SPRINKLER IRRIGATION SYSTEMS FOR WASTE DISPOSAL FROM LAGOONS

The trend to more confinement feeding of livestock and poultry has created a need for information about liquid waste disposal systems. This is especially true with the advent of both federal and state animal waste disposal regulations.

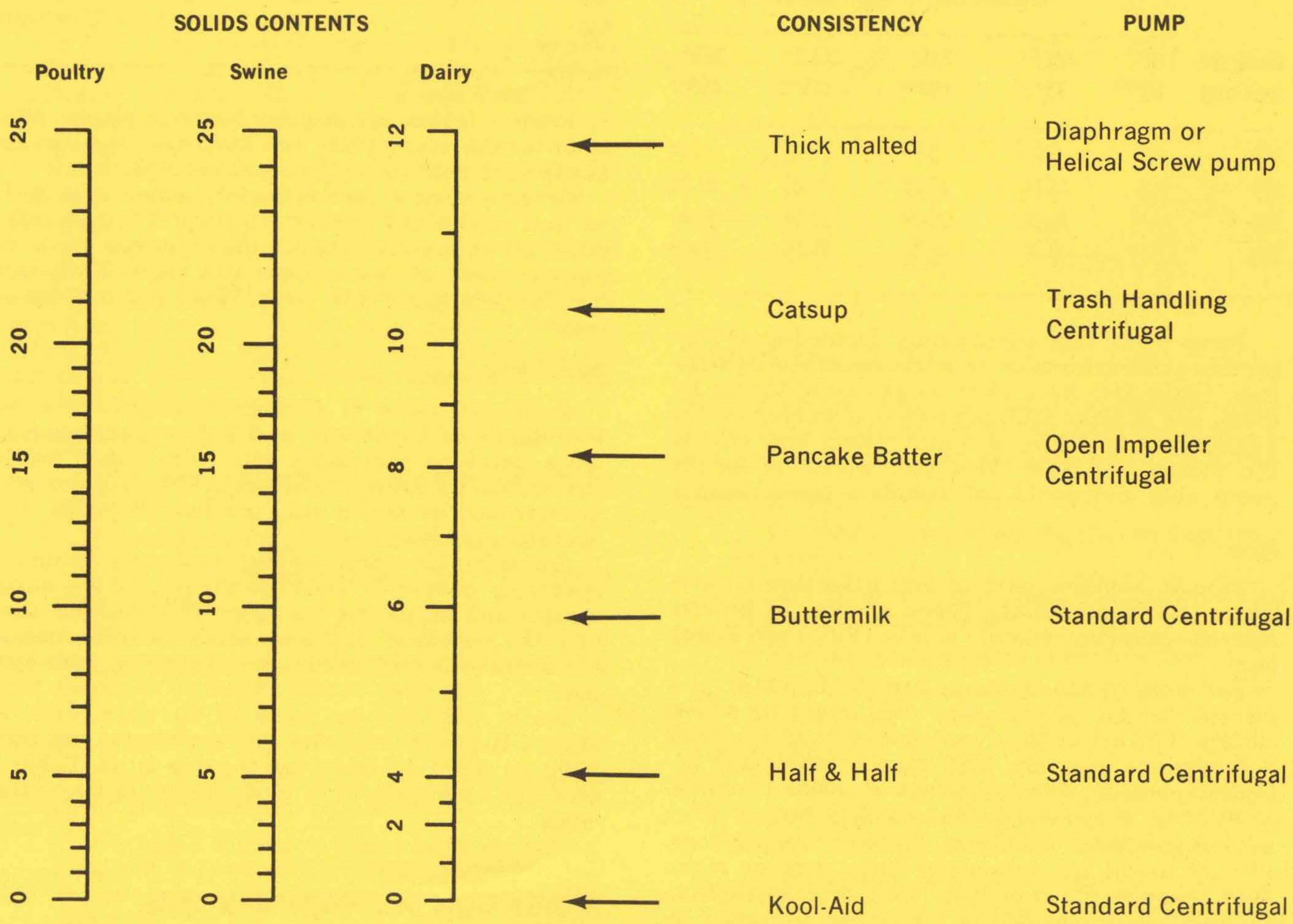
Systems utilizing deep pit storage and hauling with a tanker wagon work well up to a limit. This limit is defined by the number of trips necessary to remove the manure each year and the number of man-hours available to make those trips. Once a facility grows too large for a tanker wagon system, an alternative must be designed. Lagoons are currently a popular choice, but land disposal is still required. Irrigation spreading is generally a more efficient system than honey wagons for disposal from lagoons. Described in this publication are some basic concepts of irrigation-disposal and a few existing irrigation systems, along with their advantages and their disadvantages.

IRRIGATION SYSTEM COMPONENTS

Pumps

Start planning your irrigation disposal system by determining the size and type of pump required for your liquid waste disposal problems. Many types of pumps are available for liquid waste handling including standard centrifugal pumps, open impeller centrifugal pumps, piston pumps, diaphragm pumps, helical screw pumps, and propeller pumps. For most sprinkler systems used for outdoor feedlot runoff or lagoon effluent, a single-stage, standard centrifugal pump will work well, fig. 1. For pumping undiluted manure with nearly 15 percent solids, an

Fig. 1. Solids content, consistency, and type of pump required for liquid handling of animal and poultry wastes.



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open impeller chopper pump is required. Several different models of these are available commercially.

Pump size is determined by the volume of wastes to be pumped and the length of time available for pumping. The larger the pump, the more capacity it will have.

Power requirements for pumps are determined by two factors—pump discharge and pressure. The power requirement can be calculated by the equation:

$$\text{Horsepower} = \frac{(\text{Discharge, gpm}) \times (\text{pressure, feet of water})}{3960 \times \left(\frac{\text{pump efficiency, \%}}{100}\right)}$$

Most centrifugal pumps perform at 60 to 70 percent efficiency if they are properly selected and operated. Table 1 provides a general guideline for power requirements. The table does not include engine efficiencies.

Table 1. Horsepower requirements for pumping at varying quantities and pressures. Pump efficiency assumed to be 65 percent.

	Pressure (feet of water* and psi**)				
Discharge (gal/min)	115* 50**	172.5* 75**	230* 100**	287.5* 125**	345* 150**
100	4-5	6-7	8-9	11-12	13-14
200	8-9	13-14	17-18	22-23	27-28
300	13-14	20-21	26-27	33-34	40-41
400	18-19	27-28	35-36	44-45	53-54

Pump costs vary significantly depending on size, pressure characteristics, construction material, bearings, seals, etc. As a very rough rule of thumb for costs, use at least $150 per inch of diameter on the discharge side. Thus, a 4-inch pump may cost in the vicinity of $600. This cost would be for the pump only and would not include a power source.

Pipe

Pipe is a major part of any irrigation system. There are two primary types of pipe to be considered—polyvinylchloride plastic (PVC) and aluminum.

For very small systems, small diameter (1-2 inches) flexible polyethylene pipe might be a possibility. Two major disadvantages of small diameter polyethylene pipe are high friction losses and potential plugging due to the use of inside couplers.

PVC is a newcomer to the field but it offers advantages over aluminum in some applications. PVC is useful for permanent lines such as mainlines that are never moved. It will deteriorate from sunlight, so it should be buried or protected by some other means.

The primary advantages of plastic pipe are (1) low cost in low-pressure applications, (2) resistance to corrosion and chemical attack, and (3) it's slightly smoother than aluminum pipe, so it does not have quite as high pressure losses due to friction. For high-pressure lines (80 psi and up) price is comparable to aluminum—from approximately $0.80 per foot to approximately $2.00 per foot for 4- to 6-inch pipe.

Aluminum pipe offers the advantages of (1) being quickly and easily assembled and disassembled, making it portable, (2) resistance to cracking and mechanical damage, and (3) not being affected by sunlight.

Once you've determined whether your application dictates plastic, aluminum, or both, you have to select the size. Size is determined by the discharge rate, the length of run, and the amount of friction loss you can tolerate. Friction losses increase with increasing velocities in the pipe. Table 2 shows approximate pipe sizes needed for various flow rates.

Table 2. Pipe sizes needed for varying flow rates for aluminum pipe and couplers.

Discharge (gpm)	Pipe size (inches)	Head loss per 100 feet (psi)
100	3	1.4
200	4	1.3
300	5	0.9
400	6	0.7

Friction losses are slightly lower in plastic pipe than in aluminum pipe, but ordinarily will not be enough different to justify a smaller pipe size.

Another type of pipe is flexible rubber hose such as that used with traveling big guns. It is generally not used as a substitute for the other two types of pipe because of cost. Prices run about $2.50 per foot for 2-inch hose to over $7.00 per foot for 5-inch.

Sprinklers

Sprinklers come in all sizes ranging from 1/16-inch diameter nozzle size and 2 gpm discharges to large gun-type sprinklers with over 1-inch nozzle size and over 1,000 gpm discharge. Discharge volume is controlled by nozzle size, number of nozzles, and operating pressure.

Sprinklers have one, two or three nozzles. Minimum operating pressures start at 20 psi for the small nozzles and 90 psi for the large ones. Assume that you can purchase any size nozzle or combination of nozzles you may need when designing your system.

Prices will vary as much as the sizes. Plan on about $10 per sprinkler for the small ones, and from $100 to $500 or more for the big guns. Table 3 provides a general idea of nozzle operating characteristics.

IRRIGATION DISPOSAL SYSTEMS

Several systems, each using different combinations of the three components mentioned, have been adopted over the years as more or less "standard" irrigation systems. Each system has its own advantages and disadvantages for waste disposal.

Table 3. Discharge (gallons per minute) for various sizes of nozzles at several operating pressures.

Pressure	Nozzle diameter (inches)								
(psi)	1/8	3/16	1/4	5/16	3/8	1/2	3/4	1	1 1/4
40	2.9	—	—	—	—	—	—	—	—
50	3.2	7.1	12.9	—	—	—	—	—	—
60	3.5	7.8	14.0	22.0	—	—	—	—	—
70	3.8	8.5	15.4	23.9	33.2	—	—	—	—
80	4.1	9.1	16.4	25.7	35.7	61.6	154	264	416
100	—	—	—	—	40.7	68.9	173	296	462
120	—	—	—	—	—	—	189	324	511

Handmove System

The handmove sprinkler system, shown in fig. 2, has been used for many years. It consists of a mainline and one or more laterals. The laterals are usually made of 20- to 40-foot sections of aluminum pipe joined by couplers. Small sprinklers are placed along the length of the laterals (usually on 40-foot intervals).

As the pump runs, a strip is sprinkled as long as the lateral and as wide as the diameter of an individual sprinkler. That strip is one "set." After the desired amount of water is applied to that set, the pump is shut off and the pipe is disassembled by hand and moved to a new location (usually 60 feet to the side), reassembled, and the new set is sprinkled.

With this system a one-fourth mile lateral will cover 1.8 acres with 60-foot moves. Such a system would have 32 sprinklers that might discharge 10 gpm each for a total of 320 gpm pumped through 5-inch pipe. The application rate would be 0.4 inches per hour and the power requirement would be about 20 horsepower.

Advantages:

Low initial investment; used systems may be available.

Few mechanical parts to malfunction.

Low power requirements (50 psi at the sprinklers).

Flexible with respect to land area. Different lengths can be set, and can be run almost any direction to get to isolated corners.

Disadvantages:

High labor requirement; moves must be made by moving individual pipe sections.

The small sprinklers might be prone to plugging with lagoon effluent, although no problem should occur with properly managed open feedlot runoff.

Towline

The towline system shown in fig. 3 is similar to the handmove system. The difference is that the towline has stronger, more permanent couplers between the lateral pipe sections. The lateral is moved by hooking a tractor onto the end of the lateral and towing it from one set to the next as a unit.

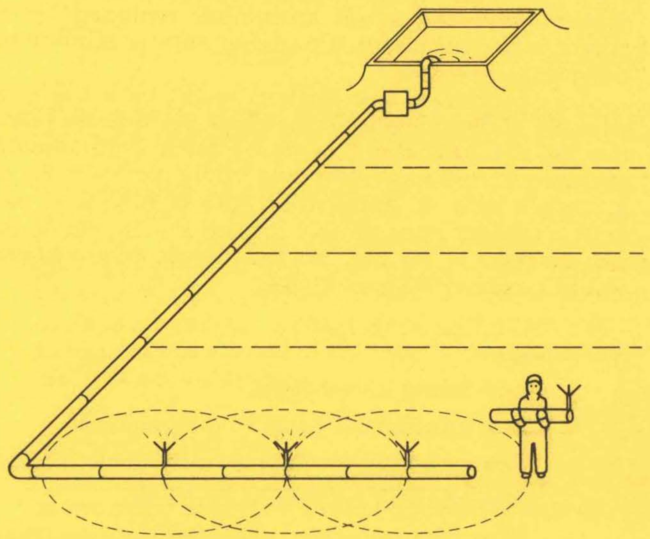

Fig. 2. Handmove System

Advantages:

Low initial investment; similar to handmove system.

Lower labor requirement; don't have to work in mud to make moves.

Few mechanical parts to malfunction.

Low power requirement (50 psi at the sprinklers).

Disadvantages:

Not flexible with respect to land area. Irregularly shaped fields can be a problem because of "permanent" lateral length.

Small sprinklers might plug.

Driving lanes for the tractor are required in tall row crops.

Stationary Big Gun

This system might be applicable to waste disposal systems, fig. 4. It is essentially a handmove

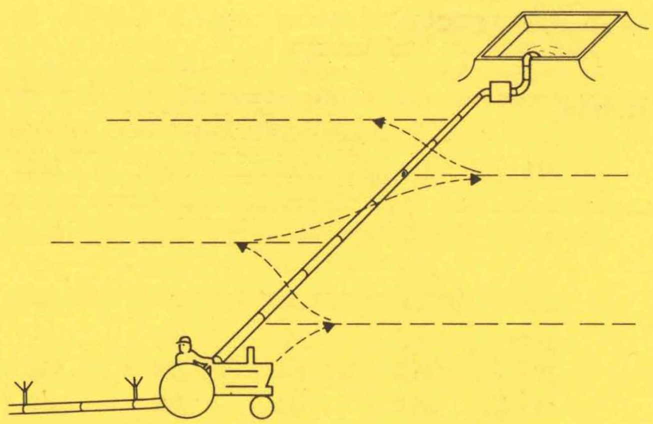

Fig. 3. Towline System

system with the small sprinklers replaced by a single large sprinkler. Changing sets is similar to handmove systems.

An example of this system might be a big gun capable of discharging 330 gallons per minute (similar to the handmove system). Such a gun would sprinkle a 350-foot diameter circle, or an area of 2.2 acres with an application rate of 0.33 inch per hour. Pressure requirement for this gun would be 90 psi instead of 50 psi, so the power requirement would be about 30 horsepower.

Advantages:

Low initial investment.

Few mechanical parts to malfunction.

Few plugging problems with large nozzle.

Flexible with respect to land area.

Pipe requirements are slightly less than with small sprinklers.

Disadvantages:

Higher power requirements (80 psi at the sprinkler).

High labor requirement.

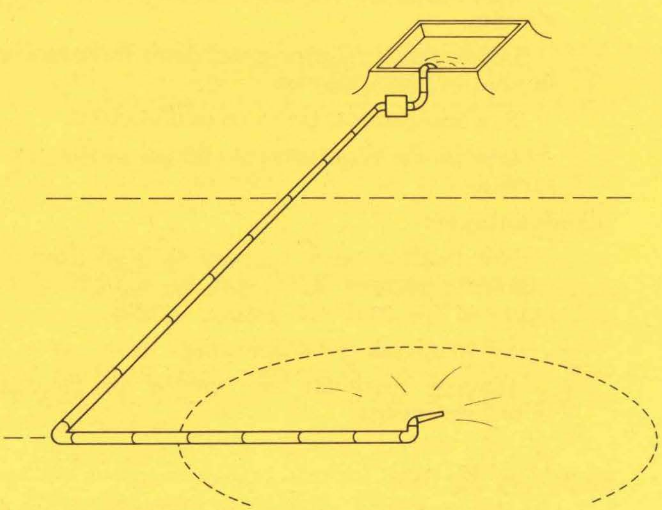

Fig. 4. Stationary Big Gun

Towed Big Gun

This system, fig. 5, is an intermediate system between stationary and traveling big guns. It is essentially a towline with the small sprinklers replaced by a big gun. Or it is a stationary big gun with the pipe couplers replaced by towline couplers. As such, it retains the nonplugging advantage of the big gun and the lower labor requirement of the towline.

Advantages:

Low initial investment.

Few mechanical parts to malfunction.

Lower labor requirement than handmove or stationary gun systems.

No plugging problems with large nozzle.

Pipe requirements are slightly less than with small sprinklers.

Disadvantages:

High power requirement.

Not as flexible with respect to land area.

Driving lanes are required for tractor.

Traveling Big Gun

The traveling big gun, fig. 6, is a system commonly used as a disposal method by large livestock producers. It is basically a single large nozzle mounted on a running gear that can be pulled across the field by a cable. The guns are usually pulled by one of two methods: (1) by a winch mounted on the running gear that is powered by a water turbine in the irrigation line or a small auxiliary gasoline engine; or (2) they are pulled by a winch on the far end of the cable that is powered by an auxiliary gas engine.

The systems are designed to move either 660 or 1,320 feet on each set, and have variable speeds which control the application rate. They are fed by dragging a flexible hose behind them. The hose is relatively expensive and constitutes a major part of the cost of a traveler. The primary advantage of the system is that it reduces labor requirements.

Traveling guns are available in a wide range of sizes. A common size of traveling gun will irrigate 10 acres per set. A comparable size stationary gun irrigates about 2 acres per set. Four sets are therefore eliminated by the traveler on each 10 acres.

Advantages:

Lowest labor requirement of systems mentioned.

No plugging problems with large nozzle.

Flexible with respect to land area.

Disadvantages:

Higher initial cost than other systems discussed.

High power requirement.

More mechanical parts than other systems, especially with an auxiliary gas engine.

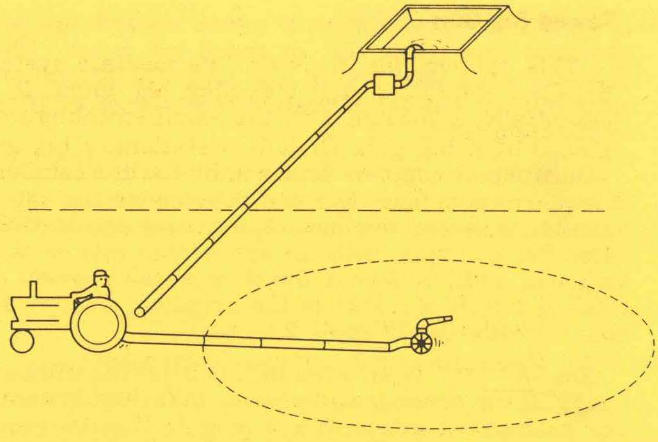

Fig. 5. Towed Big Gun

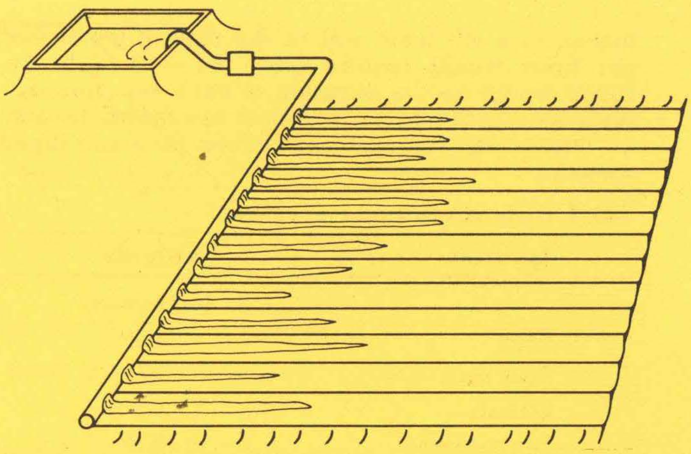

Fig. 7. Surface System

Other Sprinkler Systems

Other sprinkler systems are used for irrigation, but they are not generally considered for waste disposal in the Midwest.

Center pivot systems—which move around in a circle like the spoke of a wheel—offer almost complete automation, but they have many disadvantages. High cost, high power, small sprinklers, fixed land area covered, and mechanical maintenance problems are some disadvantages. Costs for these units run around $200 per acre.

Side roll systems—which move sideways across a rectangular field—are more adaptable than center pivot systems. They have small sprinklers, require rectangular fields, can have alignment problems, and have several mechanical devices to deal with.

Solid set systems permanently installed throughout an entire field are generally too expensive to install, except perhaps for small systems that could utilize small diameter polyethylene plastic pipe. Another disadvantage of solid set systems is that the risers and sprinklers are always in place and must be avoided with machinery and protected from animals.

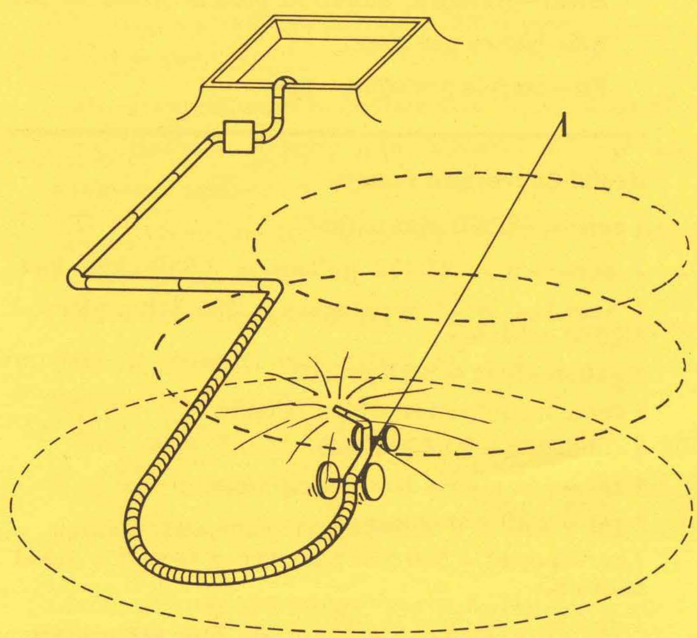

Fig. 6. Traveling Big Gun

Surface spreading is another possible system for waste disposal, as shown in fig. 7. Surface systems involve pumping the liquid onto the ground through pipe with numerous adjustable small openings called gates, and letting it run down a gentle slope. Surface systems can be used either on crop ground or forage ground, but require very good management to avoid runoff and get uniform distribution. Surface systems should not be used on land with greater than 2 percent slopes. If you want to try surface spreading, contact a soil and water engineer to inspect the site and help you determine the feasibility of such a system.

Advantages: Low cost; low power requirement; few mechanical parts.

Disadvantages: Requires high degree of management skill; inflexible with respect to land area; high labor requirement.

SYSTEM MANAGEMENT

Management of a disposal system involves more than the initial purchase. It must be operated properly to apply the right amount of waste over the desired area.

A major difference exists between irrigation systems and disposal systems. Irrigation systems are used to apply a large amount of water (up to 20 inches) each year in at least three or four separate, smaller applications. The equipment must be large enough to cover the entire area one set at a time, and be back to the starting point before the plants are out of water.

Waste disposal systems may only apply 1 or 2 inches of water in a single application each year. The crop's water requirements are not considered. Size is therefore much less critical with disposal systems, and is more affected by the amount of time the livestock producer wants to spend spreading wastes each year. If he wants to spend 3 days instead of 3 weeks, he buys bigger equipment. Costs are proportional to size.

The time required for a set (called the duration) is controlled by the application rate, soil intake rate, and the total amount of waste to be applied at that rate. For example, an application of 1.5

inches to a silt loam soil at the rate of 0.4 inches per hour would require 1.5 ÷ 0.4 = 3.75 hours, which would be the duration of each set. Approximate soil intake rates for water are shown in table 4. These may have to be reduced for some liquid wastes.

Table 4. Intake rates for various soil textures.

Soil texture	Intake rate
	(inches/hour)
Sandy	1.0
Sandy loam	0.75
Silt loam	0.5
Silty clay loam	0.25
Clay	0.1 or less

Table 5 can be used to estimate labor requirements for each system. The total number of sets is determined by the area to be sprinkled, which in turn is determined by the number of animals and the waste system being used. Iowa State University Extension pamphlet Pm-552 (Rev.) deals with this problem.

Table 5. Number of sets and labor required per 10 acres for various sprinkler systems.

System	No. of sets/ 10 acres	Labor/set (minutes)	Labor/10 acres (hours)
Hand move*	5.5	70	6.4
Towline*	5.5	23	2.1
Stationary big gun**	4.5	70	5.2
Towed big gun**	4.5	23	1.7
Traveling big gun***	1.0	60	1.0

*1/4 mile lateral with 60 feet between sets
**350 feet wetted diameter
***350 feet wetted diameter and 1/4 mile travel

The times shown in table 5 are in addition to the pumping times shown in fig. 1. To combine them, divide the disposal area in acres by 10 and multiply that number by the appropriate number from column 3 in table 5. Add the result to the time from fig. 1 for an estimate of the total time required to dispose of wastes each year for your own particular system. The worksheet at the end of this publication is to help you get an idea of what each system will do for you.

Once you have decided to irrigate for disposal, and have an idea of the system you want, you can obtain additional help from the extension service, SCS, consulting engineers, or irrigation equipment dealers and manufacturers to complete your design.

GLOSSARY

Application rate—Rate at which water is artificially applied to the soil. The application rate for a sprinkler system should never exceed the infiltration rate of the soil, or runoff will result. The finer textured your soil is, the lower its infiltration rate will be. Lower infiltration rates require lower application rates.

Duration—Length of time a sprinkler is operated in one location. The duration determines the total amount of water applied at any one application rate. For example, with an application rate of 0.5 inch per hour, a 2-hour duration would provide a total of 1 inch of water to the irrigated area. A 4-hour duration would apply 2 inches.

Set—A "set" is an area that is irrigated without changing or moving any pipe or other equipment. For example, if a lateral will irrigate 2 acres each time it is assembled, the 2 acres are considered to be a set. There would be five, 2-acre sets in a 10-acre field.

Intake rate—Rate at which soil will infiltrate water. The intake rate of the soil determines the maximum allowable application rate for a sprinkler system. If the application rate exceeds the soil intake rate, runoff will result.

Mainline—Primary pipeline for transporting water from the pump to the field. It may be the same size or larger than the lateral lines that it supplies, but it should never be smaller. Mainlines may be either portable, or permanently installed such as a buried mainline.

Laterals—Lines that hold the sprinklers or contain the gates that distribute water in the field. One mainline may feed one or more laterals. Generally, a lateral will be moved several times for each time a mainline is moved.

Acre-inch—one acre of area one-inch deep.

Cfs—cubic feet per second.

Gpm—gallons per minute.

Head—pressure, either in feet of water or psi.

Iph—inches per hour.

Psi—pounds per square inch.

Useful Conversion Factors

1 acre = 43,560 square feet.

1 acre-inch = 27,152 gallons = 3,630 cubic feet.

1 acre-foot = 12 acre-inches = 325,848 gallons = 43,560 cubic feet.

1 gallon water = 8.34 pounds.

1 cubic foot of water = 62.4 pounds.

1 cubic foot = 7.48 gallons.

1 cfs = 448 gpm = 1 acre-inch/hour.

1 psi = 2.30 feet of water.

1 horsepower = 550 foot pounds per second = 1.341 kilowatts.

1 ppm = 1 mg/liter = .0001 percent.

IRRIGATION WASTE DISPOSAL WORKSHEET

This worksheet is designed for use in conjunction with Iowa State University Extension publication Pm-552 (Rev.), "Area needed for Land Disposal of Beef and Swine Wastes," to help producers estimate the size and type of equipment needed for various sizes of livestock production enterprises.

1. Volume of waste to be disposed of each disposal period = 8% of body weight per day ÷ 8.34 x no. of days = ____________gallons.

2. Total disposal area required from table 2, Pm-552 (Rev.) = ______ acres. (250 pounds N per acre is the recommended maximum rate for land used every year for disposal.)

3. Estimate pump size needed.

   A. Irrigating days available _______ x hours per day _______ = total hours of pumping. This does not include time to change sets.

   B. Determine the size of pump required per gallons of waste (from 1 above) ÷ total hours of pumping (from A) ÷ 60 = _______ gpm.

4. Pipe size needed from table 2, = _______ inches.

5. Soil intake rate from table 4, = _______ inches/hour.

6. Area to be irrigated with each set by using the above pump capacity in gpm _______ ÷ soil intake rate in iph _______ ÷ 450 = _______ acres per set.

7. Select a nozzle size from table 3, then determine the proper spacing from table 6 so that the application rate is equal to or less than the rate in 5 above.

8. After selecting nozzle size, calculate number of nozzles needed for each set = pump capacity in gpm _______ ÷ nozzle discharge in gpm _______ = _______ nozzles.

Note: These nozzles can be all on one long lateral or on two or more shorter laterals. There are many combinations of nozzle sizes and spacings that yield the same application rate. Many sprinkler heads contain two or more nozzles of different sizes.

9. Calculate the time for each set:

   Total volume of wastes in gallons _______ ÷ total disposal area (from 2 above) in acres _______ x acres per set (from 6 above) _______ ÷ pump capacity in gpm _______ = minutes per set _______.

10. Time required to change sets, (from table 5) = _______ minutes.

11. Number of sets: total disposal area in acres _______ ÷ area per set in acres _______ = number of sets.

12. Travel time to change sets = number of sets (from 11 above) _______ x 15 minutes per set = minutes _______.

13. Now, minutes per set (from 9 above) _______ x number of sets (from 11 above) _______ + time to change sets (from 10 above) _______ + travel time (from 12 above) _______ = total disposal time required _______.

This value should be close to the estimate in 3 above. If it is considerably larger, you may wish to start with a larger pump, and larger set areas and/or use a different system and rework the problem until it meets your time table.

Basically, the soil intake rate limits the maximum application rate, but more area can be sprinkled at once to reduce the number of sets. Therefore, by using a larger pump and adding on pipe and sprinklers, disposal time can be reduced.

Table. 6. Precipitation, inches per hour.

Spacing Feet	Gallons per Minute from each Sprinkler																			
	1	2	3	4	5	6	8	10	12	15	18	20	25	30	40	50	100	200	500	1000
20 x 20	.24	.48	.72	.96	1.20	1.44	1.92													
20 x 30	.16	.32	.48	.64	.80	.96	1.28	1.60	1.93											
20 x 40	.12	.24	.36	.48	.60	.72	.96	1.20	1.45	1.81	2.17									
25 x 25	.15	.30	.46	.61	.77	.92	1.23	1.54	1.85	2.31										
30 x 30	.11	.21	.32	.43	.54	.64	.86	1.07	1.28	1.61	1.93	2.14								
30 x 40		.16	.24	.32	.40	.48	.64	.80	.96	1.20	1.45	1.61	2.01	2.40						
30 x 50		.13	.19	.25	.32	.38	.51	.64	.76	.96	1.15	1.28	1.60	1.92						
30 x 60		.11	.16	.21	.27	.32	.43	.53	.64	.80	.96	1.07	1.54	1.61	2.14					
40 x 40		.12	.18	.24	.30	.36	.48	.60	.72	.90	1.08	1.20	1.50	1.80	2.40					
40 x 50		.10	.14	.19	.24	.29	.38	.48	.58	.72	.86	.96	1.20	1.44	1.92					
40 x 60			.12	.16	.20	.24	.32	.40	.48	.60	.72	.80	1.00	1.20	1.60	2.00				
50 x 50			.12	.15	.19	.23	.31	.39	.46	.58	.69	.77	.96	1.15	1.54	1.92				
50 x 60			.10	.13	.16	.19	.26	.32	.39	.48	.58	.64	.80	.96	1.28	1.60				
50 x 70				.11	.14	.17	.22	.28	.33	.41	.49	.55	.69	.82	1.10	1.37				
60 x 60					.13	.16	.21	.27	.32	.40	.48	.53	.67	.80	1.07	1.34				
60 x 70					.11	.14	.18	.23	.27	.34	.41	.46	.57	.69	.92	1.15				
60 x 80					.10	.12	.16	.20	.24	.30	.36	.40	.50	.60	.80	1.00				
70 x 70					.10	.12	.16	.20	.24	.29	.35	.39	.49	.59	.79	.98	1.96			
70 x 80						.10	.14	.17	.21	.26	.31	.34	.43	.52	.69	.86	1.72			
70 x 90							.12	.15	.18	.23	.28	.30	.37	.46	.61	.76	1.52			
80 x 80							.12	.15	.18	.23	.27	.30	.38	.45	.60	.75	1.50			
80 x 100							.10	.12	.14	.18	.22	.24	.30	.36	.48	.60	1.20			
100 x 100								.10	.12	.14	.17	.19	.24	.29	.39	.48	.96	1.93		
100 x 120									.10	.12	.14	.16	.20	.24	.32	.40	.80	1.60		
150 x 150													.11	.13	.17	.21	.43	.85	2.14	
150 x 180														.11	.14	.18	.36	.71	1.78	
200 x 200															.10	.12	.24	.48	1.20	
300 x 300																	.11	.21	.53	1.07
360 x 360																		.15	.37	.74

The indicated diameters in this catalog are obtainable when operating without wind and with 6″ riser pipe for discharges up to 10 GPM, 9″ riser pipe for discharges from 10 GPM to 26 GPM, 12″ riser pipe for discharges from 26 GPM to 50 GPM and 18″ riser pipe for discharges above 50 GPM.

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