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Manure Management For Cattle Feedlots

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Manure handling costs constitute approximately 12 percent of the total feedlot operating expense for 20,000-head, dirt-surfaced feedlots. Efficient management of feedlot manure can mean savings for feedlot operators and profit for manure contractors who sell manure for fertilizer. Other uses of manure—production of methane, synthesis of gas, or animal feedstuffs—depend in part on having a manure supply available at reasonable cost. For manure handling to be profitable, time, energy and equipment costs must be controlled.

Management of feedlot manure involves three functions: collection, loading and spreading. An intermediate step such as composting and/or stockpiling is employed in some feedyards. Machines used to collect manure include the wheel loader, with or without chisel plow or rototiller, and the elevating scraper. Loading is performed by wheel or track loaders. Spreader trucks are used for hauling and distribution.

Manure Quantities

Beef cattle on high concentrate rations excrete about 63 pounds of wet manure per day (85 percent moisture**; includes feces and urine) per 1,000 pounds liveweight. For an 850-pound steer, this amounts to 8-pounds per head per day of manure solids, of which 20 percent (1.6 lbs/hd/day) is ash. Natural processes of evaporation and biological decomposition reduce this approximately 2 tons of manure (at 40 percent moisture) per animal per year that must be harvested from the feedlot surface. Quantities to be removed vary from this average figure depending upon ration, animal density, feedlot surfacing material, cleaning procedures and other factors.

Manure removal frequencies are dictated in part by climatic conditions, animal comfort, labor scheduling and water and air pollution potentials. In most feedyards, however, solid wastes are collected from the feedlot surface after each pen of cattle has been shipped.

Climatic conditions and management practices affect feedlot manure quality with regard to use as fertilizer, fuel or feed. Fiber and ash contents increase as decomposition progresses. Nitrogen losses of 50 to 60 percent can occur on the feedlot surface. Hence, the value of feedlot manure for feed and fertilizer is improved by frequent collection.

Collection Strategy

Aerobic decomposition of manure on the feedlot surface is desirable from an environmental standpoint. Maintaining a surface manure moisture content in the range of 25 to 40 percent will promote aerobic decomposition, which minimizes the formation and release of odorous gases. To minimize odors during pen cleaning, only the loose, surface manure layer should be removed. This aerobic layer generally varies in thickness from 0 to 5 inches, depending on moisture conditions, cleaning interval, stocking rate and other factors. This loose, surface manure soaks up precipitation and adds to mud, odor and fly problems.

The aerobic manure pack of approximately 3-inch thickness above the soil interface should be left intact if possible. In pens where the aerobic manure pack has been disturbed, high odor intensity levels of 170 dilutions to threshold have been recorded as compared to odor intensities of 2 to 7 dilutions to thresholds where only the surface layer is collected. Research also shows that the aerobic manure pack seals off infiltration through the soil-manure interface. It also prevents groundwater pollution by denitrification of nitrate compounds.

Economical Equipment Use Rates

Investment and operating costs of solid manure handling systems are influenced by feedlot size and equipment usage. Operating costs per animal-day generally are lower for large feedlots than for small ones and increase with haul distance. Equipment size requirements and costs decrease drastically as equipment usage increases from 25 to 100 days per year. On the other hand, use-rates above 100 days per year may not decrease investment and

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**All moisture contents in this fact sheet are calculated on a wet weight basis.

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Table 1. Annual machine useage (hrs/yr) for manure collection and loading.

Feedlot Size head	Annual Manure Tonnage tons/yr	Actual Manure Collection Rate, tons/hr					Actual Manure Loading Rate, tons/hr				
		100	150	200	250	300	100	200	300	400	500
1,000	2,000	20	13	10	8	7	20	10	7	5	4
5,000	10,000	100	67	50	40	33	100	50	33	25	20
10,000	20,000	200	130	100	80	67	200	100	67	50	40
50,000	100,000	1,000	667	500	400	333	1,000	500	333	250	200
100,000	200,000	2,000	1,300	1,000	800	667	2,000	1,000	667	500	400

operating costs significantly. Table 1 can be used to estimate annual hours of machine use for a given feedlot size and rate of collection or loading. These manure handling rates are discussed in detail below.

Collection Methods and Systems

Basic collection systems for feedlot manure collection are:

Wheel loader
Wheel loader plus plowing or rototilling
Elevating scraper
Road grader plus elevating scraper

The latter two systems are capable of achieving a very smooth, uniform pen surface condition. However, systems involving wheel loaders are predominantly used in the feedlot industry.

Factors that influence the cost and efficiency of feedlot manure collection include type and size of equipment, operator skill and technique, pen size, terrain, presence of obstacles (shades, cattle, etc.), manure moisture content and operator fatigue.

Comparison of Collection Systems

The operating efficiency, productivity, energy efficiency and cost of feedlot manure collection were compared for three collection systems: elevating scraper, wheel loader and wheel loader plus plowing or rototilling. These systems are depicted in Figures 1, 2, and 3. Time-motion data was collected for four Southern Great Plains feedlots with 28,000 head or more capacity. Results are shown in Tables 2 and 3.

Operating efficiencies (ration of productive time to total elapsed time) determined from the feedlot time-motion study ranged from 79 percent for the loader to 90 percent for the elevating scraper (Table 2). By comparison, a "rule of thumb" estimate of operating efficiency for wheel loaders is 75 percent, or 45 minutes of productive work per hour.

Table 2. Observed operating efficiency (%) of manure collection machinery at Southern Great Plains feedlots

Machinery	Percent of Operating Efficiency	
	Average	Range
Wheel Loaders	79	70-87
Elevating Scraper	90	78-98
Tractor-Drawn Scarifier	84	56-93

Collection rates—The highest collection rates (or productivities) are realized with a *wheel loader chisel plow* combination. An average manure collection rate of 175 tons per hour can be achieved with this system, assuming the collection rate is adjusted to 100 percent operating efficiency, or 60 minutes operation per hour. If an operating efficiency of 80 percent is realized, the average collection rate would be 140 tons per hour. Variations of 50 to 75 percent can be expected from the average collection rate, depending upon operator skill and other factors.

Figure 1. The efficiency of wheel loaders in feedlot manure collection depends largely on operator skill.

The manure pack can be broken up using a rototiller or chisel plow at the rate of 330 square feed per minute, plus or minus 10 percent. Chisel plowing the feedlot surface before collection reduces particle size and loosens the manure surface. This reduces mechanical energy needed to excavate an otherwise tightly-compacted manure pack with the loader. Manure collection rates are closely related to the amount of manure collected per bucketfull, which is itself related to particle size. Thus, wheel loaders without prior chisel plowing give a 33 percent lower collection rate (120 vs. 175 tons per hour) and consume 30 percent more energy than the loader/chisel plow combination.

An *elevating scraper*, followed by a wheel loader to clean the pen corners, can provide a collection rate as high as 170 tons per hour, or 125 tons per hour average, assuming 100 percent operational efficiency. Actual operational efficiencies are usually about 90 percent. The collection rate with elevating scrapers appears to corrolate more closely with pen surface area than with manure tonnage present. The elevating scraper can collect manure at the rate of 430 square feed per minute, as compared to 120 to 250 square feed per minute for a wheel loader.

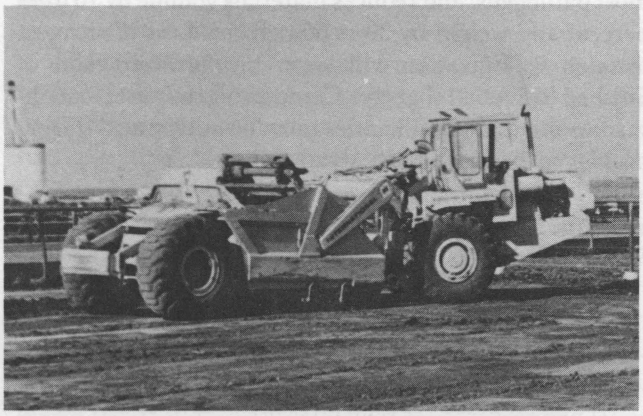

Figure 2. The elevating scraper provides efficient manure collection and leaves the feedlot surface in excellent condition for drainage.

Chisel plowing is not needed with an elevating scraper. This is because chain-driven paddles break up the manure as it is loaded into the scraper bowl. The depth of cut can be adjusted accurately to remove as little as 1 or 2 inches of surface manure to leave a smooth surface for rapid drainage.

The elevating scraper cannot clean within about 10 feet of the corners of feedpens. It takes 5 to 13 minutes with a wheel loader to clean the 4 corners, at a loss of 20 tons per hour in system productivity. This operation can be performed, however, during waiting periods incurred during the truck loading operation.

Energy consumption—The energy consumption for wheel loader collection without surface preparation is 1.56 horsepower hours (hp-hr) per ton (Table 3). Use of a chisel plow or rototiller to break up the manure pack requires 0.33 hp-hr per ton but reduces the overall energy consumption to only 1.17 hp-hr per ton (range of 0.79 to 1.94). Collection using the elevating scraper requires only 0.81 to 1.49 hp-hr per ton (1.07 average). Hence, the elevating scraper system is 9 to 46 percent more energy efficient than wheel loader systems.

Cost—Once manure collection rates are established from time-motion measurements, collections costs can be

Figure 3. Chisel plowing the manure pack prior to collection with a wheel loader increases productivity and reduces energy consumption by at least one-third.

estimated using manufacturers' data. The total fixed and operating costs ($/hour) for collection machinery (not including operator's labor) can be estimated from the following table:

	Hourly Fixed and Variable Costs, $/hr (as Percent of Purchase Price)
Elevating scrapers (800 hr/yr)	0.035
Wheel loaders (1300 hr/yr)	0.029
Farm tractor and scarifiers (500 hrs/yr)	0.055

For example, a wheel loader with a purchase price of $60,000 will cost $17.40 per hour to own and operate, plus labor. As a rule, hourly costs can be expected to decrease as annual hours of use increase.

Collection method had little if any effect on collection cost in the time-motion studies. Estimated cost (1976 prices) of collection (stacking in pens) was 18¢ per ton for the wheel loader preceeded by rototilling or chisel plowing. Chisel plowing or rototilling contribute 3.5¢ per ton to the collection cost. The wheel loader with no surface preparation gives a cost of 21¢ per ton. Cost of collection with the elevating scraper was 19¢ per ton.

These apparent cost differences are so small that it does not appear justifiable to change collection systems until obsolescence dictates a need for new equipment.

Table 3. Comparison of productivity, energy requirement and cost of different pen cleaning methods.

Feedlot	Pen cleaning method	Pen Cleaning Rate (100% Efficiency) tons/hr.	hp-hr/ton	Cost per ton to stack in pile*
A	Elevating Scraper	126	1.07	19¢
B	Loader and Rototiller	117	1.21	17¢
C	Loader Only	118	1.56	21¢
C&D	Loader & Chisel Plow	176	1.17	18¢

*Cost does not include loading into truck and hauling manure away.

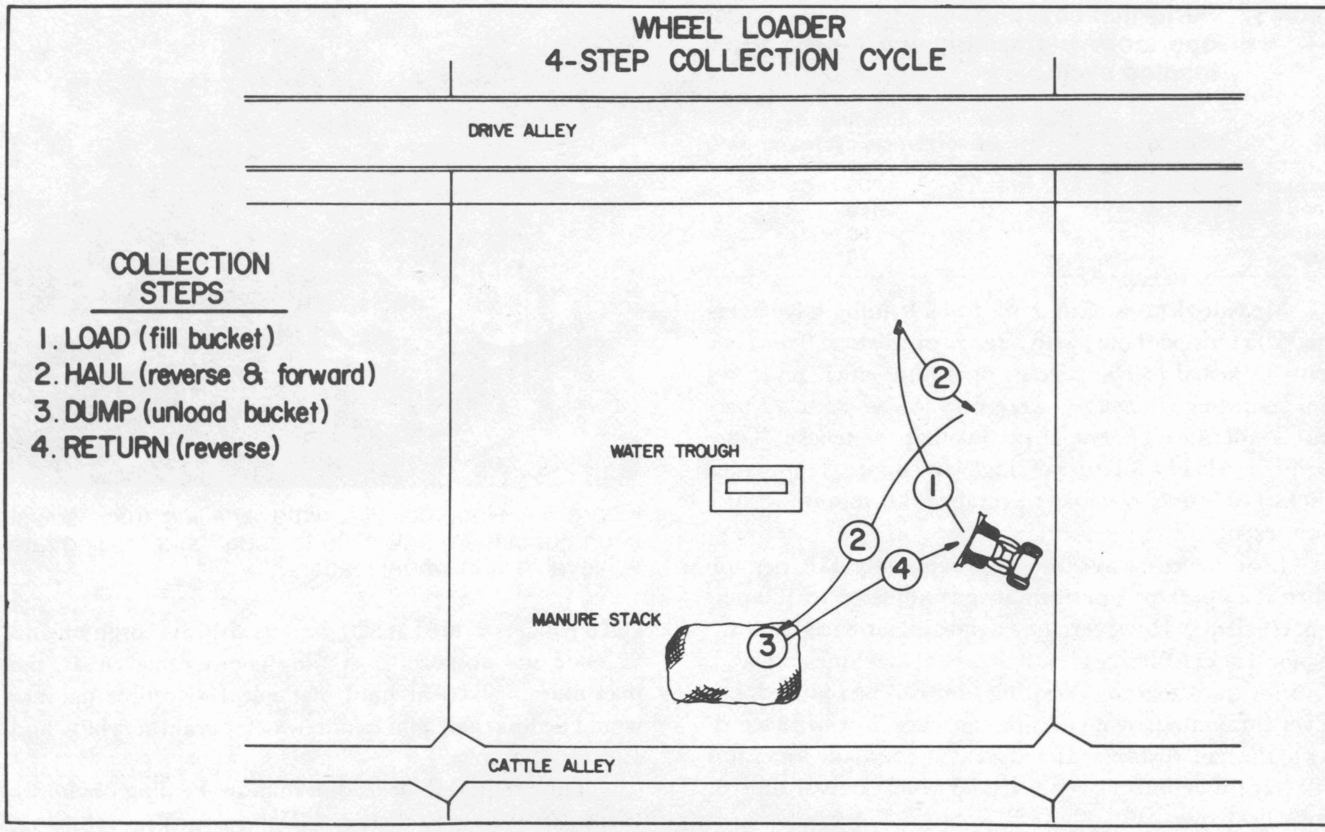

Figure 4. The four-step collection cycle of wheel loaders requires 0.4 to 0.8 minutes to complete and involves 300 to 500 gear shifts per hour.

Collection Cycles and Times

Use of *wheel loaders* for manure collection entails a collection cycle consisting of four steps—load, haul, dump and return—as illustrated in Figure 4.

An average wheel loader operator requires 0.64 minutes to complete each collection cycle. Each step has the following average time requirement (minutes): load—0.23, haul—0.22, dump—0.05 and return—0.14. Thus, at 100 percent operating efficiency, the operator could theoretically complete 94 cycles per hour, entailing 376 gear shifts per hour. This task obviously calls for superior manual dexterity!

The operator can reduce his cycle time slightly and improve his collection rate by dozing manure toward the nearby stack. This in effect, represents a three-step collection cycle in which the "haul" step is eliminated. Improvements in collection rate result mainly from the fact that the loader bucket can move more manure by dozing than by lifting and hauling. This technique is primarily useful near the center of the pen.

The *elevating scraper* is driven through a four-step collection cycle in a circular motion. The average cycle time is 2.01 minutes, divided as follows: load—1.33, haul—0.25, dump—0.19 and return—0.22. Each cycle results in approximately 6 tons of manure collected, as compared to 1-1/3 tons per cycle for wheel loaders. With essentially no gear shifts to perform, the operator can concentrate on controlling the depth of the scraper blade, thereby leaving a smoother feedlot surface than with a wheel loader. Operator skill needed to attain high productivity is probably less critical than for wheel loaders. However, minimum pen size requirements for efficient scraper operation is believed to be 20,000 square feet with no overhead shades.

Efficiency in Truck Loading

Regardless of the system used to collect (i.e., stack) manure in the feedpens, a wheel loader is nearly always used to load manure into trucks (Figure 5). A combination of conveyor belt and wheel loader is used in several Cailfornia feedlots. In some cases, an evalating scraper has been used to haul manure directly to a stockpile, where later reloading with a wheel loader is necessary.

Loading a manure spreader truck entails a four-step cycle. Differences between operators can be highly significant, with cycle times ranging from 0.50 to 0.78 minutes. An average, wheel loader cycle time of 0.61 minutes was divided among steps as follows: load—0.12, haul—0.23, dump—0.10 and return—0.16.

A feedyard foreman can evaluate a loader operator's performance in truck loading by recording at least 50 observations of cycle times required for truck loading. Observations should be spread over 2 or more days operation. The average of these cycle time observations can be compared with the operator rating table (Table 4).

Table 4. Performance rating scale for wheel loader operators performing the 4-step truck loading cycle.

Rating	Loading Performance, cycles/hours
Excellent	130
Good	110
Fair	90
Poor	70

Measured rates of manure truck loading have averaged 205 tons per hour, with a range of 160 to 280 tons per hour (adjusted to 100 percent operating efficiency). Actual operating efficiencies were very low — 23 to 27 percent — because of time spent waiting for trucks. Time required to load a mixture of single and dual axle spreader trucks (10.3 tons per load) averaged 3.0 minutes ± 0.7 minutes.

Loading costs average approximately 11¢ per ton when the operator's performance is adjusted to 100 percent efficiency. However, long delays experienced in waiting for trucks to arrive greatly increase machine and labor costs for truck loading. Waiting time can be reduced, but never eliminated, by increasing the truck fleet size according to the haul distance. In most cases, the loader operator will have no control over spreader truck arrival time or truck fleet size.

Nonproductive Time

Machine and operator time not spent in acutal collection or loading and regarded as nonproductive includes:

Travel time—travel to, from and between feedpens
Machine delay—refueling, breakdown, etc.
Personal delay time—breaks, conversation, etc.
Waiting time—interferences caused by other machines (e.g., truck arrival) or by cattle.

Much of the nonproductive time is necessary and inevitable. An effort should be made to reduce nonproductive time that is not necessary.

Hauling Time and Cost

Transporation costs limit distances that manure can be hauled economically. Charges paid by farmers to feedyards and contractors for manure hauling and spreading on cropland vary widely, typically ranging from $1.25 to $2.60 per ton plus 7¢ to 10¢ per ton-mile. Of that cost, the feedlot typically receives $0.50 to $1.00 per ton to cover collection costs. In times of low manure demand, feedyards often give the manure to contract haulers for resale, and in some instances have actually paid contractors to haul manure away.

The contract hauler must adjust his charge to the farmer for manure and limit his hauling range according to the price of commercial fertilizer. As the price of commercial fertilizer (particularly nitrogen) increases, the affordable haul distance for manure also increases. For example, farmers in the Great Plains may apply commer-

Figure 5. Nonproductive time awaiting truck arrival often detracts from the 200 tons per hour loading rate achievable with wheel loaders.

cial fertilizers valued at $20 per acre to grain sorghum and $27 per acre to corn. Assuming comparable yields, the maximum, practical haul distance for feedlot manure would be less than 5 miles one-way for grain sorghum and 15 miles for corn.

Time required for feedlot manure hauling obviously varies according to distance. Delays such as refueling, coffee breaks, meals and waiting time can cause wide variation between trips of equal distance. For example, one study showed that a one-way haul distance of 6 miles took from 28 to 47 minutes for different operators. The following equation was developed for estimating the mean round-trip cycle time required for hauling and spreading feedlot manure:

$$T = 0.7 + 3.2\,D - 0.043\,D^2$$

where T = round-trip cycle time, minutes
D = round-trip haul distance, miles

Energy consumption for feedlot manure transportation and spreading varies with distance and size of spreader truck. Fuel mileage for both single- and dual-axle trucks is 3 to 3.5 miles per gallon. Using a 10-ton spreader truck (single axle), manure transportation and spreading takes an estimated 42,000 and 155,000 BTU per ton of manure for 5 and 20-mile (one-way) haul distances, respectively. A tandem-axle (14-ton) truck may require 33 percent less energy and 30 percent lower cost per ton at 5 to 20-mile haul distances than the 10-ton truck. Calculated energy savings from use of 38-ton semi-trailer trucks for hauling farther than 5 miles appear sufficient to offset the added energy requirements for on-farm reloading into spreader trucks.

Storage and Composting

Intermediate storage of manure in stockpiles allows regular removal of solids from feedlots regardless of the immediate readiness of land for application. Mounding of solids inside the pens, an intermediate step in collection, promotes drainage and provides a dry resting area for cattle during adverse weather. Another advantage of intermediate storage is that further drying and decomposition of the manure, accompanied by volume and weight reductions, occur during storage. However, storing manue can lead to greater losses of nitrogen. Storage periods longer than 4 to 5 days without aeration cause anaerobic conditions to develop, with subsequent release of malodors during excavation.

Storage time can be utilized beneficially to compost manure in windrows, typically 4 to 6 feet high. Composting reduces odor potential of manure and improves spreading characteristics. Windrows are aerated by turning every 2 days for 2 weeks, followed by twice-weekly turning for 2 weeks. Alternately, feedlot manure can be aerated by injecting compressed air (or applying a vacum) through underlying perforated pipe. Windrow composting requires 30 days to complete if satisfactory moisture (40 to 55 percent) and temperature (130 to 170 degrees F) can be maintained.

Aerobic composting produces no offensive odors; generates enough heat to kill weed seeds, fly larvae and most pathogens; and reduces materials volume by 10 to 45 percent and weight by 30 to 60 percent. Loss of nitrogen through volatilization will lower the fertilizer value of finished compost slightly. Composting requires careful management, and difficulties must be anticipated during prolonged periods of wet weather.

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