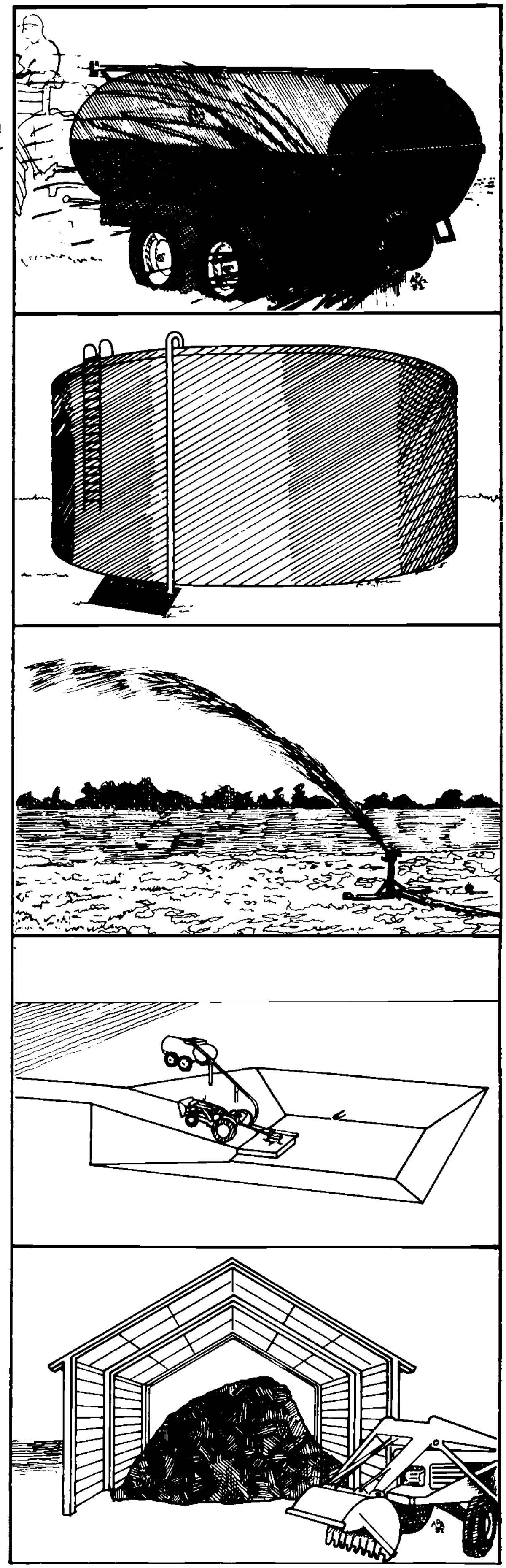

Selecting a Dairy Waste Management System for the Oregon Coast

EC 1104 September 1982

Oregon State University Extension Service

As a dairy operator thinks about building a new facility or expanding or modifying an existing one, a number of factors influence that decision: rainfall, temperature, soil type, surface drainage, topography, water table depth, farm size, cropping and feeding practices, availability of cropland to receive manure, existing buildings and machinery—all are important to consider.

Herd size, availability of labor and capital, future expansion plans, and operator's age also influence the selection of a waste management system.

Another very important factor in the selection of a waste management system is to recognize your own preference as the operator and your management capabilities. While this is extremely difficult to quantify and categorize, you must include it in any decisionmaking process.

Because of the number of influencing factors, there is no one "best" waste management system that can be recommended to a dairy operator. As with most decisionmaking, it is a series of trade-offs that offers choices, advantages, and disadvantages. We prepared this circular to help narrow the choices and provide an evaluation of possible alternatives. Its purpose is not to offer precise instructions, but rather to suggest areas for comparison that will be helpful to you as a dairy operator.

We attempted to assign costs to equipment and structures that are components of the six waste management systems compared here. These costs will vary widely; the availability of concrete, labor, lumber, and material will influence the total cost. When you can adjust these suggested costs, you will more accurately compare the various systems for your specific situation.

The six systems represent combinations of components that you can use successfully to handle and manage dairy waste. Each of the systems was adjusted for milking herd sizes of 100, 200, and 300 cows. The livestock waste you must manage is generated by milking cows, dry cows, replacement heifers, calves, and a cleanup bull (table 1). Multiply values in this table by two and three for herds of 200 and 300 milking cows.

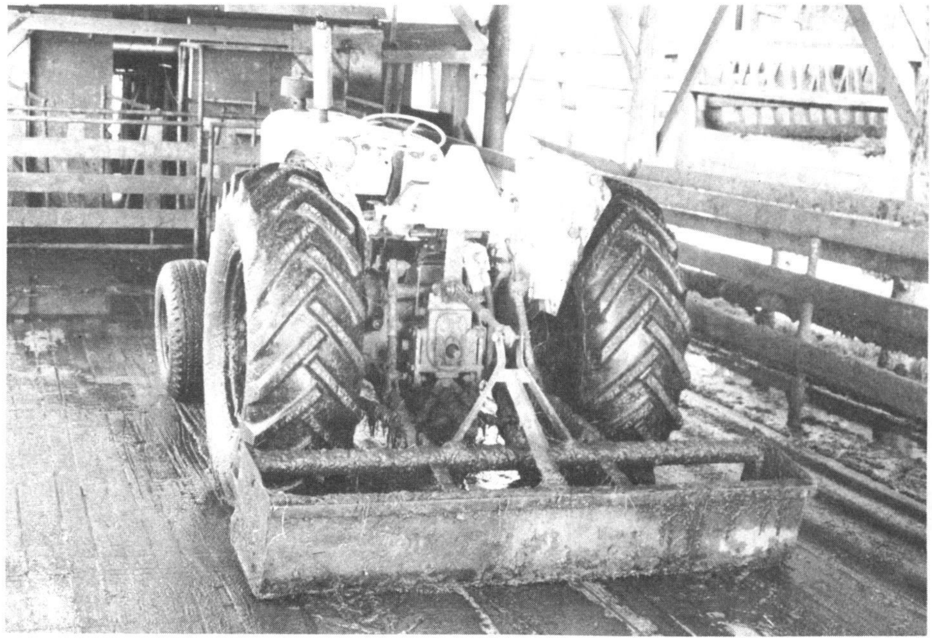

Figure 1. *A rear-mounted tractor-scraper is commonly used to collect manure on dairy operations.*

Liquid wastes include rainfall on outside lots and holding area, milking parlor and milkhouse waste water for all systems. The outdoor lot area was assumed to be 15 square feet per milking cow. This includes open alleyways between buildings, outside feed areas, and other exposed lots where manure will contaminate rainwater. The rainfall for the 150-day storage period (Nov.-Mar.) averages 62.7 inches. Waste water was assumed to be generated at a rate of 0.79 cubic feet per milking cow day.

Other assumptions include a small tractor (figure 1) to scrape, store, and load manure mixed with bedding and a larger tractor to pull the box spreader for the solid manure and the tanker for the liquid manure. As the herd size increases, the solid- and liquid-storage units, box spreader, and liquid tanker all increase in size. Each of the systems is defined in additional detail, and the assumptions for each are stated, in the following sections.

SYSTEM 1, DRY STACK

This system assumes the daily use of 6 pounds of bedding per milking cow for the 5 months of the winter season, 3 pounds per cow-day for 3 months during the late fall and early spring, and 1 pound per cow-day for

Table 1. Average manure production from a 100-milking-cow dairy

Animal	Number of animals	Average wt./head	Manure production: Per animal day			Manure production: Per group year		
		Pounds	*Pounds*	*Cubic feet*	*Gallons*	*Tons*	*Cubic feet*	*Gallons*
Lactating cow[1]	100	1,400	115	1.85	13.9	2.099	67,525	507,350
Dry cow[2]	16	1,400	103	1.65	12.4	308	9,636	72,416
Replacement calves[3]	37	500	41	0.66	5	277	8,913	67,525
Replacement heifers[4]	37	1,000	82	1.32	9.9	554	17,827	133,700
Cleanup bull[5]	1	1,400	115	1.85	13.9	21	675	5,073
Total, herd/yr						3,259	104,576	786,064
Total, herd/day						8.9	288	2,154

[1] The average cow is kept for 3 lactations. For Jerseys and other small cows (weighing about 1,000 pounds), multiply values in the table by 0.7 or 70%.
[2] A calving interval-lactation cycle includes being dry for 60 days.
[3] Sell bull calves the first week and lose 18 percent of heifers the first year.
[4] This stock freshens at 27 months.
[5] Artificial insemination is used for most dairy breeding. A single bull on premises will help identify and settle the heifers that did not conceive.

the remaining 4 months when the cows will be on pasture during the summer season. Dry and young stock are bedded at 10% of the rate of the milking cows. The dry-stack storage has a paved, sloping floor and a truss-supported metal roof. The storage unit is designed for 150-day capacity (figure 2).

Seepage from the stack is directed to, and collected in, a liquid holding tank. The seepage is generated at a rate of 1.3 gallons per cow-day. The liquid storage capacity of the holding tank is 75 days.

SYSTEM 2, EARTHEN STORAGE

A small tractor scrapes manure daily into an earthen storage facility. Bedding is used at a rate of 30% of the dry-stack system (#1), about 1.8 lbs. per milking cow daily for the winter season.

A PTO agitator/removal pump empties the storage unit. The storage unit is designed to hold the wastes for 150 days. In addition to the lot area and milking parlor wastes, the unit is designed to hold the rain that falls into the storage unit. A tractor drives the pump and pulls the tank spreader to the field (figure 3).

SYSTEM 3, DAILY SPREAD

A small tractor scrapes and loads manure daily. It loads this semisolid waste into a flail spreader and spreads it on nearby cropland. Bedding is used at a rate of 40% of System 1 or 2.4 lbs. per milking cow daily in the winter season. The liquid wastes are channeled to a holding tank with a 75-day storage capacity. A tractor powers the pump to load the liquids into the tanker and to pull both the solid and liquid waste to the field.

SYSTEM 4, ABOVEGROUND TANK

A small tractor with scraper daily collects the manure from the free-stall area and moves it to a collection sump. The waste water also is routed to this unit. After agitation, the slurry is pumped into an aboveground storage unit. An agitator in the storage unit mixes the manure slurry prior to withdrawal and loading into a tank spreader. A tractor provides the power for both agitation pumps and pulls the tanker to nearby cropland for land application. The storage unit has the capacity to store all liquid and solid wastes for 150 days. Bedding is used at the rate of 30% of System 1.

SYSTEM 5, LAGOON FLUSH

Manure is flushed twice a day into the nearby lagoon. Liquid from the far side of the lagoon is withdrawn and recycled as flushing water. While the other facilities have storage capacity of less than 6 months, the lagoon provides sufficient storage capacity for 1 year.

Bedding is used at 30% of the rate for the dry-stack system. A tractor is required in this system to power the irrigation pump for the annual land spreading operation. An electric motor drives the recycle pump. A complete irrigation system is charged against this system as a necessary component of waste handling.

SYSTEM 6, LAGOON FLUSH WITH SEPARATOR

This system has all of the components described in System 5 above and adds a collection sump to gather the flushing waste water. A float-controlled motor and pump feed the separator, which is placed on top of a tower. This tower allows gravity flow, in most cases, of the liquid fraction to the lagoon. The separated solids fall to a concrete slab at the base of the tower (figure 4).

After heating, the solids can be used in the dairy operation as bedding. Twice as much bedding material is produced as is used in the operation, allowing a positive allowance to the system for bedding.

COST COMPUTATIONS

The major components and equipment items for all systems are listed in tables 2, 3, and 4. The items stay the same for all systems; however, the sizes change for some units. We obtained the initial cost for the farm equipment from the *Official Guide, Tractor and Farm Equipment 1981.* This contains sizes and price information, and is distributed by the National Farm and Power Equipment Dealers' Association.

Figure 2. *Heavily bedded manure is collected and handled as a solid with the tractor-mounted front-end loader. The solid manure is stored in a bunker-type covered building.*

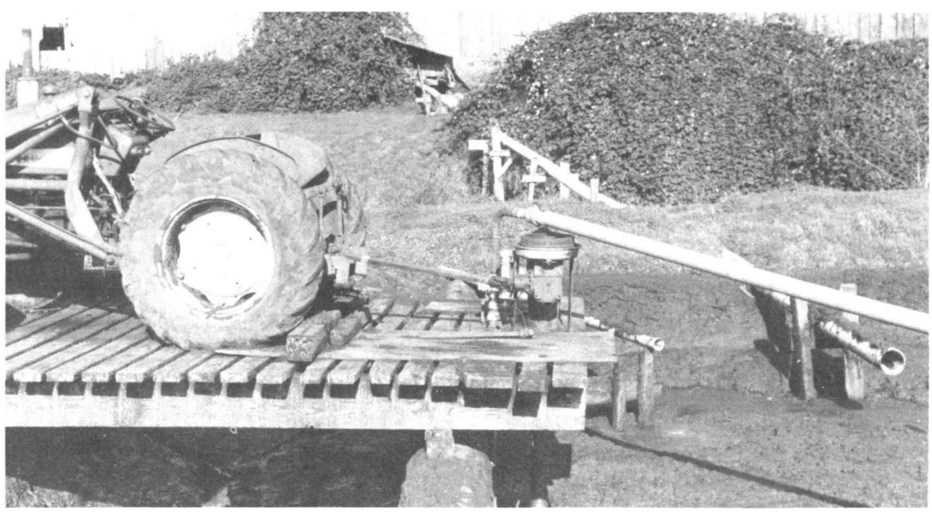

Figure 3. *The pipe from the barn moves the manure to an earthen storage unit. The wooden dock allows the tractor to agitate and pump the manure slurry to nearby fields, where it is applied through sprinklers.*

Table 2. **Manure handling systems for 100-milking-cow herds**

System	Initial cost ($)	Insurance repair, taxes (%)	Insurance repair, taxes ($/yr)	Life (yr)	% of time devoted to manure handling	Capital recovery ($/yr)
1) *Covered dry stack*						
pump PTO 1,000 gpm	3,000	3	90	8	100	669
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
storage structure ($6/ft²)	31,600	3	316	20	100	5,048
box spreader, 138 bu	4,000	3	120	8	100	862
tractor, 105 hp	27,000	3	81	10	10	525
liquids tank, 11,140 ft³	15,800	1	158	20	100	2,524
tanker for liquids (800 gal)	5,100	3	153	8	100	1,099
Total	100,500		1,254			13,902
2) *Earthen storage*						
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
earthen pond, 178,000 ft³	3,840	1	38	20	100	613
agitation/removal pump, 10 ft	4,800	3	144	8	100	1,035
tractor for agitating, 105 hp	27,000	3	162	10	20	1,050
tank spreader, 2,200 gal	7,920	3	238	8	100	1,707
Total	57,560		918			7,580
3) *Daily spread*						
pump PTO 1,000 gpm	3,000	3	90	8	100	669
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
flail spreader, 177 bu	4,700	3	141	8	100	1,013
tractor for spreading, 130 hp	30,000	3	90	10	10	583
liquids tank 9,840 ft³	13,600	1	136	20	100	2,173
liquid tanker, 800 gal	5,100	3	153	8	100	1,099
Total	70,400		946			8,712
4) *Aboveground storage tank*						
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
agitation pit	2,500	1	25	20	100	399
agitation transfer pump, 10 ft	4,800	3	144	8	100	1,035
aboveground tank, 97,000 ft³	96,900	1	969	20	100	15,386
tractor for agitator, 105 hp	27,000	3	162	10	20	1,050
tank spreader, 1,500 gal	8,150	3	245	8	100	1,757
Total	153,350		1,881			22,802
5) *Lagoon flush*						
tractor, 105 hp	27,000	3	40	10	5	262
recycle pump, ½ hp, 5 hr day	250	1	7	8	100	56
flush tanks, manual gate	6,000	1	60	20	100	959
lagoon, 924,000 ft³	15,390	1	154	20	100	2,459
irrigation pump, 500 gpm, PTO	6,800	3	204	10	100	1,321
travelling big gun, 1,200-ft hose	17,000	3	510	10	100	3,304
mainline 6-inch PVC, 1,400 ft	2,440	1	24	15	100	417
Total	74,880		999			8,778
6) *Lagoon flush—separator*						
Includes all in #5 above	74,880		999			8,778
collection sump	2,500	1	25	20	100	399
separator tower	6,000	1	60	20	100	953
separator	22,000	3	660	10	100	4,275
pump & motor (35 hp-150 gpm)	4,000	3	120	8	100	891
float control	800	3	24	5	100	239
Total	110,180		1,888			15,535

Table 3. Manure handling systems for 200-milking-cow herds

System	Initial cost ($)	Insurance repair, taxes (%)	Insurance repair, taxes ($/yr)	Life (yr)	% of time devoted to manure handling	Capital recovery ($/yr)
1) *Covered dry stack*						
pump PTO 1,000 gpm	3,000	3	90	8	100	669
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
storage structure ($6/ft^2)	63,200	1	632	20	100	10,097
box spreader, 275 bu	4,900	3	147	8	100	1,056
tractor, 105 hp	27,000	3	81	10	10	525
liquids tank, 22,280 ft^3	31,000	1	310	20	100	4,953
tanker for liquids (1,500 gal)	7,200	3	216	8	100	1,552
Total	150,300		1,812			22,027
2) *Earthen storage*						
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
earthen pond, 312,000 ft^3	6,200	1	62	20	100	991
agitation/removal pump, 10 ft	4,800	3	144	8	100	1,035
tractor for agitating, 105 hp	27,000	3	162	10	20	1,050
tank spreader, 2,200 gal	9,820	3	295	8	100	2,117
Total	61,820		999			8,368
3) *Daily spread*						
pump PTO 1,000 gpm	3,000	3	90	8	100	669
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
flail spreader, 360 bu	8,200	3	246	8	100	1,768
tractor for spreading, 130 hp	30,000	3	90	10	10	583
liquids tank 19,680 ft^3	27,500	1	275	20	100	4,393
liquid tanker, 1,500 gal	7,200	3	216	8	100	1,552
Total	89,900		1,253			12,140
4) *Aboveground storage tank*						
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
agitation pit	2,500	1	25	20	100	399
agitation transfer pump	4,800	3	144	8	100	1,035
aboveground tank, 186,000 ft^3	144,200	1	1,442	20	100	22,897
tractor for agitator, 105 hp	27,000	3	162	10	20	1,050
tank spreader, 2,220 gal	7,920	3	238	8	100	1,707
Total	200,420		2,347			30,263
5) *Lagoon flush*						
tractor, 105 hp	27,000	3	40	10	5	262
recycle pump, ½ hp, 10 hr day	250	3	7	8	100	54
flush tanks, manual gate	12,000	1	120	20	100	1,917
lagoon, 1,725,000 ft^3	24,500	1	245	20	100	3,914
irrigation pump, 500 gpm, PTO	6,800	3	204	10	100	1.321
travelling big gun, 1,200-ft hose	17,000	3	510	10	100	3,387
mainline 6-inch PVC, 2,600 ft	4,880	1	49	15	100	834
Total	92,430		1,175			11,689
6) *Lagoon flush—separator*						
Includes all in #5 above	92,430		1,175			11,689
collection sump	2,500	1	25	20	100	399
separator tower	6,000	1	60	20	100	953
separator	22,000	3	660	10	100	4,275
pump & motor (35 hp-150 gpm)	4,000	3	120	8	100	891
float control	800	3	24	5	100	239
Total	127,730		2,064			18,446

Table 4. Manure handling systems for 300-milking-cow herds

System	Initial cost ($)	Insurance repair, taxes (%)	Insurance repair, taxes ($/yr)	Life (yr)	% of time devoted to manure handling	Capital recovery ($/yr)
1) *Covered dry stack*						
pump PTO 1,000 gpm	3,000	3	90	8	100	669
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
storage structure ($6/ft²)	94,800	1	948	20	100	15,145
box spreader, 510 bu	13,100	3	393	8	100	2,824
tractor, 105 hp	27,000	3	81	10	10	525
liquids tank, 33,420 ft³	45,000	1	450	20	100	7,189
tanker for liquids (2,200 gal)	7,920	3	238	8	100	1,707
Total	204,820		2,536			31,234
2) *Earthen storage*						
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
earthen pond, 440,000 ft³	8,350	1	84	20	100	1,334
agitation/removal pump, 10 ft	4,800	3	144	8	100	1,035
tractor for agitating, 105 hp	27,000	3	162	10	20	1,025
tank spreader, 3,200 gal	9,820	3	295	8	100	2,117
Total	63,970		1,021			8,686
3) *Daily spread*						
pump PTO 1,000 gpm	3,000	3	90	8	100	669
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
flail spreader, 510 bu	13,200	3	396	8	100	2,846
tractor for spreading, 130 hp	30,000	3	90	10	10	583
liquids tank 29,500 ft³	36,000	1	360	20	100	5,751
liquid tanker, 2,200 gal	7,920	3	238	8	100	1,707
Total	104,120		1,510			14,731
4) *Aboveground storage tank*						
small scraper tractor, 37 hp	14,000	3	336	5	80	3,175
agitation pit	2,500	1	25	20	100	399
agitation transfer pump	4,800	3	144	8	100	1,035
aboveground tank, 195,000 ft³	240,000	1	2,400	20	100	38,109
tractor for agitator, 105 hp	27,000	3	162	10	20	1,050
tank spreader, 3,200 gal	9,820	3	295	8	100	2,117
Total	298,120		3,362			45,885
5) *Lagoon flush*						
tractor, 105 hp	27,000	3	40	10	5	262
recycle pump, ½ hp, 15 hr day	250	3	7	8	100	56
flush tanks, manual gate	18,000	1	180	20	100	2,876
lagoon, 2,289,000 ft³	29,500	1	295	20	100	4,713
irrigation pump, 500 gpm, PTO	6,800	3	204	10	100	1,321
travelling big gun, 1,200-ft hose	17,000	3	510	10	100	3,304
mainline 6-inch PVC, 3,800 ft	7,320	1	73	15	100	1,252
Total	105,870		1,309			13,784
6) *Lagoon flush—separator*						
Includes all in #5 above	105,870		1,309			13,784
collection sump	2,500	1	25	20	100	399
separator tower	6,000	1	60	20	100	953
separator	22,000	3	660	10	100	4,275
pump & motor (35 hp-150 gpm)	4,000	3	120	8	100	891
float control	800	3	24	5	100	239
Total	141,170		2,198			20,541

Figure 4. *The lagoon in the foreground collects, treats, and stores the liquid wastes. The separation screen (left) removes the solids, which can be used as bedding material.*

We used the Washington State University Cooperative Extension publication, *Costs of Owning and Operating Farm Machinery in Washington,* in selecting values for the repair, maintenance, insurance, taxes, and years of life. The term *capital recovery* indicates the cost of annual ownership of a piece of equipment or structure and is explained in the 1980 edition of the Midwest Plan Services' *Structures and Environment Handbook.* We used this formula to obtain the capital-recovery values in tables 2 to 4:

$$CR = \frac{V_a - V_s}{SPWF} + V_s \cdot i$$

where CR = capital recovery

V_a = value when acquired ($)

V_s = value when salvaged ($)

SPWF = series present worth factor (uses the expected life and interest rate)

i = interest rate, decimal fraction

A salvage value of 10% of initial cost was used for all machinery. The interest rate selected for this circular was 15%.

Energy costs are becoming a bigger item in most dairy budgets. One of the larger energy items for these six manure handling systems is the diesel fuel and lubrication costs. The magnitude of these is related to the fuel price, consumption per hour, and the number of hours the engine is operated. The fuel and lubricating costs were determined by using the following formula:

$$FLC = \frac{\text{PTO hp x load factor x price/gal}}{K} \text{ x 1.15 x hrs of use}$$

where FLC = fuel and lubrication costs

K = constant for engine type (11.2 for diesel engine)

load factor = 75% for tractors with a horsepower rating of 100 and above; 65% for ratings less than 100

1.15 includes 15% of fuel expenditures for lubrication costs

For this study, we set the value of diesel at $1.05 per gallon, since farmers receive a rebate for off-the-highway operation. We set electrical energy at 3 cents per kilowatt hour.

It was difficult to determine the hours needed to scrape, haul manure, agitate the tank, etc. These tasks will vary in time requirements with the farmstead layout, labor source, season, and personal preference—to name just a few variables. The following is an example of the level of calculations that were conducted to determine the time required to spread the manure.

First, what about the nutrient content of the manure and wastes after storage in each of the six different systems? (This will be discussed later, but the data are included in table 8.) We assumed that each of the operations would have some pastureland for the cattle and that this land would receive the manure. The application rate used was 60 lb of nitrogen per acre.

Dividing the total nitrogen available from each system by 60 lb/acre provided the total acreage needed to receive the annual manure generated. The farmstead was selected to sit on the edge of the square field. The average travel distance was calculatd for the land-spreading operation and varied as the field size varied.

Recent research has furnished loading and emptying times for various sizes and types of manure spreaders. Using these values, and assuming a travel speed of 6 mph, the total time spent hauling and spreading manure was calculated. Similar calculations were made for systems milking 200 and 300 cows. The total waste volume (which is different for each system) then allows you to calculate the number of trips necessary to land-spread all the waste.

Using the total numbers of hours for the tasks listed in tables 5, 6, and 7 gives the total labor required. The labor costs can then be determined, using a $4.00/hour value, and this is totaled in the tables.

All of the agitating and pumping of manure slurries were done using tractors to power PTO-driven pumps. The one situation in which an electrical motor is necessary is the need to return lagoon recycle water to the flush tanks in Systems 5 and 6. The pumps were sized to operate at 20 gallons per minute. This then required that they be operated for 5, 10, and 15 hours per day for the three herd sizes. System 6 also uses an electric motor to pump the liquid slurry up to and over the separator.

As energy costs increase, the cost of fertilizer for croplands goes up proportionately. One of the ways to reduce out-of-pocket costs is to use manure as a fertilizer to the greatest extent possible. See the O.S.U. Extension publication, *Calculating the Fertilizer Value of Manure from Livestock Operations* (EC 1094, January 1982).

Table 5. Annual energy and labor costs, 100-cow dairy

System	Task (Hrs)	Labor cost ($4.00/hr)	Fuel and lubrication (Cost)	Electricity ($.03/kWh) kWh	Electricity ($.03/kWh) Cost
Dry stack					
small scrape tractor	145		376		
tractor (hauling)	108		917		
tractor (loading solids)	16		135		
tractor (loading liquids)	6		51		
Total	275	1100	1479		
Earthen storage					
small scrape tractor	145		376		
tractor (agitation & loading)	55		476		
tractor (spreader)	213		1808		
Total	413	1652	2651		
Daily spread					
small scrape tractor	145		376		
tractor (spreader)	101		1062		
tractor (loading liquids)	5		53		
Total	251	1004	1491		
Aboveground tank					
small scrape tractor	145		376		
tractor (agitation/transfer)	30		255		
tractor (spreader)	126		1069		
Total	301	1204	1700		
Lagoon flush					
recycle pump				680	20
tractor (irrigation pump)	138		1172		
flushing alleys	30				
moving big gun	35				
Total	203	812	1172		20
Lagoon flush—separator					
all of lagoon flush	203	812	1172		20
pumping over separator				6342	190
solids handling & screen maintenance	91	364	41		
Total	294	1176	1213		210

The annual value of nitrogen, phosphorus, and potassium in the manure from a dairy of 100 milking cows is shown in table 8. A range of the percentages of each of the three nutrients retained through collection and storage is also shown. Using summer 1981 values for these nutrients, the annual worth of manure is shown for each of the six systems.

Bedding is the one major operational cost item evaluated for each system. The amounts used are explained in the system descriptions. The bedding most commonly used in Oregon is shavings or sawdust. Availability and price vary widely by area, and you can substitute local costs when you know specific values.

For this circular, a value of $100.00 for the purchase and delivery of a five-unit load makes bedding cost 1 cent per pound. The lagoon flush separator system uses half the recovered solids as bedding in the dairy. An equal amount is sold. This may go to another dairy as bedding, to a nursery as a soil amendment, or even used as feed.

NET ANNUAL COSTS

The net annual system costs are summarized in table 9 for herd sizes of 100, 200, and 300 head. For the 100-cow dairy, Systems 2, 3, and 5 have low annual fixed costs (capital recovery) and correspondingly low repair, taxes, and insurance costs. The high bedding cost for the dry-stack system is one reason why it is one of the more expensive systems. The earthen storage system has the highest energy and labor costs, but it still is the least expensive system on an annual basis, followed closely by the daily haul system. The aboveground tank and the lagoon flush separator are almost twice as expensive as the other systems.

When one looks at the data for the 200-cow herds, the earthen storage system is quite appealing, being almost $5,000 cheaper than the next least expensive system. The negative sign indicates that, based upon what we have considered, the manure handling system more than pays for itself. The low investment cost is primarily responsible for its

Table 6. Annual energy and labor costs, 200-cow dairy

System	Task (Hrs)	Labor cost ($4.00/hr)	Fuel and lubrication (Cost)	Electricity ($.03/kWh) kWh	Cost
Dry stack					
small scrape tractor	290		752		
tractor (hauling)	164		1392		
tractor (loading solids)	32		272		
tractor (loading liquids)	11		93		
Total	497	1988	2509		
Earthen storage					
small scrape tractor	290		752		
tractor (agitation & loading)	98		832		
tractor (spreader)	403		3421		
Total	791	3164	5005		
Daily spread					
small scrape tractor	290		752		
tractor (spreader)	165		1734		
tractor (loading liquids)	10		105		
Total	465	1860	2591		
Aboveground tank					
small scrape tractor	290		752		
tractor (agitation/transfer)	53		450		
tractor (spreader)	255		2165		
Total	598	2392	3367		
Lagoon flush					
recycle pump				1360	40
tractor (irrigation pump)	245		2080		
flushing alleys	60				
moving big gun	61				
Total	366	1461	2080		40
Lagoon flush—separator					
all of lagoon flush	366	1461	2080		40
pumping over separator				12682	380
solids handling & screen maintenance	182	728	82		
Total	548	2189	2162		420

ranking. The costs of the two lagoon systems and the aboveground tank drop down slightly; the daily-spreading system's costs decreases significantly.

A similar pattern is followed with the data for the 300-cow herds. The annual cost of the earthen storage system and the daily spreading option continues to decrease as herd size goes up. Systems 1, 5, and 6 stay about the same in total cost. Even by staying the same, the cost per cow will decrease sharply as herd size doubles and triples. The purchase of the two aboveground storage units in the high rainfall coast increases the capital recovery costs—and this increases the net annual cost of this system.

The addition of a separator does not appear to be economically justified. However, other factors not considered in this circular make the addition of a separator to a lagoon-flush system more appealing. These include a constant and known supply of bedding (which will likely become more expensive in the future), a reduction of maintenance and plugging problems when the lagoon effluent is spread on the field, and a slightly reduced organic loading to the lagoon-treatment unit.

Economics is only one factor to consider when you select a dairy waste management system. Safety is an item that is difficult to translate into dollars—yet it is very important. Daily haul has no storage unit to serve as a potential hazard, which is an advantage. However, the dry-storage unit offers little potential as a safety problem. The aboveground-storage unit is difficult to get to, which reduces its hazard potential. While all earthen storage units and lagoons should be fenced, you should still consider them as hazards.

Pollution control is another factor to consider when you evaluate waste management systems. All systems have a storage component except daily haul, which increases the pollution potential for that system. A storage unit provides the operator flexibility to put the manure on when the crop can use the nutrients and minimize runoff and escape. The two lagoon systems might have a slight advantage since they have 12 months' storage versus 150 days' for Systems 1, 2, and 4.

Table 7. Annual energy and labor costs, 300-cow dairy

System	Task (Hrs)	Labor cost ($4.00/hr)	Fuel and lubrication (Cost)	Electricity ($.03/kWh) kWh	Electricity ($.03/kWh) Cost
Dry stack					
small scrape tractor	435		1128		
tractor (hauling)	204		1732		
tractor (loading solids)	49		416		
tractor (loading liquids)	16		136		
Total	704	2816	3412		
Earthen storage					
small scrape tractor	435		1128		
tractor (agitation & loading)	147		1248		
tractor (spreader)	671		5697		
Total	1253	5012	8073		
Daily spread					
small scrape tractor	435		1128		
tractor (spreader)	233		1978		
tractor (loading liquids)	15		127		
Total	683	2732	3233		
Aboveground tank					
small scrape tractor	435		1128		
tractor (agitation/transfer)	81		688		
tractor (spreader)	333		2827		
Total	849	3396	4643		
Lagoon flush					
recycle pump				2040	61
tractor (irrigation pump)	291		2471		
flushing alleys	90				
moving big gun	73				
Total	454	1816	2471		61
Lagoon flush—separator					
all of lagoon flush	454	1816	2471		61
pumping over separator				19026	570
solids handling & screen maintenance	273	1092	123		
Total	727	2908	2594		631

The nearness and availability of cropland was assumed in determining speading costs. However, land may not always be nearby, and its location is very important in influencing the labor and equipment costs in land-spreading operations. While retaining nutrients is beneficial and the system is credited with a fertilizer savings, it does take more land to receive the manure from a nutrient-conservative system.

In some locations, the lagoon systems are desirable; additional water for crop production will be important and valuable. In other settings or years, the additional water volume may be detrimental.

The most important factor, and one of the most difficult to assign a value, is level and amount of management required. Because of its complexity, we made no attempt here to assign a value; however, each dairy operator should try to evaluate this factor. Another companion item is operator preference. This also should be objectively evaluated when expanding or selecting a waste management system.

Table 8. Annual value of nitrogen (N), phosphorus (P), and potassium (K) in the manure from a dairy of 100 milking cows[a].

System	Percent retained through collection and storage			Average value[b]			Total value ($)
	N	*P*	*K*	*N*	*P*	*K*	
1 Dry stack	60-80	80-95	80-95	4785	3298	3124	11,207
2 Earthen storage	60-80	80-95	80-95	4785	3298	3124	11,207
3 Daily haul	70-85	85-95	85-95	4194	2559	2343	9,096
4 Aboveground tank	70-85	85-95	85-95	5592	3412	3124	12,128
5 Lagoon flush	20-35	30-50	40-70	1960	1516	1974	5,450
6 Lagoon flush—separator	20-35	30-50	40-70	1960	1516	1974	5,450

[a] Losses occurring after storage and before crop uptake were assumed to be 20% for N and zero for P and K, for all systems except daily haul, which experiences a 40% loss of N.
[b] Price per pound: N = $.27, P = $.67, K = $.18.

Table 9. Net annual system cost

System	Capital recovery +	Repair, taxes and insurance ±	Bedding +	Energy +	Labor −	Manure Value =	Net Annual Costs
100-cow dairy							
Dry stack	13,902	1,254	1,420	1,479	1,100	11,207	7,948
Earthen storage	7,580	918	426	2,651	1,652	11,207	2,020
Daily spread	8,712	946	568	1,491	1,004	9,096	3,625
Aboveground tank	22,802	1,881	426	1,700	1,204	12,218	15,885
Lagoon flush	8,778	999	426	1,192	812	5,450	6,757
Lagoon flush—separator	15,535	1,888	- 426	1,423	1,176	5,450	14,146
200-cow dairy							
Dry stack	22,027	1,812	2,840	2,509	1,988	22,414	8,762
Earthen storage	8,368	999	852	5,005	3,164	22,414	-4,026
Daily spread	12,140	1,253	1,136	2,591	1,860	18,192	788
Aboveground tank	30,263	2,347	852	3,367	2,392	24,256	14,965
Lagoon flush	11,689	1,175	852	2,120	1,461	10,900	6,397
Lagoon flush—separator	18,446	2,064	- 852	2,582	2,189	10,900	13,529
300-cow dairy							
Dry stack	31,234	2,536	4,260	3,412	2,186	33,621	10,007
Earthen storage	8,686	1,021	1,278	8,078	5,012	33,621	-9,546
Daily spread	14,731	1,510	1,704	3,233	2,732	27,288	-3,378
Aboveground tank	45,885	3,362	1,278	4,634	3,396	36,384	22,171
Lagoon flush	13,784	1,309	1,278	2,532	1,816	16,350	4,369
Lagoon flush—separator	20,541	2,198	-1,278	3,225	2,908	16,350	11,244

The Oregon State University Extension Service provides education and information based on timely research to help Oregonians solve problems and develop skills related to youth, family, community, farm, forest, energy, and marine resources.

Extension's agriculture program provides education, training, and technical assistance to people with agriculturally related needs and interests. Major program emphasis is on food and fiber production, farm business management, marketing and processing of agricultural products, and resource use and conservation.

This publication was prepared by James A. Moore, Extension agricultural engineer, and Ted L. Willrich, professor emeritus, Agricultural Engineering Department, Oregon State University. Partial support was provided by Federal funds from the Oregon Department of Environmental Quality and the Soil and Water Conservation Commission for the Confined Animal Feeding Operations project, conducted by Agri-Check, Inc.

Extension Service, Oregon State University, Corvallis, Henry A. Wadsworth, director. This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.