C. Baird. Belt System for Manure Removal. AG/SF/PSF/Frontline Agreement Project Report. April, 2004.

Van Kempen, Theo. Personal Communications. May 2004.

Tables BELTS.1 through BELTS.6: Performance Data, Specifications, and Invoiced Costs for the Lake Wheeler Belt System.

Table BELTS.1. Average Daily Swine Manure Collected: Lake Wheeler Belt System (Rice, et al.)

Rotation—Type of Pig	Solids* (lbs / pig / day)	Liquid (gal / pig / day)
2nd rotation—barrows	0.60	0.77
3rd rotation—gilts	0.52	0.69
4th rotation—barrows	0.70	0.96
Average	**0.61**	**0.81**

* dry matter basis

Table BELTS.2. Average Manure Solids Characterization: Lake Wheeler Belt System (Rice, et al.)

Rotation—Type of Pig	% of TKN in Solids	% of TP in Solids	TKN (ppm)	TP (ppm)	% Moisture Content
2nd rotation—barrows	-	-	14,328	8,515	65.62 %
3rd rotation—gilts	41 %	91 %	13,261	6,405	68.55 %
4th rotation—barrows	41 %	91 %	12,799	7,729	67.83 %
Average	**41 %**	**91 %**	**13,632**	**7,637**	**67.09 %**

Table BELTS.3. Average Liquid Characterization for Lake Wheeler Belt System (Rice, et. al)

Rotation—Type of Pig	% of TKN in Liquids	% of TP in Liquids	TKN (ppm)	TP (ppm)
2nd rotation—barrows	-	-	7,455	308
3rd rotation—gilts	59 %	9 %	5,164	144
4th rotation—barrows	59 %	9 %	4,981	226
Average	**59 %**	**9 %**	**6,141**	**235**

Table BELTS.4. Actual Costs of Installing the Lake Wheeler Demonstrational Facility Belt System (AREa)

Component	Cost
Salaries and fringe benefits	$17,507.00
Travel to visit existing belt sites	$7,300.00
Analytical costs	$9,900.00
Animal care costs	$1,750.00
Project management	$18,367.00
Operation oversight	$18,110.00
Direct costs	$2,980.73
Electrical cost of belt operation (per year)	$37.27
Belt system design and construction*	$54,000.00
Belt installation	$6,300.00
Belt modifications	$300.00
Building modifications and belt removal	$3,448.00
Total overhead	$21,000.00
Total cost of demonstrational belt system	**$161,000.00**

* See Table BELTS.2 for detailed belt design and construction costs.

Table BELTS.5. Detailed Costs of Lake Wheeler Belt System Design and Construction (AREa)

Component	Cost
Purchase price of belt	$545.28
Belt installation	$1,000.00
Belt supporting structure	$17,280.00
Purchase price of motors	$1,800.00
Motor installation	$1,300.00
Purchase price of augers	$11,000.00
Auger installation	$2,300.00
Electrical installation	$1,000.00
Gear reducers for drive units	$16,500.00
Miscellaneous expenses	$1,274.72
Total cost of belt system design and construction	**$54,000.00**

Table BELTS.6. Construction Parameters of the Lake Wheeler Belt System (AREa)

Belt width	5.5 ft.
Belt length	32 ft. (64 ft. of total belt material)
Specifications of all motors (belt, auger)	3 @ 1 HP each
# of augers	2
# of gear reducers for drive units	3
Electricity usage	30 min. / day / motor
kWh per day (all 3 motors)	1.28 kWh
kWh per year (all 3 motors)	465.93 kWh
Operation labor for the belt system	30 min. / day
Maintenance labor for the belt system	30 min. / month

Tables BELTS.7 through BELTS. 10: Performance, Specifications, and Invoiced Cost of the van Kempen-Koger Belt System

Table BELTS.7. Average Daily Swine Manure Collected with van Kempen-Koger Belt System (Koger(b))

Trial—Type of Pig	Solids output* (lbs / pig / day)	Liquid output (gal / pig / day)
1—grower pigs	0.51	-
2—grower pigs	0.58	0.28
3—grower pigs	0.49	0.41
4—grower pigs	0.76	0.34
5—grower pigs	0.58	0.37
Average	**0.58**	**0.35**

* dry matter basis

Table BELTS.8. Actual (Invoiced) Cost of Installing van Kempen-Koger Belt System at Grinnells Experimental Facility (Koger(a))

Component	Cost
Gear motor	$850.00
Frame and solder	$488.00
Gutter	$200.00
Electronic timer for belt operation	$46.00
Miscellaneous hardware	$100.00
Construction labor	
Frame	$540.00
Assembly	$192.00
Angle iron	$24.00
Support walls	$192.00
Skirts	$24.00
Treadplate	$16.00
Gates	$235.50
Cement slab floor	$1,990.00
Tribar	$1,751.00
Circulating fans	$240.00
Exhaust fan	$465.00
Lumber	$45.00
Angle iron	$178.20
Supporting walls	
Cinder block	$320.00
Cement	$8.00
Sump pump	$211.50
Flow meter (water consumption)	$135.00
Solid waste collection bin	
Casters	$60.00
Plywood	$25.00
L-hooks	$2.40
Miscellaneous hardware	$2.50
Liquid waste collection bin	$30.00
Aluminum treadplate and adhesives	$1,112.00
Total Actual Cost of Experimental Belt System	**$9,483.10**

Note: Some items in table above are components of the pig housing system that were necessary to accomodate the pilot scale belt system but would not be required in a commercial facility.

Table BELTS.9. Estimated Cost of Components Donated to the Grinnells Facility (Koger(a))

Component	Cost
Belt	$200.00
Belt welding	$200.00
Belt drive set with scraper	$2,500.00
Skirts and material	$55.00
Electrical costs of belt operation (per year)	$19.00
Penning—solid partitions and supports	$1,500.00
Wet-dry feeders	$1,500.00
Polypropylene/polyethylene/nylon	$600.00
Total Estimated Cost of Donated Components	**$6,574.00**

Note: Some items in table above are components of the pig housing system that were necessary to accomodate the pilot scale belt system but would not be required in a commercial facility.

Table BELTS.10. Total Replacement Cost of Installing van Kempen-Koger Belt System at Grinnells Facility (Koger(b))

Component	Cost
Actual cost of components purchased for use at Grinnells facility*	$9,483.10
Estimated cost of components donated for use at Grinnells facility**	$6,574.00
Total Replacement Cost of Experimental Belt System	**$16,057.10**

* Costs detailed in Table BELTS.1.
** Costs detailed in Table BELTS.2.

Tables BELTS.11 and BELTS. 12: Barn and Belt Design Specifications for Four Types of Feeder to Finish Barns Used in Hypothetical Cost and Returns Analysis

Table BELTS.11. Pit Specifications and Manure Characteristics for Four Common Finishing Barns (Elmer)

	Type I 1,224 Natural	Type II 800 Natural	Type III 800 Tunnel	Type IV 880 Tunnel
Pit Specifications				
Pit type	flush	pit-recharge	pit-recharge/ flush	pit-recharge/ flush
Flooring style	partial slat	full slat	full slat	full slat
Pits / barn	2	4	4	4
Minimum width (ft.)	7.67	-	-	-
Width of outer pits (ft.)	-	9.58	9.58	9.58
Width of inner pits (ft.)	-	9.42	9.42	9.42
Length (ft.)	199.17	151.67	163.50	179.67
Pit depth (ft.)	0.67	2.67	1.33	1.33
Flooring depth (ft.)	0.33	0.33	0.33	0.33
Total depth (ft.)	1.00	3.00	1.67	1.67
% lengthwise slope	1.5	0.10	0.15	1.66
# of center dividers / pit	1	1	1	1
Depth of center divider (ft.)	0.25	0.25	0.25	0.25
Manure Characteristics				
Head per belt	612	200	200	220
Volume of liquid / head / day* (cubic feet)	183.6	60.0	60.0	66.0
Volume of manure / head / day** (cubic feet)	79.6	26.0	26.0	28.6
Weight of liquid / belt*** (lbs)	11,383	3,720	3,720	4,092
Weight of manure / belt**** (lbs)	2,498	816	816	898
Total weight / belt (lbs)	13,881	4,536	4,536	4,990

* Based on a maximum liquid excretion rate of 0.3 cubic feet / head / day
** Based on a maximum manure solids excretion rate of 0.13 cubic feet / head / day
***Based on a liquid density of 62 lbs / cubic foot
**** Based on a manure solids density of 31.4 lbs / cubic foot

Table BELTS.12. Belt System Design Specifications for Four Common Finishing Barns (Elmer)

	Type I 1,224 Natural	Type II 800 Natural	Type III 800 Tunnel	Type IV 880 Tunnel
Belt Specifications				
Belt material	2-ply poly/PVC	2-ply poly/PVC	2-ply poly/PVC	2-ply poly/PVC
Belt yield strength (lbs / in.)	86	86	86	86
Belt thickness (mm)	4	4	4	4
Belt density (g / cubic cm)	0.94	0.94	0.94	0.94
Weight of belt material (lbs / ft.)	5.79	7.13	7.13	7.13
Maximum belt width (ft.)	7.51	-	-	-
Maximum outer belt width (ft.)	-	9.25	9.25	9.25
Maximum inner belt width (ft.)	-	9.09	9.09	9.09
Barn belt length (ft.)	205.17	157.67	169.50	185.67
Minimum depth of belt from slat (ft.)	0.20	0.33	0.33	0.33
Maximum depth of belt from slat (ft.)	0.35	0.52	0.52	0.52
Volume capacity of belt (cubic ft.)	236	279	300	329
Maximum solids weight / belt (lbs)	7,418	8,772	9,431	10,330
Conveyor Carrying				
Belt slope support	rod	rod	rod	rod
Spacing of belt slope support (ft.)	1	1	1	1
Quantity of slope supports/idlers	205	158	170	186
Idler load (lbs)	323	281	291	308
Quantity of wedge devices	10	8	8	9
Conveyor Return				
Depth between carry belt and return (ft.)	0.17	0.17	0.17	0.17
Belt return support	rod	rod	rod	rod
Spacing of belt return support (ft.)	5	5	5	5
Quantity of return supports/idlers	41	32	34	37
Idler load (lbs)	90	89	91	95
Minimum depth between return and pit floor (ft.)	0.06	1.89	0.55	0.55
Liquid Removal				
Trough length (ft.)	202.17	154.67	166.50	182.67
Trough material	belt	belt	belt	belt
Trough width (ft.)	0.17	0.17	0.17	0.17
Minimum freeflow liquid velocity (ft. / sec.)	1.85	0.48	0.58	1.94
Drive Specifications				
Belt weight capacity (lbs)	14,647	17,321	18,621	20,397
Maximum belt speed (ft. / min.)	11.00	12.00	12.00	11.00
Time to remove solids (min./ belt)	18.65	13.14	14.13	16.88
Effective drive (hp)	0.73	0.71	0.73	0.71
Start-up drive (hp)	1.23	1.18	1.22	1.19

Tables BELTS.13 through BELTS.20: Construction Costs, Specifications, and Annualized Costs per Unit for Hypothetical Retrofits of Four Types of Feeder to Finish Barns: 4,320-Head Feeder to Finish Farm

Table BELTS.13. Belt System Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices for 1,224-Head, Natural Ventilation (Type I) Barns (4,320-Head Feeder-Finish)

Number of Animals	**4,320**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Belt System**				
Incremental Cost ($ / 1,000 Lbs of SSLW)					
Total Annualized Cost per Unit			**Forages**		**Row Crops**
	If Nitrogen-Based Application	**$**	**89.39**	**$**	**70.86**
	If Phosphorus-Based Application	**$**	**254.61**	**$**	**71.09**

Note: Daily volume discharged from barns is 9,936 gallons / day.
SSLW equals 583,200 pounds.

Table BELTS.14. Belt System Technology Costs—Standardized Quantities and Prices for 1,224-Head, Natural Ventilation (Type I) Barns (4,320-Head Feeder-Finish)

Material Costs		Total Cost		Annualized Cost
Belt Material	$	15,284.59	$	2,546.56
Carrying Idlers	$	2,051.70	$	305.76
Return Idler	$	410.34	$	61.15
Liquid Scraper	$	200.00	$	33.32
Liquid Trough - Barn Removal	$	70.00	$	10.43
Solids Scraper	$	200.00	$	33.32
Solids Belt - Barn Removal	$	6,000.00	$	894.18
Drive Pulley	$	400.00	$	59.61
Tail Pulley	$	300.00	$	44.71
Snub Pulley	$	300.00	$	44.71
Drive Pulley Frame	$	400.00	$	59.61
Tail Pulley Frame	$	300.00	$	44.71
Wedge Device	$	102.59	$	15.29
Trough Pipe	$	252.71	$	37.66
Motor/reducer	$	490.50	$	81.72
Control Panel/Timer	$	100.00	$	14.90
Electrical Wiring	$	300.00	$	49.98
Storage				
Temporary Storage	$	2,500.00	$	372.57
Retrofitting Costs				
Remove & Replace High End Wall	$	500.00	$	74.51
Solids Removal House	$	2,000.00	$	298.06
Remove and Replace Low End Wall	$	500.00	$	74.51
Liquid Removal House	$	1,500.00	$	223.54
Removal of Pit Center Divider	$	-	$	-
Removal of Flush Tanks	$	-	$	-
Installation Costs				
Penning Removal and Replacement	$	500.00	$	74.51
Slat Removal and Replacement	$	497.93	$	74.21
Belt System Fabrication	$	1,025.85	$	152.88
Installation of Belt System	$	1,025.85	$	152.88
Freight	$	200.00	$	29.81
Contractor & Engineering Services & Overhead	$	16,124.60	$	2,403.04
Total Construction Cost	**$**	**53,536.65**	**$**	**8,268.17**
Maintenance Cost			$	607.96
Property Taxes			$	190.06
Electric Power Cost			$	249.81
Total Operating Cost			**$**	**1,047.83**

TOTAL CONSTRUCTION COST PER BARN	**$**	**53,536.65**
TOTAL OPERATING COST INCLUDING ROYALTIES PER BARN	**$**	**1,047.83**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION PER BARN (total)	**$**	**9,316.01**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION PER BARN ($ / 1,000 lbs. of SSLW)	**$**	**56.38**

Table BELTS.15. Belt System Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices for 800-Head, Natural Ventilation (Type II) Barns (4,320-Head Feeder-Finish)

Number of Animals	**4,320**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Belt System**				
Incremental Cost ($ / 1,000 Lbs of SSLW)					
Total Annualized Cost per Unit			**Forages**		**Row Crops**
	If Nitrogen-Based Application	**$**	**90.51**	**$**	**71.98**
	If Phosphorus-Based Application	**$**	**255.73**	**$**	**72.21**

Note: Daily volume discharged from barns is 9,936 gallons / day.
SSLW equals 583,200 pounds.

Table BELTS.16. Belt System Technology Costs—Standardized Quantities and Prices for 800-Head, Natural Ventilation (Type II) Barns (4,320-Head Feeder-Finish)

Material Costs		**Total Cost**		**Annualized Cost**
Belt Material	$	14,497.98	$	2,415.50
Carrying Idlers	$	1,576.70	$	234.97
Return Idler	$	315.34	$	46.99
Liquid Scraper	$	400.00	$	66.64
Liquid Trough - Barn Removal	$	70.00	$	10.43
Solids Scraper	$	400.00	$	66.64
Solids Belt - Barn Removal	$	6,000.00	$	894.18
Drive Pulley	$	800.00	$	119.22
Tail Pulley	$	600.00	$	89.42
Snub Pulley	$	600.00	$	89.42
Drive Pulley Frame	$	800.00	$	119.22
Tail Pulley Frame	$	600.00	$	89.42
Wedge Device	$	78.84	$	11.75
Trough Pipe	$	193.34	$	28.81
Motor/reducer	$	471.04	$	78.48
Control Panel/Timer	$	100.00	$	14.90
Electrical Wiring	$	300.00	$	49.98
Storage				
Temporary Storage	$	2,500.00	$	372.57
Retrofitting Costs				
Remove & Replace High End Wall	$	500.00	$	74.51
Solids Removal House	$	2,000.00	$	298.06
Remove and Replace Low End Wall	$	500.00	$	74.51
Liquid Removal House	$	1,500.00	$	223.54
Removal of Pit Center Divider	$	-	$	-
Removal of Flush Tanks	$	-	$	-
Installation Costs				
Penning Removal and Replacement	$	1,000.00	$	149.03
Slat Removal and Replacement	$	379.18	$	56.51
Belt System Fabrication	$	788.35	$	117.49
Installation of Belt System	$	788.35	$	117.49
Freight	$	200.00	$	29.81
Contractor & Engineering Services & Overhead	$	16,360.38	$	2,438.18
Total Construction Cost	**$**	**54,319.48**	**$**	**8,377.70**
Maintenance Cost			$	620.20
Property Taxes			$	192.83
Electric Power Cost			$	310.56
Total Operating Cost			**$**	**1,123.59**

TOTAL CONSTRUCTION COST PER BARN	**$**	**54,319.48**
TOTAL OPERATING COST INCLUDING ROYALTIES PER BARN	**$**	**1,123.59**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION PER BARN (total)	**$**	**9,501.29**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION PER BARN ($ / 1,000 lbs. of SSLW)	**$**	**57.50**

Table BELTS.17. Belt System Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices for 800-Head, Tunnel Ventilation (Type III) Barns (4,320-Head Feeder-Finish)

Number of Animals	**4,320**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Belt System**				
Incremental Cost ($ / 1,000 Lbs of SSLW)					
Total Annualized Cost per Unit			**Forages**		**Row Crops**
	If Nitrogen-Based Application	**$**	**92.81**	**$**	**74.28**
	If Phosphorus-Based Application	**$**	**258.03**	**$**	**74.52**

Note: Daily volume discharged from barns is 9,936 gallons / day.
SSLW equals 583,200 pounds.

Table BELTS.18. Belt System Technology Costs—Standardized Quantities and Prices for 800-Head, Tunnel Ventilation (Type III) Barns (4,320-Head Feeder-Finish)

Material Costs		**Total Cost**		**Annualized Cost**
Belt Material	$	15,548.25	$	2,590.49
Carrying Idlers	$	1,695.00	$	252.60
Return Idler	$	339.00	$	50.52
Liquid Scraper	$	400.00	$	66.64
Liquid Trough - Barn Removal	$	70.00	$	10.43
Solids Scraper	$	400.00	$	66.64
Solids Belt - Barn Removal	$	6,000.00	$	894.18
Drive Pulley	$	800.00	$	119.22
Tail Pulley	$	600.00	$	89.42
Snub Pulley	$	600.00	$	89.42
Drive Pulley Frame	$	800.00	$	119.22
Tail Pulley Frame	$	600.00	$	89.42
Wedge Device	$	84.75	$	12.63
Trough Pipe	$	208.13	$	31.02
Motor/reducer	$	489.41	$	81.54
Control Panel/Timer	$	100.00	$	14.90
Electrical Wiring	$	300.00	$	49.98
Storage				
Temporary Storage	$	2,500.00	$	372.57
Retrofitting Costs				
Remove & Replace High End Wall	$	500.00	$	74.51
Solids Removal House	$	2,000.00	$	298.06
Remove and Replace Low End Wall	$	500.00	$	74.51
Liquid Removal House	$	1,500.00	$	223.54
Removal of Pit Center Divider	$	-	$	-
Removal of Flush Tanks	$	-	$	-
Installation Costs				
Penning Removal and Replacement	$	1,000.00	$	149.03
Slat Removal and Replacement	$	408.75	$	60.92
Belt System Fabrication	$	847.50	$	126.30
Installation of Belt System	$	847.50	$	126.30
Freight	$	200.00	$	29.81
Contractor & Engineering Services & Overhead	$	16,954.80	$	2,526.77
Total Construction Cost	**$**	**56,293.09**	**$**	**8,690.61**
Maintenance Cost			$	645.37
Property Taxes			$	199.84
Electric Power Cost			$	345.63
Total Operating Cost			**$**	**1,190.85**

TOTAL CONSTRUCTION COST PER BARN	**$**	**56,293.09**
TOTAL OPERATING COST INCLUDING ROYALTIES PER BARN	**$**	**1,190.85**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION PER BARN (total)	**$**	**9,881.46**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION PER BARN ($ / 1,000 lbs. of SSLW)	**$**	**59.80**

Table BELTS.19. Belt System Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices for 880-Head, Tunnel Ventilation (Type IV) Barns (4,320-Head Feeder-Finish)

Number of Animals	**4,320**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Belt System**				
Incremental Cost ($ / 1,000 Lbs of SSLW)					
Total Annualized Cost per Unit			**Forages**		**Row Crops**
	If Nitrogen-Based Application	**$**	**95.94**	**$**	**77.42**
	If Phosphorus-Based Application	**$**	**261.16**	**$**	**77.65**

Note: Daily volume discharged from barns is 9,936 gallons / day.
SSLW equals 583,200 pounds.

Table BELTS.20. Belt System Technology Costs—Standardized Quantities and Prices for 880-Head, Tunnel Ventilation (Type IV) Barns (4,320-Head Feeder-Finish)

Material Costs		**Total Cost**		**Annualized Cost**
Belt Material	$	16,983.83	$	2,829.67
Carrying Idlers	$	1,856.70	$	276.70
Return Idler	$	371.34	$	55.34
Liquid Scraper	$	400.00	$	66.64
Liquid Trough - Barn Removal	$	70.00	$	10.43
Solids Scraper	$	400.00	$	66.64
Solids Belt - Barn Removal	$	6,000.00	$	894.18
Drive Pulley	$	800.00	$	119.22
Tail Pulley	$	600.00	$	89.42
Snub Pulley	$	600.00	$	89.42
Drive Pulley Frame	$	800.00	$	119.22
Tail Pulley Frame	$	600.00	$	89.42
Wedge Device	$	92.84	$	13.84
Trough Pipe	$	228.34	$	34.03
Motor/reducer	$	475.78	$	79.27
Control Panel/Timer	$	100.00	$	14.90
Electrical Wiring	$	300.00	$	49.98
Storage				
Temporary Storage	$	2,500.00	$	372.57
Retrofitting Costs				
Remove & Replace High End Wall	$	500.00	$	74.51
Solids Removal House	$	2,000.00	$	298.06
Remove and Replace Low End Wall	$	500.00	$	74.51
Liquid Removal House	$	1,500.00	$	223.54
Removal of Pit Center Divider	$	-	$	-
Removal of Flush Tanks	$	-	$	-
Installation Costs				
Penning Removal and Replacement	$	1,000.00	$	149.03
Slat Removal and Replacement	$	449.18	$	66.94
Belt System Fabrication	$	928.35	$	138.35
Installation of Belt System	$	928.35	$	138.35
Freight	$	200.00	$	29.81
Contractor & Engineering Services & Overhead	$	17,750.60	$	2,645.36
Total Construction Cost	**$**	**58,935.29**	**$**	**9,109.38**
Maintenance Cost			$	677.85
Property Taxes			$	209.22
Electric Power Cost			$	402.58
Total Operating Cost			**$**	**1,289.65**

TOTAL CONSTRUCTION COST PER BARN	**$**	**58,935.29**
TOTAL OPERATING COST INCLUDING ROYALTIES PER BARN	**$**	**1,289.65**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION PER BARN (total)	**$**	**10,399.03**
TOTAL ANNUALIZED COSTS WITHOUT LAND APPLICATION PER BARN ($ / 1,000 lbs. of SSLW)	**$**	**62.93**

Tables BELTS.21 through BELTS. 23: Land Application Costs and Mass Balance: 4,320-Head Feeder to Finish Farm

Table BELTS.21. Belt System Technology Sprayfield Costs for Four Land Application Scenarios—Standardized Quantities and Prices

Annual Cost of Applying Lagoon Effluent		Forages		Row Crops
If Nitrogen-Based Application	$	15,366.51	$	12,828.17
If Phosphorus-Based Application	$	10,705.76	$	7,875.20
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		88.85		287.97
If Phosphorus-Based Application		45.54		124.49
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	5,331.14		-
If Phosphorus-Based Application	$	2,732.51		-
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	9,179.69	$	17,973.32
If Phosphorus-Based Application	$	7,973.25	$	10,610.27
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(5,145.15)
If Phosphorus-Based Application		-	$	(2,735.07)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	855.68		-
If Phosphorus-Based Application		-		-

Note: These costs pertain to Barn Types I-IV.
4,029,305 gallons of effluent land applied yearly

Table BELTS.22. Belt System Technology Solids Application Costs for Four Land Application Scenarios—Standardized Quantities and Prices

Annual Cost of Applying Solids		Forages		Row Crops
If Nitrogen-Based Application	$	20,703.87	$	9,863.44
If Phosphorus-Based Application	$	125,261.64	$	16,096.22
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		74.09		240.14
If Phosphorus-Based Application		538.46		1,438.58
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	4,445.63		-
If Phosphorus-Based Application	$	32,307.89		-
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	11,956.53	$	15,139.26
If Phosphorus-Based Application	$	19,089.35	$	31,430.24
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application		-	$	(5,275.82)
If Phosphorus-Based Application		-	$	(15,334.01)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	3,301.70		-
If Phosphorus-Based Application	$	73,864.39		-

Note: These costs pertain to Barn Types I-IV.
2,053,042 lbs.of wet solids land applied yearly

Table BELTS.23. Summary and Mass Balance of Generated and Land Applied Nutrients—Standardized Quantities and Prices

Nutrient Balance	Nitrogen (lbs / year)	Phosphorus (lbs / year)	Potassium (lbs / year)
Generated At Barn	87,437	25,056	42,984
Land Applied in Separated Solids	35,849	22,801	8,597
Land Applied in Separated Liquids	51,588	2,255	34,387

Note: These numbers pertain to Barn Types I-IV.

Tables BELTS.24 and BELTS. 25: Effect of Price of Belt Material on Cost Estimates

Table BELTS.24. Summary of Belt Material Costs for Different Belt Thicknesses and Per-Square Foot Prices

	Elmer (4 mm, $4.80 / sq. foot)	**van Kempen 1** (1.2 mm, $0.30 / sq. foot)	**van Kempen 2** (1.2 mm, $0.45 / sq. foot)	**van Kempen 3** (1.2 mm, $0.60 / sq. foot)
1,224, Natural (Type I)	$15,284.59	$1,424.04	$1,886.06	$2,348.07
800, Natural (Type II)	$14,477.98	$1,374.87	$1,812.31	$2,249.75
800, Tunnel (Type III)	$15,548.25	$1,440.52	$1,910.77	$2,381.03
880, Tunnel (Type IV)	$16,983.83	$1,530.24	$2,045.36	$2,560.48

Note: These numbers pertain to both 4,320-head and 8,800-head feeder-to-finish facilities.

Table BELTS.25. Summary of Incremental Costs ($ / 1,000 lbs. SSLW) for Four Scenarios of Land Application as Determined by Barn Type and Belt Type Combinations (4,320-Head Feeder-Finish)

	1,224, Natural (Type I)		**800, Natural (Type II)**		**800, Tunnel (Type III)**		**880, Tunnel (Type IV)**	
	Forages	Row Crops	Forages	Row Crops	Forages	Row Crops	Forages	Row Crops
Elmer (4 mm, $4.80 / sq. foot)								
Nitrogen-based	$89.30	$70.86	$90.51	$71.98	$92.81	$74.28	$95.94	$77.42
Phosphorus-based	$254.61	$71.09	$255.73	$72.21	$258.03	$74.52	$261.16	$77.65
van Kempen 1 (1.2 mm, $0.30 / sq. foot)								
Nitrogen-based	$67.92	$49.39	$70.19	$51.66	$70.96	$52.43	$72.01	$53.48
Phosphorus-based	$233.14	$49.63	$235.40	$51.89	$236.18	$52.67	$237.23	$53.71
van Kempen 2 (1.2 mm, $0.45 / sq. foot)								
Nitrogen-based	$68.64	$50.11	$70.86	$52.34	$71.69	$53.16	$72.81	$54.28
Phosphorus-based	$233.86	$50.34	$236.08	$52.57	$236.91	$53.39	$238.03	$54.51
van Kempen 3 (1.2 mm, $0.60 / sq. foot)								
Nitrogen-based	$69.35	$50.83	$71.54	$53.01	$72.42	$53.89	$73.61	$55.08
Phosphorus-based	$234.77	$51.06	$236.76	$53.24	$237.64	$54.12	$238.82	$55.31

Tables BELTS.26 through BELTS.33: Annualized Costs per Unit, Land Application Costs, Mass Balance, and Belt Price Effects for Hypothetical Retrofits of Four Types of Feeder to Finish Barns: 8,800-Head Feeder to Finish Farm

Table BELTS.26. Belt System Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices for 1,224-Head, Natural Ventilation (Type I) Barns (8,800-Head Feeder-Finish)

Number of Animals	8,800				
Type of Operation	Feeder-Finish				
Barn Cleaning System	Belt System				
Incremental Cost ($ / 1,000 Lbs of SSLW)					
Total Annualized Cost per Unit			Forages		Row Crops
	If Nitrogen-Based Application	$	85.90	$	66.28
	If Phosphorus-Based Application	$	249.66	$	68.62

Note: Daily volume discharged from barns is 20,240 gallons / day.
SSLW equals 1,188,000 pounds.

Table BELTS.27. Belt System Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices for 800-Head, Natural Ventilation (Type II) Barns (8,800-Head Feeder-Finish)

Number of Animals	8,800				
Type of Operation	Feeder-Finish				
Barn Cleaning System	Belt System				
Incremental Cost ($ / 1,000 Lbs of SSLW)					
Total Annualized Cost per Unit			Forages		Row Crops
	If Nitrogen-Based Application	$	87.03	$	67.40
	If Phosphorus-Based Application	$	250.78	$	69.74

Note: Daily volume discharged from barns is 20,240 gallons / day.
SSLW equals 1,188,000 pounds.

Table BELTS.28. Belt System Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices for 800-Head, Tunnel Ventilation (Type III) Barns (8,800-Head Feeder-Finish)

Number of Animals	**8,800**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Belt System**				
Incremental Cost ($ / 1,000 Lbs of SSLW)					
Total Annualized Cost per Unit			**Forages**		**Row Crops**
	If Nitrogen-Based Application	**$**	**89.33**	**$**	**69.70**
	If Phosphorus-Based Application	**$**	**253.08**	**$**	**72.04**

Note: Daily volume discharged from barns is 20,240 gallons / day.
SSLW equals 1,188,000 pounds.

Table BELTS.29. Belt System Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices for 880-Head, Tunnel Ventilation (Type IV) Barns (8,800-Head Feeder-Finish)

Number of Animals	**8,800**				
Type of Operation	**Feeder-Finish**				
Barn Cleaning System	**Belt System**				
Incremental Cost ($ / 1,000 Lbs of SSLW)					
Total Annualized Cost per Unit			**Forages**		**Row Crops**
	If Nitrogen-Based Application	**$**	**92.46**	**$**	**72.83**
	If Phosphorus-Based Application	**$**	**256.21**	**$**	**75.17**

Note: Daily volume discharged from barns is 20,240 gallons / day.
SSLW equals 1,188,000 pounds.

Table BELTS.30. Belt System Technology Sprayfield 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	$ 26,125.20	$ 21,593.13
If Phosphorus-Based Application	$ 15,752.74	$ 11,129.53
Acres Needed For Assimilation	**Forages**	**Row Crops**
If Nitrogen-Based Application	181.00	586.61
If Phosphorus-Based Application	92.77	253.60
Opportunity Cost of Land	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 10,859.74	-
If Phosphorus-Based Application	$ 5,566.23	-
Irrigation Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 13,522.42	$ 32,074.00
If Phosphorus-Based Application	$ 10,186.50	$ 16,700.96
Savings From Not Having To Buy Fertilizer	**Forages**	**Row Crops**
If Nitrogen-Based Application	-	$ (10,480.86)
If Phosphorus-Based Application	-	$ (5,571.43)
Extra Fertilizer Purchase Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 1,743.04	-
If Phosphorus-Based Application	-	-

Note: These costs pertain to Barn Types I-IV.
8,126,093 gallons of effluent land applied yearly

Table BELTS.31. Belt System Technology Solids Application Costs for Four Land Application Scenarios—Standardized Quantities and Prices (8,800-Head Feeder-Finish)

Annual Cost of Applying Solids	Forages	Row Crops
If Nitrogen-Based Application	$ 36,192.03	$ 14,047.85
If Phosphorus-Based Application	$ 249,370.24	$ 29,857.34
Acres Needed For Application	**Forages**	**Row Crops**
If Nitrogen-Based Application	150.93	489.18
If Phosphorus-Based Application	1,096.87	2,930.44
Opportunity Cost of Land	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 9,055.92	-
If Phosphorus-Based Application	$ 65,812.38	-
Application Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 20,410.41	$ 24,794.90
If Phosphorus-Based Application	$ 33,093.36	$ 61,093.29
Savings From Not Having To Buy Fertilizer	**Forages**	**Row Crops**
If Nitrogen-Based Application	-	$ (10,747.05)
If Phosphorus-Based Application	-	$ (31,235.95)
Extra Fertilizer Purchase Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 6,725.69	-
If Phosphorus-Based Application	$ 150,464.50	-

Note: These costs pertain to Barn Types I-IV.
7,104,592 lbs of wet solids land applied yearly

Table BELTS.32. 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	51,040	87,560
Land Applied in Separated Solids	73,026	46,446	17,512
Land Applied in Separated Liquids	105,086	4,594	70,048

Note: These numbers pertain to Barn Types I-IV.

Table BELTS.33. Summary of Incremental Costs ($ / 1,000 lbs. SSLW) for Four Scenarios of Land Application as Determined by Barn Type and Belt Type Combinations (8,800-Head Feeder-Finish)

	1,224, Natural (Type I)		**800, Natural (Type II)**		**800, Tunnel (Type III)**		**880, Tunnel (Type IV)**	
	Forages	Row Crops	Forages	Row Crops	Forages	Row Crops	Forages	Row Crops
Elmer (4 mm, $4.80 / sq. foot)								
Nitrogen-based	$85.90	$66.28	$87.03	$67.40	$89.33	$69.70	$92.46	$72.83
Phosphorus-based	$249.66	$68.62	$250.78	$69.74	$253.08	$72.04	$256.21	$75.17
van Kempen 1 (1.2 mm, $0.30 / sq. foot)								
Nitrogen-based	$64.44	$44.81	$66.70	$47.07	$67.48	$47.85	$68.52	$48.90
Phosphorus-based	$228.19	$47.15	$230.45	$49.41	$231.23	$50.19	$232.28	$51.24
van Kempen 2 (1.2 mm, $0.45 / sq. foot)								
Nitrogen-based	$65.15	$45.53	$67.38	$47.75	$68.20	$48.58	$69.32	$49.70
Phosphorus-based	$228.91	$47.87	$231.13	$50.09	$231.96	$50.92	$233.03	$52.03
van Kempen 3 (1.2 mm, $0.60 / sq. foot)								
Nitrogen-based	$65.87	$46.24	$68.06	$48.43	$68.93	$49.31	$70.12	$50.49
Phosphorus-based	$229.62	$48.58	$231.81	$50.77	$232.69	$51.65	$233.87	$52.83

Appendix BELTS.A (Koger(a)):

Grinnells Belt System—Description of Design and Construction

Pens: 5 pens; 2.25 x 4.5 m, ea; 2/3 solid concrete floor; 1/3 tribar; solid partitions around 3 sides of the solid floor; open partitions or room walls elsewhere

44	solid partitions 85" long "planks" (~8" wide)—stacked 4 per partition		
22	rails above partition boards		
6	gates	64" w X 40" tall (3 uprights, 9 crossbars, + top and bottom bars)	
11	solid partition supports		
22	solid partition end supports		
125	bolts		
20	concrete slats (solid floor) 4in X 2ft X 7.5 ft		
16	tribar	30 in X 90 in (~0.8m X 2.3m)	
10	angle iron	2" X 2" X 20 ft	
5	treadplate	¼" X 7.5 ft X 2 ft	
	2"X4" X 40' lumber; support for tribar flooring		
2	supporting walls:		24" (high) X 40 ft(long) of cinder block (3 courses)
			32" (high) X 40 ft(long) of cinder block (4 courses)
5	wet/dry feeders		

Belt:

1	belt, polypropylene	1.8 m wide X 30.5m long; welded together to form continuous circle
2	skirts	to direct and retain waste material on the belt; one 18" long, the other, 12" long (commercially, only 4-5" long would be required)
1	motor	
1	drive shaft	
1	idle shaft – holds the belt taut and permits rotation from the non-drive end	

Frame:

1 15.4m long X 2m wide; galvanized steel; legs are square tubing; angle iron touching belt; remainder is sheet metal bent into appropriate shapes.