Waste Management Systems for Dairy Herds

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Acknowledgments

Cover photograph: Manure is controlled in a dairy barn alleyway at Whitehead Farm in Conway, Mo. Some 2,000 gallons of water was released with the turn of a valve at the upper end of the barn. The waste is flushed into a manure disposal lagoon that meets Missouri pollution control standards. The big flush system was demonstrated to visitors during the Commercial Agriculture Dairy Institute. Photo by Duane Dailey.

Executive Summary

Waste management is an important consideration in animal agriculture. Environmental aspects concerning waste management are of particular importance to dairies because, in general, dairies are located relatively close to populated areas.

This study provides an overview of waste management regulations in Missouri and Clean Water Act procedures. In addition, this study provides a comparative analysis of two waste management systems — lagoon and liquid tank. Both annual ownership and operating costs are computed for various herd sizes (100, 200, 300, 500, 750, and 1,000 cows). Also detailed cost calculations provided. In addition, a breakeven analysis is provided for the irrigation system used with the lagoon system. Many factors may influence the decision to custom hire or own an irrigation system. The breakeven point is calculated to be 300 cows for ownership to be deemed profitable.

Lagoon systems manage dairy waste at a lower cost than liquid tank alternative systems for all herd sizes. As a result of owning/operating a lagoon system, production costs could increase by 40¢ to 60¢ per cwt. of milk produced. On the other hand, costs per cwt. could exceed $1 for comparable liquid tank systems.

Significant size economies are observed for the waste management system. For example, a lagoon system for a 100-cow herd would cost $64 per cow. This would decline to $41 per cow at the 500-cow level. Most economies, however, can be realized at the 300-cow herd size ($46 per cow).

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Contents

Objectives and Missouri Laws

The following are specific publication objectives:

1. Describe animal waste regulations for dairy production in Missouri and methods of distributing waste and its availability to plant growth.
2. Describe two waste handling systems and the investment cost of each system available to Missouri dairy producers for herd sizes of 100, 200, 300, 500, 750, and 1,000 cows.
3. Conduct an economic analysis of each system that provides (a) an estimate of annual production costs (operating and ownership), (b) an estimate of waste value for crop production and (c) a comparison of the net annual cost of each system per cow and per 100 pounds of production for cows producing 15,000 pounds of milk annually.
4. Identify the most economical system and the optimal size herd for each system.

Animal waste regulations for livestock production in Missouri[1]

Livestock manure represents a potential pollutant that can adversely affect water quality if allowed to enter surface or groundwater sources. Missouri dairy producers have generally demonstrated good waste management practices which protect agricultural resources.

However, dairy production is becoming more concentrated with larger numbers of cattle being raised on smaller land areas. This growth, coupled with the increasing use of land for recreational purposes and general public concern for water quality, results in a greater awareness of environmental problems.

Preventive measures are essential. It is easier to prevent environmental problems than to correct the problems after they occur. The legal instrument intended to prevent water pollution throughout the state is the Missouri Clean Water Law.

Missouri's Clean Water Law

The Missouri Clean Water Law in simple terms states, "It is a violation to allow the discharge of a pollutant or contaminant to waters of the state" without a discharge permit. For practical purposes, manure from dairy operations, as well as treated forms of animal manure are considered pollutants. Any water that is not completely confined upon one's own property is defined as state waters. This includes streams, ponds, waterways, sinkholes, drainage ditches and groundwater.

Complying with the Clean Water Law

The owner of a "concentrated animal feeding operation" must conduct that operation so there is no discharge of pollutants to state waters. The "no discharge" concept requires that no waste be allowed to move, directly or indirectly, off the owner's property into surface or subsurface waters.

Compliance is required regardless of the operation size. However, only operations consisting of a 100-cow dairy herd or larger are required to obtain a permit or letter of approval from the Missouri Department of Natural Resources (MDNR). Two types of permits are issued by MDNR: One is a construction permit and the other is an operating permit.

The operation size determines whether a permit is required. Permits are mandatory when the combined capacity of all concentrated feeding operations are located on one property or under one ownership equals or exceeds the numbers in the following table. The numbers refer to animals or birds "on hand" at any one time rather than annual production.

Type of Approval Needed by Size of Operation

Animal type	CLOA* required	OLOA** required
Dairy cows	100 head	200 head
Beef cattle	1,000 head	1,000 head
Swine	1,500 head	2,500 head
Laying hens	30,000 birds	30,000 birds
Poultry broilers	100,000 birds	100,000 birds
Turkeys	55,000 birds	55,000 birds

*Construction permit
**Operating permit

Construction permit/ Operation permit

Construction permits are obtained by submitting construction and management plans along with the specifications for a waste management system to the Department of Natural Resources (DNR). These plans are developed according to guidelines for a no-discharge system, which have been developed jointly by the University of Missouri and the Soil Conservation Service.

The operating permit is obtained by submitting "as built" dimensions and specifications for the waste management system to DNR. This application must include certification that all design sizes and specifications were met and that proper construction and compaction procedures were followed in developing the system.

After certification by DNR, a permit is issued to the producer/applicant.

Waste Management

Good waste management includes a plan that enables the producer to take advantage of benefits which can be realized from dairy waste. Such a plan reduces the risk of environmental problems when manure is used as a nutrient source for farm crops.

The waste management plan[2]

A good waste management plan covers all aspects of manure management on a farm from production to eventual field application. The overall purpose of the plan is to assist animal waste managers in preventing degradation of water, soil and air resources along with protecting public health and the environment. This plan should address liquid and solid wastes produced in the operation as well as runoff and erosion control in areas where manure is stored or applied. The scope of the plan should include collection and storage of manure at the point of production and appropriate use on crop or pasture land.

In some cases, manure will be applied to land not owned by the dairy operator, therefore the plan should include an appropriate agreement to ensure land availability.

A waste management plan is a specific combination of physical components, conservation practices and management measures for manure handling, storage, treatment and use on crop or pasture land. These practices fall into two categories. One involves the methods or structures needed for the collection, handling, storage and treatment of manure. The second category outlines the application of manure nutrients to the soil and the nutrient retention when used by plants.

Waste management system benefits are:

1. Reduces the cost of commercial fertilizers. If the application of manure to cropland increases plant production and/or substitutes for cash previously expended for commercial fertilizer, then it has economic value to the dairy operation.
2. Improves production efficiency. A sound waste management plan allows managers to direct their time and skills to other important facets of the operation without continual worry about manure accumulation and potential detrimental effects.
3. Improves animal health. Good animal waste management practices result in improved animal health.
4. Protects water resources and water quality. Virtually all drinking water and recreational use of water comes from groundwater and surface water. Many other uses, such as food processing and irrigation, are dependent upon abundant supplies of high quality water.

Distribution of dairy waste and its availability to plants

Proper land application of dairy waste[3]

Manure should always be spread or irrigated uniformly on fields at the proper application rate. Nutrient losses, pollution potential and odor are reduced if manure is incorporated into the soil as soon as possible after spreading. In the case of irrigated lagoon effluent, incorporation occurs if the soil is dry enough for the liquid to soak in and the application rate does not exceed the infiltration rate of the soil.

Most dairy waste in Missouri is applied to pasture or hay land where erosion is not a problem. If waste is applied to cultivated land, it is important it is not subjected to excessive erosion because erosion can move manure nutrients from a field into a stream.

Application timing

Application timing is essential for efficient use of nutrients and pollution prevention. The longer manure is in or on the soil before plants use the nutrients, the more of those nutrients, especially nitrogen, are lost through mineralization, volatilization, denitrification, leaching and erosion.

Timing manure application to fields is critical. Spring application is the best choice because the manure will release nutrients through mineralization to growing crops.

Summer application is acceptable and is most suited to non-crop fields and pastures. Grasses, such as fescue or reed canary, are excellent choices because they can use high rates of nitrogen application while tolerating relatively wet soil conditions. Applying manure to legumes tends to stimulate broadleaf weeds and grass growth, thus shortening the legume stand.

Applying manure in the fall generally results in greater nutrient loss than does spring application unless the waste is incorporated. If the manure is incorporated and soil temperatures are below 50°F, most of the nutrients will stabilize and tend to remain in the soil until spring.

Winter application is the least desirable because nutrients cannot soak into the frozen soil. Manure spread on frozen soil or snow can be carried off during a snow melt or other runoff events.

Surface application

Manure that is spread on the surface and not incorporated or allowed to soak into the soil will lose most of the volatile nitrogen compounds as ammonia evaporates into the atmosphere. While this may not represent an pollution potential, the lost nutrients are not available for plant growth.

Manure solids spread on frozen or snow-covered soil have a high runoff and pollution potential. If manure is surface-spread on long slopes or areas with high erosion potential, strip cropping, diversion and other conservation practices can reduce runoff, nutrient loss and pollution. Manure should not be applied to soil near wells, springs or sinkholes or on slopes adjacent to streams, rivers or lakes.

In Missouri, areas covered with cool season grasses, such as fescue, are commonly used for manure application. While manure is usually surface-applied without incorporation, this practice does not necessarily maximize nutrient conservation. Pollution potential is no greater than with practices involving incorporation, as long as manure is applied at the proper rate.

Subsurface application

Water pollution potential can be decreased and the amount of nitrogen available to plants can be increased by working manure into the soil either by tillage or by subsurface injection. A soaking rain with no runoff or irrigation of lagoon effluent with no runoff is approximately equivalent to manure incorporation. When a tillage operation is used to incorporate manure, it should be completed as soon as possible after the spreading operation to reduce nutrient loss (see on page 7) and runoff potential should a heavy rain occur.

Subsurface injection is probably the best incorporation method because it occurs immediately as manure is spread and only minimally disturbs the soil surface. This makes it attractive for reduced till and no-till cropping systems.

Disadvantages of injection include equipment cost and maintenance, high power requirements, and the time, labor and management involved. Additionally, injection is not as well suited to pasture and grass programs or areas of the state with shallow, rocky soils.

Application rate

Manure should be applied to fields at a rate compatible with the nutrient needs of the crop. Supplying an excess of nutrients may result in ground or surface water pollution and eventual depressed crop yields, besides being a waste of resources. Determining the rate at which manure should be applied requires consideration of crop requirements and nutrients already present in the soil.

Manure nutrients, especially nitrogen, are used more efficiently by grain crops than by legumes. However, using manure for the nitrogen needs of continuous grain crops could result in phosphorus and potassium buildup in the soil. Forage crops, or whole-plant removal in rotation with grain crops, will reduce this effect.

Because the rate at which manure should be applied depends upon the amount of nutrients already in the soil, soil tests should be used to determine the amounts of available residual nutrients. When determining the application rate, consideration should be given to all sources of nitrogen. Manure organic nitrogen mineralized during the current growing season from previous years' applications should be estimated. If a legume crop is plowed down and followed by grain or another crop, credit should be given to the nitrogen available from the legume crop. Table 4 in Water Quality Guide 202 gives estimates of the amount of nitrogen available following various legume crops. Also, Table 3 reported in Water Quality Guide 202 lists the nitrogen, phosphate and potash removal from the soil by various crops. This data helps determine the nutrient needs of a crop by crop type and expected yield.

In managing manure as a fertilizer, it is highly desirable (and necessary for accuracy) to have a laboratory analysis of the manure immediately prior to spreading and to have soil test data to provide nutrient information for the crop being grown. However, in the field, one or both of these pieces of information may not be available when it is time to spread manure. Hence, one of four scenarios may result:

1. Manure is applied to land without lab analysis or soil test.
2. Manure is applied to land with lab analysis but no soil test.
3. Manure is applied to land with soil test but no lab analysis.
4. Manure is applied to land with soil test and with lab analysis.

If a laboratory analysis is not available, use the average values of manure nutrients in similar waste management systems as reported in the literature. It should be noted that such values are highly variable, and variations of 50 to 100 percent among test samples are not unusual. Water Quality Guide 201 gives average nutrient values for swine, dairy and poultry manures.

If soil test results are not available for nutrient application rates, a standard rate of 100 pounds of nitrogen per acre is a guide that can be used. This application rate conforms with the regulatory guidelines for sizing soil-plant filters under the conservation management approach. This guideline can be determined from the data reported in the following tables.

Manure Ammonia-Nitrogen Loss by Days until Worked into the Soil

Days until incorporation	Percent of ammonia-N available for crops
0 - 2	80
2 - 4	60
4 - 7	40
>7	20

Manure Organic Nitrogen Available by Year

Manure applied	Percent of organic N available during current year
Current year	40 - 60
1 year ago	10
2 years ago	5
3 years ago	5

Waste Management Systems Available to Missouri Dairy Producers

Three systems will meet Missouri Clean Water Law requirements for dairy herds. These systems are (1) daily scrape, store and haul; (2) lagoon-gutter flush and (3) liquid storage tank.

Daily scrape, store and haul system

A daily scrape and haul system requires a relatively small investment in a concrete ramp, a solid waste manure spreader and a tractor to pull it. The system is labor intensive but the workload can be distributed throughout the year. A separate facility is required for milking center wastes.

Because of Missouri's rainy seasons, periods of freezing and thawing and the crop growing season, land is often unavailable for spreading. To overcome this problem, a short-term storage facility is needed. A storage facility accommodating a 60-day accumulation of waste will provide the necessary flexibility and a place for milking center waste. But, the additional storage increases the cost of the basic scrape and haul system. Also, management becomes more complicated and the labor distribution is not as uniform. Because of the very short holding period and problems associated with inclement weather in Missouri, the scrape and haul system works best for dairy herds of 100 cows or less. Therefore, the economic analysis in this bulletin does not include this system because herds studied exceeded 100 cows.

Lagoon-gutter flush system

The anaerobic lagoon system has low labor cost, relatively low investment cost for storage and disposal flexibility. A low concentration of solids is required for irrigation and a low amount of water recycling is needed for flushing. If no domestic waste is included, milking center wastes can be discharged into the lagoon.

The disadvantages are: access to a traveling gun is needed for waste distribution; there is a potential for odor; nitrogen is lost through volatilization; sludge can build up in the lagoon over time unless fibrous materials are separated out; and there may be a salt problem in the gutter flush recycling system.

The lagoon capacity specifications are based on 365 days storage; 100 percent of waste going into the lagoon; calf and replacement heifer waste is not included, but dry cow waste is included. The amount of land required for spreading is based on 100 pounds of nitrogen used annually by plant production per acre. Estimated costs include a clay pond seal compacted via a sheepfoot compactor.

Other equipment includes water storage tanks for flushing gutters and an electric pump and pipe needed to recycle water from the lagoon to storage tanks. Lagoon waste was assumed to be spread by a traveling gun irrigation system.

Liquid storage tank system

The above-ground tanks in this system are either a circular silo type or rectangular. They are constructed from cast-in-place reinforced concrete, concrete reinforced stave silos or glass-fused steel panels. The construction or purchase cost of storage tanks varies. A concrete stave silo with adequate reinforcement can be purchased at 70 percent of the cost stated in this study. Other storage facilities will normally cost more than the in-ground concrete tank.

Open impeller centrifugal chopper-type pumps are used for agitating the manure and emptying the storage tanks. The waste is hauled from storage to fields a minimum of three times per year with required storage capacity being 120 days.

Advantages of the tank system are maximum fertilizer value and the ability to discharge milking center wastes into the system.

The disadvantages are high capital costs, gases and odors produced during agitation, dependence on a pump for transfer of waste in and out of the facility and the need for increased management.

Economic Analysis

Methodology

The economic analysis includes an engineering cost analysis of two waste management systems (lagoon and liquid tank). The lagoon system is used in conjunction with a traveling gun irrigation system.

We assumed the lagoon waste was spread by a traveling gun irrigation system. Because professional lagoon irrigators are available for hire, a custom irrigation charge of $60 per hour is used to estimate the cost of distributing lagoon waste. This was the prevailing custom charge reported to the authors.

Itemized investments, annual fixed and variable cost data for the lagoon system, and method of calculation are reported in Appendix Tables 1 through 4. The same data for the liquid manure system is reported in Appendix Tables 6 through 9.

The waste fertilizer value for plant production is estimated in Appendix Table 5 for the lagoon system and Appendix Table 10 for the liquid tank system.

The net annual cost of each waste system is determined by calculating costs (operating and fixed) associated with the initial investment, labor and power equipment needed minus the fertilizer nutrient value of the waste expected to be used by the plants.

The net annual cost per cow and per hundredweight of milk production for the lagoon system is shown in Table 1; the liquid manure tank system is in Table 2.

Assumptions

Specific assumptions are included with some additional discussion and explanation of the organization and supporting data for the analyses.

Assumptions regarding each waste system

Effluent from a lagoon is spread by a traveling gun irrigation system. The capacity of the traveling gun is assumed to be 500 gallons per minute which will distribute an acre-inch of waste per hour. In some sections of the state, custom irrigators have developed a business of pumping lagoons with an $60 per hour charge. The custom operator provides everything except "equipment check labor." The producer is responsible for checking irrigation equipment to see that it is operating properly. Because labor is nearly always limited on dairy operations of 100 cows or more, hiring custom irrigators may be the most economical way of distributing waste from a lagoon system. The custom irrigation approach was used in our economic analysis.

Other alternatives are: (1) Some counties offer irrigation equipment for rent by the Soil and Water Conservation Boards. (2) Individual ownership by two to four producers (partnership) or dual use through crop irrigation are viable reasons for owning the irrigation system. For comparison, an economic analysis of owning a traveling gun irrigation system is included in Appendix Tables 11 - 13.

The liquid storage tank system used in the analysis is assumed to be below ground concrete tanks that are loaded by gravity. Above ground tanks would have to be loaded daily via a mechanized loading pump. Equipment required to operate this system included a manure scraper operated with a 40 hp. tractor, an agitator-loading pump and a 3,000 gallon tank wagon pulled by a 100 hp. tractor. The number of tank wagons required varies by herd size, i.e., one wagon for 100- to 200-cow herds, but two wagons for 300-cow herds in order to distribute waste within a 10-day period for each 120-day storage period.

For labor, we assumed an individual is needed at the storage tank site to operate the tractor and agitation loading pump for filling the tank wagons. Also a tractor operator is needed for each individual tank wagon used to distribute waste to the fields.

Fertilizer nutrient equivalent

Dairy waste applied to the land has an economic value if the basic fertilizer elements (nitrogen, phosphorus and potash) in the waste replace commercial fertilizer normally purchased and/or increases the amount of plant growth which can be used by livestock or harvested and marketed.

The assumed value of these fertilizer nutrients is as follows: nitrogen, 23¢/lb; phosphate, 22¢/lb.; and potash, 14¢/lb.

The availability of these fertilizer nutrients are illustrated in Appendix Table 5 for the lagoon system and Table 10 for the liquid manure tank system. We assumed 75 percent of the phosphate and 90 percent of the potash is available for plant production. Nitrogen availability varies with more nitrogen being available through the liquid manure tank system than through the lagoon due to oxidation, denitrification and water dilution.

Costs

Tractor costs

Rather than trying to prorate tractor costs according to use, tractor operating costs per hour as reported in "Doane's Operating Costs for 1991" are used to calculate power costs.

Labor costs per hour

The cost of labor used in the analysis is $6 per hour. Labor costs will vary depending on the job market within traveling distance of the dairy operation. If the business is located close to a metropolitan area, labor costs per hour will be higher, but in rural areas where jobs are limited and living costs are lower, labor can be hired for less. Therefore, each operator will need to consider appropriate adjustments in labor costs.

Consultation

A consultation charge is included for professional engineering services to develop blueprints that meet state specifications and to assure construction companies meet these specifications. To date, Soil Conservation Service personnel and Extension Agricultural Engineers have provided these services. But with limited resources and increased demand for engineering expertise, both agencies will likely have to limit these services in the future.

Fencing

A fencing charge is included for the lagoon system to prevent animal access to the lagoon water. In fact, the Agricultural Stabilization and Conservation Service (ASCS) requires lagoons to be fenced if they provide construction cost assistance.

Government assistance

Federal cost-sharing assistance is available for construction of animal waste systems through the local ASCS office. Assistance is limited to existing dairies (operating for five years) that are not in an expansion mode. Dollar cost-share assistance is limited to 75 percent of the average cost or a maximum of $17,500 per person under a long-time agreement contract. In some instances, a husband and wife may be considered separate owners which would allow up to $35,000 maximum cost sharing on the waste system. Complete details are available at your county ASCS office. The assistance program does not cost-share on consulting fees.

Cost-sharing assistance is not included in the economic analysis. The assistance can help reduce annual costs by 20 to 30 percent for herds of 300 cows or less, depending on the size and cost of the facility.

Cost summary and system comparison

A summary of the economic analyses developed in the appendix is reported in Table 1 for the lagoon system and Table 2 for the liquid manure storage system.

A major objective of the study is to identify the most economical system to build and to evaluate the optimal size herd for each system. A comparison of the advantages of the two systems for various size herds follows.

Lagoon system:

- Average investment per cow for 100-cow herds is $363 compared to $217 per cow for 1,000-cow herds, indicating the presence of size advantage.
- Total annual costs per cow are $87 per cow for 100-cow herds, falling to $47 per cow in 1,000-cow herds — a drop of 46 percent ($87 minus $47 divided by $87).
- Value of lagoon waste offsets total annual costs 26 percent for 100-cow herds, 23 percent for 500 cows and 23 percent for 1,000 cows.
- Net annual cost for lagoons is $64 per cow for 100 cows, $41 for 500 cows and $36 for 1,000 cows. A reduction of 44 percent ($64 minus $36 divided by $64) between herds of 100 cows and 1,000 cows (see Table 1, line 7). The 500-cow herds have achieved 36 percent ($64 minus $41 divided by $64) of the 44 percent total decrease in cost, indicating that increasing from a herd of 100 to 500 cows can capture a large share of the size advantage.
- The lagoon system will add 43¢ (100-cow herds) to 25¢ (750-cow herd) to the cost per cwt. of milk produced for herds averaging 15,000 pounds of milk per cow annually.
- Based on averages, the effluent should be spread over 22 acres for 100 cows and 102 acres for 1,000 cows, or a range of .1 to .2 acres per cow is required (see Appendix Table 5, line 13).

Table 1. Summary of Lagoon System Costs

	Herd Size					
	100	200	300	500	750	1,000
1. Average investment per cow	$ 363	$ 297	$ 268	$ 242	$ 224	$ 217
2. Annual operating costs (from App. Table 4, ln 10)	$3,663	$5,367	$6,821	$10,053	$13,363	$16,765
3. Annual fixed costs (from app. Table 3, ln. 7)	5,051	8,271	11,219	16,810	23,247	29,914
4. Total annual costs (ln 2 + ln. 3)	$8,714	$13,638	$18,040	$26,863	$36,610	$46,679
5. Annual costs per cow	$ 87	$ 68	$ 60	$ 54	$ 49	$ 47
6. Value of waste (from App. Table 5, ln 12)	$2,304	$3,435	$4,292	$6,265	$8,245	$10,509
7. Net annual cost (ln 4 minus ln. 6)	$6,410	$10,203	$13,748	$20,598	$28,365	$36,170
8. Net annual cost per cow	$ 64	$ 51	$ 46	$ 41	$ 38	$ 36
9. Net cost per cwt. milk production with 15,000 pounds annual production per cow	$ 0.43	$ 0.34	$ 0.31	$ 0.27	$ 0.25	$ 0.24

Liquid tank system:

- The initial average investment cost of the system is $910 per cow for 100-cow herd, dropping to $443 per cow for 500 cows and $381 per cow for 1,000 cows.
- Total annual costs per cow by herd size is as follows: $219 for 100 cows, $144 for 300 cows, $126 for 500 cows and $121 for 1,000 cows (see Table 2, line 4).
- Waste from the liquid tank system is highly concentrated. Based on our estimates, its value as a fertilizer is $63 per cow. Unlike the lagoon system, the fertilizer value of the waste on a per cow basis remains the same because it is not diluted in storage.
- Estimated net annual cost per cow (total annual costs less value of waste as a fertilizer) is $156 for 100-cow herds and $63 for 500-cow herds — a reduction of 60 percent. The net cost per cow for 1,000-cow herds is $58 — 63 percent less than 100-cow herds — illustrating that a larger herd size has an economic advantage, with 500-cow herds receiving the largest share of this size advantage.
- The liquid tank system will add approximately $1.04 for 100- cow herds and $.39 for 1,000-cow herds to the cost per cwt. of milk production for herds producing 15,000 pounds of milk per cow annually.
- Effluent, based on average nutrient analysis, should be spread over 103 acres for 100 cows and 1,024 acres for 1,000 cows, or approximately a 1-acre soil filter system is required per cow (see Appendix Table 10, line 13).

Table 2. Summary of Liquid Manure Tank System Costs

	Herd Size					
	100	200	300	500	750	1,000
1. Average investment per cow	$ 910	$ 599	$ 546	$ 443	$ 412	$ 381
2. Annual operating costs (from App. Table 9, ln 7)	$8,025	$12,502	$18,814	$31,457	$47,265	$68,674
3. Annual fixed costs (from app. Table 8, ln 7)	13,887	17,435	24,416	31,565	43,863	52,715
4. Total annual costs (ln 2 + ln. 3)	$21,912	$29,937	$43,230	$63,022	$91,128	$121,389
5. Annual costs per cow	$ 219	$ 150	$ 144	$ 126	$ 122	$ 121
6. Value of waste (from App. Table 10, ln 12)	$6,291	$12,580	$18,872	$31,454	$47,180	$62,908
7. Net annual cost (ln 3 minus ln 5)	$15,621	$17,357	$24,358	$31,568	$43,948	$58,481
8. Net annual cost per cow	$ 156	$ 87	$ 81	$ 63	$ 59	$ 58
9. Net cost per cwt. milk production with 15,000 pounds annual production per cow	$ 1.04	$ 0.58	$ 0.54	$ 0.42	$ 0.39	$ 0.39

Conclusions

Dairy producers with herds exceeding 100 cows are required to have a letter of approval from DNR in order to operate. If this approval requires the installation of a waste management system, producers can expect production costs to increase approximately 40¢ to 60¢ per cwt. of milk production for average size herds in Missouri with the lagoon system. The liquid tank system can increase costs approximately $1 per cwt. Therefore, operators with more than 100 cows who are considering expansion and presently do not have a waste management system should count on an added production cost of at least 25¢ to 40¢ per cwt. of milk production.

If the waste system investment is added with borrowed money using a 7-year loan at 12 percent interest, the annual cash flow obligations (principal and interest payments) will be 50 to 60 percent greater than the net annual costs reported on line 7 of Tables 1 and 2 for each of the two systems.

Even though waste from the liquid tank system is more concentrated and valuable as a fertilizer, this system's net cost is 2.4 times greater than the lagoon system's cost for 100 cows, 1.8 times greater for 300 cows, 1.5 times greater for 500 cows and 1.6 times greater for 1,000 cows. Therefore, the lagoon system is more economical because it requires less capital investment per cow (compare line 1 in Tables 1 and 2). Also, the lagoon system requires virtually no labor from the dairy operation if the waste is distributed by a custom irrigator. The liquid tank system requires 4 to 5 hours of labor per cow.

Larger dairy herds have lower net annual costs per cow because costs decline as cow numbers increase. Net annual costs are lowest for 750 and 1,000-cow herds, but the 750-cow size has almost as low a cost as the 1,000-cow, indicating costs tend to level out at 750 cows.

For Missouri producers using lagoons, 64 percent of the possible cost savings associated with increased herd size going from 100 to 1,000 cows is realized by a 300 cow dairy. The 500-cow herd size picks up 82 percent of the possible savings[5]. With the liquid tank system, the 500-cow herd gains 95 percent of the size economies obtained by increasing from 100 cows to 1,000 cows. Herds of 300 cows pick up 50 percent of this advantage.

The liquid tank system requires a 5 to 10 times larger plant filter area for waste distribution per cow than does the lagoon system. This can be a problem for a total confinement dairy on small acreage.

Larger dairies (more than 300 cows) may profit by purchasing a traveling gun irrigation system rather than relying on a custom irrigator who charges $60 per hour. According to the economic analysis summarized in Table 13, the cost per acre-inch of waste distributed or per hour of operation is $60.38 for 300 cow-herds. For larger herds, this cost is less than the $60 per hour charged by custom operators. For example, the cost is $46 per acre-inch lower for the 500-head size than for 100 cows. For herds with fewer than 300 cows, hiring the waste spread appears to be less costly than owning the irrigation system. Even for larger herd sizes, under conditions of scarce management and labor resources, custom irrigating may be more desirable. Also, larger dairies could possibly bargain for more favorable rates.

Footnotes

[1]Source: Water Quality Guide 200, Charles D. Fulhage, Extension Agricultural Engineer, MU.

[2]Water Quality Guide 201, Charles D. Fulhage, Extension Agricultural Engineer, MU.

[3]Source: Water Quality Guide 202, Charles D. Fulhage, Extension Agricultural Engineer, MU.

[4]\$64 - \$46 = \$18 ÷ \$28 for 100 to 1,000 cows = 64 percent

[5]\$64 - \$41 = \$23 ÷ \$28 for 100 to 1,000 cows = 82 percent

Appendix Tables

- Lagoon waste system
- Liquid tank waste system
- Traveling gun irrigation system

Lagoon waste handling system for dairy herds

Table 1. Lagoon system: Investment

	Herd Size					
	100	200	300	500	750	1,000
1.Lagoon	$25,416	$44,253	$61,196	$97,121	$138,922	$182,455
2.Fencing ($0.727/ft.)	872	1,091	1,163	1,454	1,599	1,745
3.Storage tanks (gutter flush)	3,000	6,000	9,000	12,000	15,000	18,000
4.Recycling pump and pipe	3,500	4,000	4,500	5,500	6,500	7,500
5.Consultation	3,500	4,000	4,500	5,000	6,250	7,500
6.Total investment	$36,288	$59,344	$80,359	$121,075	$168,271	$217,200
7.Average investment per cow	$363	$297	$268	$242	$224	$217

Table 2. Lagoon system: Annual fixed costs as a percent of new cost

	Lagoon and fence	Equipment	Consultation
Years useful life	20	1020	
Fixed costs as percent			
Depreciation	5.0	9.0[1]	5.0
Interest	6.0[2]	6.0[2]	6.0
Repairs and maintenance	1.5	1.5	
Taxes	0.8[3]	1.0[3]	
Insurance		0.5	
Total percent	13.3	18.0	11.0

[1]Allows for 10 percent salvage.

[2]Annual interest charge is 6% of original investment (equivalent to investment x 50% x 12% APR.)

[3]Tax assessment varies based on value added to the property. A lagoon established on a suitable site in an area where unfavorable geological conditions predominate will add more value to the property than one established in an area with many favorable sites.

Table 3. Lagoon system: Total annual fixed costs

	Herd Size					
	100	200	300	500	750	1,000
1.Lagoon and fence[1]	$26,288	$45,344	$62,359	$98,575	$140,521	$184,200
2.Equipment, initial investment[1]	6,500	10,000	13,500	17,500	21,500	25,500
3.Consultation[1]	3,500	4,000	4,500	5,000	6,250	7,500
4.Lagoon and fence (ln 1 x 13.3%[2])	3,496	6,031	8,294	13,110	18,689	24,499
5.Equipment, annual costs (ln 2 x 18%[2])	1,170	1,800	2,430	3,150	3,870	4,590
6.Consultation (ln3 x 11%[2])	385	440	495	550	688	825
7.Total annual fixed costs (ln 4 + ln 5 + ln 6)	$5,051	$8,271	$11,219	$16,810	$23,247	$29,914

[1]Transferred from Table 1.

[2]Transferred from Table 2.

Table 4. Lagoon system: Annual operating costs

	Herd Size					
	100	200	300	500	750	1,000
Operating recycle pump						
1. Size electric pump (hp)	1.5	1.5	3.0	5.0	7.5	7.5
2. Annual pumping time (5 hrs. daily x 365 days)	1,825	1,825	1,825	1,825	1,825	1,825
3. Cost/hour (1 kw x hp x 7¢/kw)	$0.11	$0.11	$0.21	$0.35	$0.53	$0.53
4. Annual pumping costs (ln 2 x ln 3)	$201	$201	$383	$639	$967	$967
Irrigation lagoon annual pumping cost						
5. Estimated acre-inches to pump annually	57	85	106	155	204	260
6. Custom pumping charge/hour[1]	$60	$60	$60	$60	$60	$60
7. Annual lagoon pumping costs (ln 5 x ln 6)	$3,420	$5,100	$6,360	$9,300	$12,240	$15,600
8. Check labor hours/year[2]	7	11	13	19	26	33
9. Annual labor costs (ln 8 x $6/hr.)	$42	$66	$78	$114	$156	$198
10. Total operating costs (ln 4 + ln 7 + ln 9)	$3,663	$5,367	$6,821	$10,053	$13,363	$16,765

[1]Assume a traveling gun pumps 500 gallons per minute which allows pumping one acre-inch per hour.

[2]Check labor required to inspect the irrigation system periodically to determine if the traveling gun and equipment are operating adequately. Assume one hour per 8 hours operation.

Table 5. Lagoon system: Value of waste to plant production

	Herd Size					
	100	200	300	500	750	1,000
Nutrients produced (lbs./yr.)[1]						
1. Ammonia nitrogen	2,623	3,912	4,876	7,130	9,384	11,960
2. Organic nitrogen	1,312	1,956	2,438	3,565	4,692	5,980
3. Phosphorus	1,994	2,973	3,710	5,425	7,140	9,100
4. Potassium	6,838	10,198	12,770	18,600	24,480	31,200
Pounds of fertilizer nutrient equivalent available						
5. Ammonia nitrogen (ln 1 x 50%[2])	1,312	1,956	2,438	3,565	4,692	5,980
6. Organic nitrogen (ln 2 x 70%[2])	918	1,369	1,707	2,496	3,284	4,186
7. Phosphate (ln 3 x 2.3[3] x 75%[1])	3,440	5,128	6,400	9,358	12,317	15,698
8. Potassium (ln 4 x 1.2[4] x 90%[1])	7,385	11,014	13,792	20,088	26,438	33,696
Value of fertilizer equivalents						
9. Nitrogen (ln 5 + ln 6 x $0.23/lb.)	$ 513	$ 765	$ 953	$ 1,394	$ 1,834	$ 2,338
10. Phosphate (ln 7 x $0.22/lb.)	757	1,128	1,408	2,059	2,710	3,454
11. Potash (ln 8 x $0.14/lb.)	1,034	1,542	1,931	2,812	3,701	4,717
12. Total value of fertilizer equivalent	$ 2,304	$ 3,435	$ 4,292	$ 6,265	$ 8,245	$10,509
13. Minimum no, acres to irrigate[5]	22	33	41	61	80	102
14. Value of fertilizer equivalent per acre (ln 12 ÷ ln 13)	$105	$104	$105	$103	$103	$103

[1]Average analysis of lagoon waste.
[2]Average percent available to plant.
[3]Conversion of phosphorus to phosphate.
[4]Conversion of potassium to potash.
[5]Application of 100 pounds of available nitrogen per acre.

Liquid manure tank system for dairy herds

Table 6. Liquid manure tank system: Investment

	Herd Size					
	100	200	300	500	750	1,000
1.Manure tank[1]	$62,727	$91,207	$119,681	$176,624	$247,791	$318,952
2.Agitating and loading pump	10,000	10,000	10,000	10,000	10,000	10,000
3.Scraper	750	750	750	1,000	1,000	1,000
4.Tank wagon, 3,000 gal, capacity[2]	15,000	15,000	30,000	30,000	45,000	45,000
5.Consultation	2,500	2,900	3,300	4,100	5,100	6,000
6.Total new investment	$90,977	$119,857	$163,731	$221,724	$308,891	$380,952
7.Average investment per cow	$910	$599	$546	$443	$412	$381

[1]Cost based on concrete construction.

[2]Number of tank wagons: 100-200 cows – 1; 300-500 cows – 2; 750-1,000 cows – 3.

Table 7. Liquid manure tank system: Annual fixed costs as a percent of new cost

	Tank	Equipment	Consultation
Years useful life	20	20	
Fixed costs as percent			
Depreciation	5.0	12.9[1]	5.0
Interest	6.0[2]	6.0[2]	6.0
Repairs and maintenance	0.5	2.5	
Taxes	0.8[3]	1.0[3]	
Insurance		0.5	
Total percent	12.3	22.9	11.0

[1]Allows for 10 percent salvage.

[2]Annual interest charge is 6% of original investment (equivalent to investment x 50% x 12% APR.)

[3]Tax assessment varies based on value added to the property. A lagoon established on a suitable site in an area where unfavorable geological conditions predominate will add more value to the property than one established in an area with many favorable sites.

Table 8. Liquid manure tank system: Total annual fixed costs

	Herd Size					
	100	200	300	500	750	1,000
1.Tank	$62,727	$91,207	$119,681	$176,624	$247,791	$318,952
2.Equipment, initial investment[1]	25,750	25,750	40,750	41,000	56,000	56,000
3.Consultation[1]	2,500	2,900	3,300	4,100	5,100	6,000
4.Tank (In 1 x 12.3%)	7,715	11,219	14,721	21,725	30,478	39,231
5.Equipment, annual costs (In 2 x 22.9%[2])	5,897	5,897	9,332	9,389	12,824	12,824
6.Consultation (In3 x 11%)	275	319	363	451	561	660
7.Total annual fixed costs (In 4 ÷ In 5 ÷ In 6)	$13,887	$17,435	$24,416	$31,565	$43,863	$52,715
8.Total annual costs per cow	$139	$87	$81	$63	$58	$53

[1]Transferred from Table 6.
[2]Transferred from Table 7.

Table 9. Liquid manure tank system: Annual operating costs

	Herd Size					
	100	200	300	500	750	1,000
Power supply, hours use annually						
1. Scraper tractor, 40 hp	183	304	426	669	852	1,278
2. Agitation pump tractor, 100 hp[1]	7.2	10.8	14.5	21.9	31.0	40.2
3. Tank wagon(s) tractor(s), 100 hp[2]	172	260	406	699	1,118	1,610
Power Costs						
4. Scraper tractor (In 1 x $7.62/hr.[3])	$1,394	$2,316	$3,246	$5,098	$6,492	$9,738
5. Agitation and wagon tractor (In 2 + In 3 x $19.36/hr.[3])	$3,469	$5,242	$8,140	$13,957	$22,245	$31,948
Labor Costs						
6. Tractor operators (In 1 ÷ (2[4] x In 3) x $6/ hr.)	$3,162	$4,944	$7,428	$12,402	$18,528	$26,988
7. Total operating costs (In 4 ÷ In 5 ÷ In 6)	$8,025	$12,502	$18,814	$31,457	$47,265	$68,674
8. Total operating costs per cow	$80	$63	$63	$63	$63	$69

[1]Based on one hour per 16,000 cu. ft. waste.
[2]Hauling time per load by herd size (min.): 100 cows – 36 min.; 200 – 36; 300 – 42; 500 – 48; 750 – 54; 1,000 – 60.
[3]Based on Doane's Machinery Operating Costs 1991.
[4]Time on line 3 is doubled because one person is at agitation pump site plus hauling time.

Table 10. Liquid manure tank system: Value of waste to plant production

	Herd Size					
	100	200	300	500	750	1,000
Nutrients produced (lbs./yr.)						
1. Ammonia nitrogen	7,027	14,054	21,081	35,135	52,703	70,270
2. Organic nitrogen	11,225	22,450	33,675	56,125	84,188	112,250
3. Phosphorus	4,212	8,424	12,636	21,060	31,590	42,120
4. Potassium	15,444	30,880	46,332	77,220	115,830	154,440
Fertilizer nutrient equivalent (lbs./yr.)						
5. Ammonia nitrogen (ln 1 x 50%[1])	3,514	7,027	10,541	17,568	26,352	35,135
6. Organic nitrogen (ln 2 x 60%[2])	6,735	13,470	20,205	33,675	50,513	67,350
7. Phosphate (ln 3 x 2.3[3] x 75%[5])	7,266	14,531	21,797	36,329	54,493	72,657
8. Potassium (ln 4 x 1.2[4] x 90%[5])	16,680	33,350	50,039	83,398	125,096	166,795
Value of fertilizer equivalents						
9. Nitrogen (ln 5 + ln 6 x $0.23/lb.)	$2,357	$4,714	$7,072	$11,786	$17,679	$23,572
10. Phosphate (ln 7 x $0.22/lb.)	1,599	3,197	4,795	7,992	11,988	15,985
11. Potash (ln 8 x $0.14/lb.)	2,335	4,669	7,005	11,676	17,513	23,351
12. Total value of fertilizer equivalent	$6,291	$12,580	$18,872	$31,454	$47,180	$62,908
13. Minimum no, acres to irrigate[6]	103	205	307	512	769	1,024
14. Value of fertilizer equivalent per acre (ln 12 ÷ ln 13)	$61	$61	$61	$61	$61	$61

[1]Assumes 50 percent incorporated with 80 percent loss and 50 percent incorporated within two days with 20 percent loss. Value will increase if 100 percent incorporated within two days.

[2]Assumes not spread on same fields each year (50 percent year 1 plus 10 percent year 2).

[3]Conversion of phosphorus to phosphate.

[4]Conversion of potassium to potash.

[5]Average percent available to plant.

[6]100 pounds of nitrogen per acre.

Traveling gun irrigation system for waste distribution

Table 11. Annual fixed costs expressed as percent of initial cost of irrigation system

	Acre-inches lagoon waste pumped annually	
	50 to 175	175 to 300
Years useful life	15	10
Depreciation	6.0 %	9.0 %
Interest	6.0	6.0
Repairs and maintenance	7.0	10.0
Taxes	1.5	1.5
Total fixed costs	20.5 %	26.5 %

[1]Based on used equipment with above average maintenance and care.

Table 12. Traveling gun system's annual fixed costs

		Acre-inches lagoon waste pumped annually			
		50 to 175		175 to 300	
	initial cost	%	Annual fixed costs	%	Annual fixed costs
1.Traveling gun	$10,000[1]	20.5	$2,050	26.5	$2,650
2.PTO pump, 500 gpm	3,000[1]	20.5	615	26.5	795
3.Agitation pump	3,500[2]	20.5	718	26.5	928
4.Aluminum pipe:	4,200[1]	20.5	861		
	8,400[1]			26.5	2,226
5.Total annual fixed costs			$4,244		$6,599

[1]Workable used equipment.

[2]Not needed if you have a solids separator.

Table 13. Annual operating costs of traveling gun irrigation system

	Herd Size					
	100	200	300	500	750	1,000
Annual operating costs						
1. Acre-inches of waste[1]	57	85	106	155	204	260
2. Agitation pump time (hrs.)[2]	4	8	12	20	30	40
3. Minimum acres spread over[3]	22	33	41	61	80	102
4. No. times system set up[4]	2	3	4	6	8	10
5. Set up time (hrs.)	16	24	32	48	64	80
Power Costs						
6. Irrigation pump (ln 1 x $14.14/hr. 80 hp)[7]	$806	$1,202	$1,499	$2,192	$2,885	$3,676
7. Agitation pump (ln 2 x $19.36/hr. 100 hp)[7]	77	155	232	387	581	774
8. Laying pipe (ln 5 x 25%[5] x $19.36/hr. 100 hp)[7]	77	116	155	232	310	387
Labor Costs						
9. Check labor hrs.[8] (ln1 x 12.5%)	7	11	13	19	26	33
10. Total labor hours (ln 5 + ln 9)	23	35	45	67	90	113
11. Total labor costs (ln 10 x $6/hr.)	$138	$210	$270	$402	$540	$678
12. Total annual operating costs (add lines 6,7,8 and11)	$1,098	$1,683	$2,156	$3,213	$4,316	$5,515
13. Total annual fixed costs (Table 12, ln 5)	$4,244	$4,244	$4,244	$4,244	$6,599	$6,599
14. Total annual costs (ln 12 + ln 13)	$5,342	$5,927	$6,400	$7,457	$10,915	$12,114
15. Cost per acre-inch (ln 14 ÷ ln 1) or per hour operation	$93.72	$69.73	$60.38	$48.11	$53.50	$46.59

[1]Transferred from Appendix Table 4, ln 5; also irrigation operating hours.
[2]Four hours per 100 cows.
[3]Transferred from Appendix Table 5, ln 13.
[4]One set-up per 10 acres.
[5]Eight hours labor per set up.
[6]Assume tractor operates 25 percent of time required to lay pipe.
[7]Tractor power cost taken from "Doane's Machinery Operating Costs, 1991."
[8]Check labor is used to check the irrigation system periodically to determine if the system is operating adequately. Assume one hour per eight hours operation.

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