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# Dairy Waste Management

## System Planning — Estimating Storage

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Waste management in a dairy operation involves handling, storing and disposing of the manure and liquid waste produced while animals are in confinement. This management has become an important part of the overall planning and operation of the dairy facility, since the capital investment and labor required contribute to the cost of producing milk.

A waste system must be planned, designed and managed to (a) prevent water pollutants, (b) control odors, (c) eliminate breeding places for insects, (d) provide a convenient and efficient operation for the operator, (e) require minimal investment, maintenance and operational costs and (f) meet legal requirements.

Proper management of manure and waste water ensures further benefits in providing a healthy atmosphere for the animals. A facility that is clean, dry and free of manure provides a less desirable environment for disease organisms to thrive.

## Planning a Waste Management System

### Factors To Consider

Several factors influence the decision to build a new facility or to expand or modify an existing one. The following factors should be considered in a plan to handle old sources of waste.

1. **Environmental Factors**

   **Rainfall** — How many inches of rain are expected from a 24-hour, 1-in-25-year storm? What is the annual average precipitation?

   **Stream Location** — Where are nearby streams and canals located? How will locating facilities minimize potential discharges to a stream or canal?

   **Prevailing Winds** — What is the direction of natural air movement? Where are neighbors and milking facilities located?

   **Evaporation** — How will seasonal and annual evaporation rates affect the operation?

   **Temperature** — How will winter temperatures affect the operation and the ability to apply solid or liquid wastes to cropland?

   **Topography** — How can runoff from sloped terrain be controlled? Is the land too steep for pond construction?

   **Soil Type** — How permeable is the soil where the proposed storage pond is to be built? Are boulders or bedrock near the surface?

   **Surface Drainage** — How are the necessary runoff storage volumes calculated and which runoff curve number should be used?

   **Water Table Depth** — How near the surface is groundwater, which may limit the depth of the storage pond?

2. **Operational Factors**

   **Herd Size** — How much waste will the facility have to handle? Will the herd increase in size in the near future?

   **Cropping and Feeding Practices** — How can these practices be coordinated with manure and liquid waste application to cropland?

   **Land Area** — Is enough land available to construct an adequate animal waste system, i.e. for the pond(s) and other structures?

   **Cropland for Waste Application** — Is enough cropland available to accept all liquid and solid manure applications or should arrangements be made with a nearby farmer?

   **Existing Buildings and Machinery** — Which waste transport and storage options would be most efficient and economical based on available machinery and existing structures?

3. **Economic Factors**

**Availability of Capital and Labor** — How much money can affordably be invested and how labor-intensive should the waste facility be?

**Future Expansion Plans** — How can the facility be designed to accommodate any increase in herd size over the next few years?

4. **Social Factors**

**Neighbors** — Where are the nearest residences?

**Zoning** — What are the future development plans for the area? Is the land zoned for agriculture only? What are the building permit requirements?

5. **Legal Requirements (if applicable)**

**The EPA General Permit** — This permit requires sizing a waste facility to prevent discharges and to contain all waste water and runoff from a 25-year, 24-hour storm event plus snowmelt over the drainage area from a 1-in-5-year winter.

**State and Local Permits** — Have all local and state requirements been met? Have appropriate permits for new/expanding facilities been issued?

These are some of the major questions an operator will need to answer before a waste-handling plan and system can be designed.

## Design Criteria

Design considerations center primarily around handling and containing the waste. The criteria are as varied as the number of operations for which they are designed. Each dairy has an individual set of circumstances that have a tremendous impact on the type of system that will work best. Factors to consider are: (a) how different components of the wastes are to be handled, and (b) what type of facility is required to meet handling needs.

The following areas contribute to the waste that must be handled: (a) feeding area, (b) housing or loafing area, (c) holding pen area, (d) milking parlor and (e) runoff area.

Waste systems handling primarily liquids are more expensive to use and maintain. They also require more land. Limiting the amount of liquids to be handled may be economically efficient. In some cases waste in the holding pen can be handled as a solid rather than a liquid. This may be difficult, however, if access for equipment to scrape the solid waste to storage areas is limited. Runoff from the lot area is a necessary component. In areas where rainfall and/or winter precipitation is heavy, this runoff can be a major portion of the total waste to be managed.

The type of waste system to use is determined by the amount and type of waste to be handled. In many cases, two or more methods of handling wastes are used within a single operation. An example would be one in which waste from the milking operation is handled separately from the feeding and housing area waste. To design the system or systems needed, the designer must determine the amount of waste deposited within a given area of the facility (Table 1).

Most animal waste is deposited in the feeding and housing areas. In many cases, it is more economical to handle the wastes from the housing and feeding areas as a solid, keeping it separate from the highly liquid milking center wastes. Many operators flush holding pens to clean them and use sprinklers to clean cows. Both of these practices will make it impractical to handle this portion of the waste as a solid. Milking parlor waste is nearly always liquid because of the volume of water used to clean the milking center and to wash the cows.

The following criteria are important in designing a waste storage system:

1. The number of storage units to be used.
2. Type of manure being stored (solid or liquid) (see Tables 1, 2).
3. Type and amount of bedding used (refer to Table 3).

**Table 1. Waste produced daily by 1,000-pound cow and where it is deposited.**

| Area | Percent | Cubic feet |
|---|---|---|
| Housing area | 40% | .548 |
| Feeding area | 45% | .617 |
| Holding pen | 10% | .137 |
| Milk parlor | 5% | .068 |
| Total cubic feet/1,000 lb cow | | 1.370 |

**Table 2. Volume of milkhouse and parlor wastes.**

| Washing operation | Water volume |
|---|---|
| Bulk tank | |
| Automatic wash | 50 to 60 gal/wash |
| Manual wash | 30 to 40 gal/wash |
| Pipeline | |
| In parlor (Volume is higher for long stanchion barns) | 75 to 125 gal/wash |
| Pail milkers | 30 to 40 gal/wash |
| Miscellaneous equipment | 30 gal/day |
| Cow prep wash | |
| Automatic | 1 to 4.5 gal/wash/cow |
| Manual | .25 to .5 gal/wash/cow |
| Parlor floor | 40 to 75 gal/day |
| Milkhouse floor | 10 to 20 gal/day |
| Holding pen (sprinklers) | 5 gal/min/head (dependent on nozzle size and pressure) |

**Table 3. Bedding requirements for dairy cattle.**

| Housing system | Type of bedding | | | | | |
|---|---|---|---|---|---|---|
| | Long straw | | Chopped straw | | Shavings | |
| | (lb bedding/day/1,000 lb cow weight) | | | | | |
| Stanchion barn | 5.4 | (1.2) | 5.7 | (0.8) | 6.5 | (0.7) |
| Free stall barn | 2.6 | (0.6) | 2.7 | (0.4) | 3.1 | (0.3) |
| Loose housing | 9.3 | (2.1) | 11.0 | (1.6) | 12.6 | (1.4) |

*Note numbers in parenthesis are cubic feet values. Bedding volume is normally reduced during use because of compaction. To estimate volume for storage, use ½ the cubic feet values indicated.

4. Number and weight of animals.
5. The area contributing to surface runoff and amount of runoff expected.
6. Number of days of storage required (for flexibility, many would recommend 180 days as the minimum number of days for which storage must be provided).

The calculations for determining waste storage are straightforward, and the primary concern is containing all of the waste produced. Determining the proper size of storage required involves calculating the volume of waste produced and size of the structure required to hold that volume.

## Handling Systems

Different methods of handling wastes should be considered when planning a waste management system. The most commonly used types of waste management systems are made up of one or more of the following (refer to the glossary for definitions): (a) lagoons, (b) manure stack, (c) manure tank and (d) evaporation ponds.

Each of these methods can be used effectively when properly installed, operated and maintained. A critical aspect to be considered in choosing any of these storage structures is the size or holding capacity of the structure. Table 2 gives guidelines for calculating the amount of waste generated in the milk parlor, milk room and holding pen by the milking herd per day. The volumes of water shown in Table 2 are guidelines that can be used if actual amounts are not known. Equipment manufacturers often can provide more accurate amounts of water used to clean equipment.

The volume of bedding required for different types of housing systems is given in Table 3. The proportion of the total bedding to be stored will need to be estimated if only part of the manure goes into the storage facility.

Waste systems should be designed to hold waste for a minimum of 4 months, with 6 months preferred. This allows some flexibility in applying the waste to the soil. Wastes should be applied when the soil is not frozen to reduce the risk of runoff. Waste systems can be designed with two separate cells so that one can be dried up and cleaned while the other is in use. In many cases, however, a single storage cell will be adequate.

Waste systems should be designed to contain all agricultural waste water as well as the corral runoff from winter precipitation and corral runoff from 25-year, 24-hour storms. Any drainage that might come from a dry manure storage is also a pollutant that must be dealt with. The runoff from the corrals can be contained in a separate structure, allowing for evaporation to reduce the liquids.

## Biological Wastewater Treatment

An aerobic lagoon is designed to have liquid and waste deposited daily into a lagoon where the waste is degraded by aerobic organisms. The amount of waste or organic matter placed into an aerobic lagoon results in a "load" on the lagoon. The allowable amount of load per day is the loading rate of a lagoon. A lagoon that is loaded properly will develop a sufficient level of aerobes to degrade the waste that comes into the lagoon.

Aerobic lagoons are usually built from 3 to 5 feet deep and usually have a large surface area. The shallow depth and large surface area allow the water to oxygenate. Oxygenation takes place when atmospheric oxygen is dissolved in the water. This provides the necessary dissolved oxygen to support the aerobic bacteria that digest the organic matter in the waste. The shallow depth also allows the rays of the sun to penetrate to the bottom of the lagoon, which warms up the lagoon contents more rapidly in the spring. Both oxygenation and warm temperature aid in the decomposition of the solids in the lagoon.

In some cases, additional oxygenation of the waste by mechanical means may be necessary to maintain an adequate level of oxygen in the water. Levels of oxygen must be high enough to sustain the aerobic bacteria at levels necessary to keep up with the amount of waste entering the lagoon.

The aerobic lagoon can maintain itself at a fairly uniform level in areas of low precipitation and low humidity. Under those conditions, the evaporation rate in summer will exceed the inflow rate of liquids, and that period of dry down will compensate for the filling that occurs when evaporation is low or precipitation high. In many cases, however, some of the liquid must be pumped out of the lagoon and spread on cropland when the ground is not frozen and good absorption can occur.

Loading rates for aerobic lagoons are given in term of pounds of $BOD_5$ per acre of surface area per day. BOD (biochemical oxygen demand) is an indirect measure of the concentration of biologically degradable material present in organic wastes. BOD is the amount of free oxygen used by aerobic organisms when allowed to attack the organic matter in an aerobically maintained environment at a specified temperature (20°C) for a specific time period. $BOD_5$ specifies the amount of oxygen used over a 5-day period.

Loading rates of $BOD_5$ vary according to climatic conditions. Generally the cooler the climate the lower the amount of $BOD_5$ per surface acre of lagoon. The Agricultural Waste Field Manual published by the Soil Conservation Service has tables giving loading rates for specific areas.

The loading rate of $BOD_5$ is lowered if the Chemical Oxygen Demand (COD) rate exceeds a 3:1 ratio. COD is an indirect measure of the biochemical load exerted on the oxygen assets of a body of water when organic wastes are introduced into the water. The COD rate is normally in the range of 6:1 for dairy and beef waste. This level is high because large amounts of organic matter are commonly found in wastes entering lagoons on dairies and feedlots. Removing a portion of the organic matter will narrow the ratio of $BOD_5$ and COD levels. This topic is covered in the discussion on solid separation.

Water in an aerobic lagoon requires tremendous amounts of oxygen requirements to supply the aerobic bacteria needed to digest the organic matter with which it is loaded. In many areas, winds will help aerate the lagoon. Depth is critical; depth of the lagoon should not exceed 5 feet. As the depth nears or exceeds 5 feet, lack of oxygen may reduce activity of the aerobic bacteria and increase anaerobic bacteria near the bottom of the lagoon. This will cause a buildup of organic matter that may never be digested, so the usable size of the lagoon is reduced.

When this occurs, odors will increase due to anaerobic bacteria activity, and water in the lagoon will turn a reddish color. A "healthy" aerobic lagoon will produce little if any odor and the water will have a greenish color. If the lagoon is not healthy, it is lacking oxygen. If this should happen, the water level of the lagoon must be lowered or the amount of organic matter entering the lagoon must be reduced. In extreme cases, mechanical agitation and aeration of the lagoon may become necessary. Studies in Germany indicate that increasing aeration had a greater effect on reducing BOD levels than increasing the length of time the waste is treated.

## Anaerobic Lagoon

Anaerobic lagoons differ from the aerobic lagoons in that the environment of the anaerobic lagoon is nearly devoid of oxygen. The anaerobic lagoon uses the process of anaerobic decomposition which is the reduction of the net energy level and change in chemical composition of organic matter caused by microorganisms in an anaerobic or oxygen-free environment. Anaerobic lagoons are not designed to purify the water they contain. Rather they are an effective means of storing livestock waste and at the same time allowing the process of anaerobic decomposition to break down the organic matter in the lagoon until it can be applied to cropland. One of the advantages of anaerobic treatment is that this type of lagoon uses a much heavier concentration of solids to liquid than does the aerobic lagoon.

An anaerobic lagoon is a deep lagoon, with depths of 12 to 20 feet being common. Since the depth of the lagoon is greater, the surface area required is much smaller than for an aerobic lagoon. The lagoon needs to be deep to reduce the natural aeration of its contents. An anaerobic lagoon will perform better if it is covered to retard the aeration process even more. The surface of most anaerobic lagoons will form a "crust" which will provide a barrier between the atmospheric oxygen and the contents of the lagoon. This crusting effect is beneficial to the anaerobic process of degradation and reduces the amount of odor given off into the atmosphere. The crust also slows evaporation to a point where it is virtually nonexistent.

Since little if any evaporation occurs in anaerobic lagoons, they require more maintenance and labor than do aerobic lagoons. Anaerobic lagoons must be pumped dry periodically so the solids can be cleaned out.

Anaerobic lagoons use a process known as digestion in the treatment process. Digestion commonly refers to the anaerobic breakdown of organic matter in water solution or their suspension into simpler or more biologically stable compounds or both. Organic matter may be decomposed to soluble organic acids or alcohols and subsequently converted to gases as methane and carbon dioxide. Many of these compounds are odorous. They are responsible for the foul smells connected with anaerobic lagoons. Complete destruction of the organic matter by the bacteria alone is never accomplished.

Loading rates for anaerobic lagoons are given as pounds of volatile solids per 1,000 cubic feet. Volatile solids are the portion of the total or suspended solids residue which is driven off as volatile or combustible gases at a specified temperature and time (usually 600°C for 1 hour). The volatile solids loading rate for an anaerobic lagoon varies according to climatic conditions. The Agricultural Waste Field Manual published by the Soil Conservation Service has tables giving loading rates for specific areas.

Odors may become a problem if volatile solid loading rates are too high. To keep odors to a minimum, reduce the volatile solid loading rate by 50 percent. When the anaerobic lagoon is too heavily loaded, the bacteria that break the organic matter down into organic acids thrive and the pH of the lagoon is lowered. When the pH is lowered, methane-forming bacteria are inhibited and the result is an excess of foul smelling gases such as hydrogen sulfide ("rotten-egg" gas), ammonia and volatile organic compounds.

Anaerobic lagoons are sensitive to temperature. At temperatures below 40°F, the bacterial activity in an anaerobic lagoon is minimal. Sudden changes in temperature upset the bacterial balance in the lagoon, and the result can be foul and sour gases given off the surface of the lagoon. This is quite common in the spring as the weather warms up and the lagoon "turns over." This "turning over" is a phenomenon caused by the change in temperature which alters the bacterial action within the lagoon, causing the solids in the bottom of the lagoon to come to the surface. When this occurs, the lagoon puts off strong odors for a short period of time, usually 2 to 3 days.

Anaerobic lagoons can be used in series with other anaerobic lagoons or with aerobic lagoons. Using an anaerobic lagoon ahead of an aerobic lagoon will lower the $BOD_5$ significantly and will allow use of a smaller aerobic lagoon. Combining anaerobic and aerobic lagoons in a single system gives producers the advantage of evaporating a large percentage of water as well as handling a larger quantity of solids in a smaller area.

## Solid/Liquid Separation Facilities

A solid/liquid separator can be used to (1) reduce the volume of solids to be stored in a lagoon or a storage structure, or (2) reduce the load placed on a lagoon by reducing the $BOD_5$ or the volatile solids going into it.

Solid separators may be mechanical or may simply be a device used to settle out the majority of the solids. In one check done by the Division of Environment, a settling device reduced the total solids by 75 percent. Even higher amounts of the solids can be extracted by a mechanical separator.

Regardless of the type of system being used, solid separation should be strongly considered as a part of the total plan. The fewer solids entering a lagoon or liquid storage system, the fewer the problems with the system.

## Waste Storage Location

Once the decision has been made on the system to be used, including all of the component parts, an on-site evaluation should be made to ensure the components are appropriately located.

When corral slope exceeds 2 percent, the amount of runoff will be significantly higher than on those of less than 2 percent. When slopes exceed 2 percent, extra planning will be required to ensure that all potential runoff from the corrals can be contained either by a berm or by the lagoon system. Placement of the lagoon at the lowest point will allow it to be used for handling runoff. Other factors to consider are storage requirements of the lagoon system and type of surface of the storage lot (paved, frozen, unpaved) (see Table 4).

**Table 4. Storage requirements due to runoff on paved, frozen or steep (12% slope) and unpaved lots.**

| 25 yr/24 hr rainfall in inches | Paved, frozen or steep lots (> 2% slope) | | Unpaved lots | |
|---|---|---|---|---|
| | Runoff in inches | Cubic feet volume/acre | Runoff inches* | Cubic ft volume/acre |
| 1.0 | 1.0 | 3,630 | 0.359 | 1,303 |
| 1.1 | 1.1 | 3,993 | 0.430 | 1,561 |
| 1.2 | 1.2 | 4,356 | 0.504 | 1,830 |
| 1.3 | 1.3 | 4,719 | 0.580 | 2,107 |
| 1.4 | 1.4 | 5,082 | 0.659 | 2,393 |
| 1.5 | 1.5 | 5,445 | 0.740 | 2,694 |
| 1.6 | 1.6 | 5,808 | 0.823 | 2,983 |
| 1.7 | 1.7 | 6,171 | 0.905 | 3,286 |
| 1.8 | 1.8 | 6,534 | 0.990 | 3,594 |
| 1.9 | 1.9 | 6,897 | 1.076 | 3,906 |
| 2.0 | 2.0 | 7,260 | 1.163 | 4,222 |
| 2.1 | 2.1 | 7,623 | 1.251 | 4,541 |
| 2.2 | 2.2 | 7,986 | 1.340 | 4,863 |
| 2.3 | 2.3 | 8,349 | 1.429 | 5,187 |
| 2.4 | 2.4 | 8,712 | 1.519 | 5,514 |
| 2.5 | 2.5 | 9,075 | 1.610 | 5,843 |
| 2.6 | 2.6 | 9,438 | 1.701 | 6,174 |
| 2.7 | 2.7 | 9,801 | 1.793 | 6,507 |
| 2.8 | 2.8 | 10,164 | 1.885 | 6,842 |
| 2.9 | 2.9 | 10,527 | 1.977 | 7,178 |
| 3.0 | 3.0 | 10,890 | 2.071 | 7,516 |

*Soil Conservation Service runoff curve number value of 91 was used.

Several procedures have been used for predicting quantities of runoff. However, the Soil Conservation Service runoff equation has had widespread use. SCS equation:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

where:

Q = runoff (inches)

P = rainfall (inches)

S = maximum potential difference between rainfall and runoff.

$$S = \frac{1{,}000 - 10}{N}$$

where:

N = an empirical number characterizing the runoff-producing surface.

A surface with an N value of 100 would have no surface storage and all the water would runoff. SCS recommends an N value of 91 for earth lots. The N value is sometimes called the "runoff curve number."

The waste management system should not be placed in the natural drainages of surrounding land. Such a placement can be disastrous when heavy rains or sudden thaws cause these natural drainages to become filled with runoff water.

Lagoons or waste-handling facilities should not be placed near wells or in areas where the soil may have fissures due to volcanic formations. Areas with light or sandy soils can also have problems. Lagoons or storage structures should be located no closer than 100 feet from a well; 200 to 300 feet would be preferred.

Water table depths must be known before the lagoon is constructed. If water tables are shallow, a lagoon should not be considered. A soil survey should be completed by a qualified soil technician to determine the minimum distance between the base of the lagoon and the highest water table level for the year.

Lagoons should be located so that the prevailing winds do not carry odors to the milking facilities, the farmstead or to neighboring residences. Lagoons should be fenced to keep children and livestock from falling into them. Lagoon banks should be planted to grass and mowed to keep weeds from growing and creating an unsightly facility. Many problems can be averted by simply spending a little extra time and effort to make the operation look clean and neat. The lagoon should be routinely inspected for damage by rodents. These pests can cause serious leaks which can lead to major disaster if a bank of the lagoon fails due to a washout.

## Other Planning Considerations

The waste management plan should be designed for potential future expansion. It may be easier to construct a larger structure in the beginning than to enlarge existing structures later on.

Corral runoff is an often overlooked part of the total waste management planning process. In areas of low precipitation and mild winters, runoff may not seem like a problem, but unexpected extremes in weather can cause severe problems for dairymen. Runoff can be added to the lagoon (assuming the added volume was planned), or it can be contained in a separate area for evaporation.

Table 5 lists the 1-in-5 year runoff value of winter precipitation accumulations for different areas in Idaho. If site-specific winter precipitation is not known use three inches of runoff.

The ways by which wastes are disposed of play a big part in the planning process. If irrigation is an option, lagoons are a viable alternative. If manure must be handled as a solid, however, the amount of liquids must be held to a minimum. Remember that liquid wastes must not be disposed of improperly on frozen soils as the resulting runoff is not allowed.

Waste storage structures should never be located in an area that creates a hardship to others. For this reason, storage structures should be placed as far as practical from any property line, residence, business or public road. A ¼ mile distance is recommended from present or potential residences. If possible, locate waste storage structures at least 300 feet from the property line. Structures designed for areas of high precipitation and/or runoff will have to take in account the additional water that will be handled.

Waste facility designers need to keep the financial capabilities of the operator in mind. The most elaborate system is not going to do the job if it is not properly managed and operated. Most management efforts on the dairy are centered around the livestock. The simpler the management requirements of the waste system, the more likely it will receive the amount of attention it requires.

**Table 5. The 1-in-5-year (20 percent chance) precipitation and runoff values.***

| Station | Total precipitation | Total runoff | Cubic ft volume/acre |
|---|---|---|---|
| Boise Airport | 6.9 | 1.5 | 5,445 |
| Bonners Ferry 1SW | 13.3 | 5.4 | 19,602 |
| Burley Airport | 5.0 | 0.9 | 3,267 |
| Coeur d'Alene R.S. | 14.3 | 6.2 | 22,506 |
| Emmett 2E | 7.5 | 1.8 | 6,534 |
| Idaho Falls Airport | 6.2 | 1.0 | 3,630 |
| Idaho Falls 16SE | 5.8 | 0.7 | 2,541 |
| McCall | 16.0 | 7.3 | 26,499 |
| Montpelier R.S. | 6.1 | 1.2 | 4,356 |
| Payette | 6.9 | 1.6 | 5,808 |
| Parma Experiment Station | 5.9 | 1.0 | 3,630 |
| Preston KACH | 7.6 | 1.8 | 6,534 |
| Pocatello Airport | 6.0 | 1.0 | 3,630 |
| Sandpoint KSPT | 18.2 | 9.0 | 32,670 |
| Twin Falls | 5.5 | 1.1 | 3,993 |
| Weiser | 7.3 | 1.8 | 6,534 |

*The period covered in this table is the accumulated months of December, January, February and March. The runoff was computed using a 24 hour RCN of 91 for unpaved lots and converted to the 30 day RCN value of 76.

## Discussion

Managing dairy waste has become an important part of the requirements for a dairy herd. The handling of livestock waste was not regulated in the past. This has changed in today's society where environmental quality is a high priority, and we now have limited restrictions applying to the management of livestock waste.

The dairyman has an obligation to his neighbors and family to produce a high quality product and to maintain the quality of the environment while doing so. Managing the manure and waste water (which are byproducts of milk production) is his largest single challenge in meeting those obligations.

To manage waste water and manure properly on a dairy operation requires careful planning. The first step is selecting a facility that will fit the dairyman's management abilities and physical features. Once the facility has been planned and designed, proper installation and proper operation of the facility are essential to ensure that it works correctly, performing the function for which it was designed.

A waste system is not a static system or one without change. Waste systems can change on a daily basis due to changes in loading, volume or weather. Such changes require regular monitoring to detect when they affect the operation of the system. Constant monitoring will allow corrections in the operation to be made in a timely manner and before a system failure does occur.

Producers should keep updated on changes in the regulations that affect livestock waste management, and the waste management system should be changed as often as necessary to ensure compliance with current laws. These efforts by the producer may be of great value in avoiding confrontation with regulating agencies and may be less costly in the long run.

The worksheet on pages 8 and 9 illustrates a step-by-step procedure to estimate the total cubic feet of storage needed to contain the wastes and runoff from an example dairy. An additional worksheet (pages 10 and 11) is provided for your use.

### Additional Sources of Information

Sources 1 and 2 provide pertinent guidance in design, operation and maintenance of livestock waste systems.


1. Midwest Plans Service. 1985. Livestock waste facilities handbook, MWPS-18. Iowa State Univ.
2. Idaho Department Health and Welfare. 1987. Idaho waste management guidelines for concentrated animal feeding operations. A report of the Water Quality Bureau, Division of Environment, Boise, ID.
3. USDA Soil Conservation Service. 1975. Agricultural waste management field guide.
4. Ohlensehlen, Robert M. 1986. Dairy waste management, a technical paper presented in partial fulfillment of an M.S. degree, Univ. of Idaho, Moscow.

Name: EXAMPLE Date: ____

Location of operation: TWIN FALLS Plan prepared by: ____

# Storage Volume Worksheet

1. Number of cows in the herd — 200
2. Average weight of cows in the herd — 1300
3. Manure volume per day (cu ft)
   Line 1 × line 2/1,000 × 1.37 — 356.2
4. Number of milkings per day — 2
5. Number of sprinklers in holding pen — 0
6. Sprinkler output in gallons per minute (gpm)
   (@ 50 psi 9/64 = 4.04; 5/32 = 4.98;
   11/64 = 6.01; 3/16 = 7.18) — 0
7. Minutes per day sprinklers are used — 0
8. Gallons of water used to wash holding pen per day — 200
9. Percent of total manure being stored (in decimal) (see Table 1) — .15
10. Runoff due to 25-year, 24-hour storm in cu ft (see Table 4) — 3594 (cu ft vol/acre) × 2 (acres) = 7188
11. Runoff due to winter precipitation in cu ft (see Table 5) — 3993 (cu ft vol/acre) × 2 (acres) = 7986

**Milkhouse and parlor volumes (see Table 2)**

12.

| | Gallons | |
|---|---|---|
| Bulk tank | 60 | |
| Pipeline | 200 | |
| Miscellaneous equipment | 30 | |
| Wash parlor floor | 75 | |
| Wash milkhouse floor | 20 | |
| Total (gallons/7.5 = cu ft) | 385 | cu ft = 51.3 |

13. Holding pen volume (line 8) + (line 5 × line 6 × line 7) = gallons
    gallons/7.5 = cu ft — 26.7
14. Cow prep per cow per day (see Table 2)
    [(use per milking gal) × line 1 × line 4] = gallons
    gallons/7.5 = cu ft — 26.7
15. Manure being stored per day in cu ft
    (line 9 × line 3) — 53.4
16. Total daily estimated volume in cu ft
    (sum lines 12 + 13 + 14 + 15) — 158.1
17. Total estimated volume from runoff events
    (sum line 10 + line 11) — 15174
18. Number of days of storage required
    (minimum 4 months; 6 months recommended) — 180
19. Cubic feet of storage required
    (line 18 × line 16) + line 17 — 43632

**Comments:** These calculations do not account for volume changes due to precipitation and evaporation occurring in the storage structure. If bedding is stored in this structure, then adjust the volume accordingly. Add the cubic feet of volume to line 19. Refer to Table 3.

# Manure Stack Volume Worksheet

| | | |
|---|---|---|
| 1. | Number of cows in the herd | 200 |
| 2. | Average weight of cows in the herd | 1300 |
| 3. | Manure volume per day in cu ft (line 1 × line 2/1,000 × 1.37) | 356.2 |
| 4. | Percent of manure being stored (in decimal) (see Table 1) | .85 |
| 5. | Manure being stored per day in cu ft (line 4 × line 3) | 302.8 |
| 6. | Contribution of bedding stored with manure in cu ft per day (line 1 × line 2/1,000 × amt from Table 3) | 273 |
| 7. | Cu ft of manure and bedding per day (line 5 + line 6) | 575.8 |
| 8. | Days of storage required | 180 |
| 9. | Volume of storage required in cu ft (line 8 × line 7) | 103644 |

Given information for example dairy:

- 200 dairy cows, 1,300 pounds average body weight.
- 2 acres unpaved lot area with less than 2 percent slope.
- Runoff is contained in storage facility.
- Winter precipitation is from Twin Falls.
- 25 year, 24 hour storm is 1.8 inches.
- Long straw bedding is used in loose housing.

Name: ______________________ Date: ____________

Location of operation: ____________ Plan prepared by: ____________

# Storage Volume Worksheet

1. Number of cows in the herd ____________
2. Average weight of cows in the herd ____________
3. Manure volume per day (cu ft) ____________
   Line 1 × line 2/1,000 × 1.37
4. Number of milkings per day ____________
5. Number of sprinklers in holding pen ____________
6. Sprinkler output in gallons per minute (gpm)
   (@ 50 psi 9/64 = 4.04; 5/32 = 4.98;
   11/64 = 6.01; 3/16 = 7.18) ____________
7. Minutes per day sprinklers are used ____________
8. Gallons of water used to wash holding pen per day ____________
9. Percent of total manure being stored (in decimal) (see Table 1) ____________
10. Runoff due to 25-year, 24-hour storm in cu ft (see Table 4) ________ cu ft vol/acre × ____ acres = ____________
11. Runoff due to winter precipitation in cu ft (see Table 5) ________ cu ft vol/acre × ____ acres = ____________

**Milkhouse and parlor volumes (see Table 2)**

12.

| | **Gallons** | | |
|---|---|---|---|
| Bulk tank | ______ | | |
| Pipeline | ______ | | |
| Miscellaneous equipment | ______ | | |
| Wash parlor floor | ______ | | |
| Wash milkhouse floor | ______ | | |
| Total (gallons/7.5 = cu ft) | ______ | cu ft = | ____________ |

13. Holding pen volume (line 8) + (line 5 × line 6 × line 7) = gallons ____________
    gallons/7.5 = cu ft
14. Cow prep per cow per day (see Table 2)
    [(use per milking gal) × line 1 × line 4] = gallons ____________
    gallons/7.5 = cu ft
15. Manure being stored per day in cu ft ____________
    (line 9 × line 3)
16. Total daily estimated volume in cu ft ____________
    (sum lines 12 + 13 + 14 + 15)
17. Total estimated volume from runoff events ____________
    (sum line 10 + line 11)
18. Number of days of storage required ____________
    (minimum 4 months; 6 months recommended)
19. Cubic feet of storage required ____________
    (line 18 × line 16) + line 17

**Comments:** These calculations do not account for volume changes due to precipitation and evaporation occurring in the storage structure. If bedding is stored in this structure, then adjust the volume accordingly. Add the cubic feet of volume to line 19. Refer to Table 3.

# Manure Stack Volume Worksheet

1. Number of cows in the herd ___________
2. Average weight of cows in the herd ___________
3. Manure volume per day in cu ft (line 1 × line 2/1,000 × 1.37) ___________
4. Percent of manure being stored (in decimal) (see Table 1) ___________
5. Manure being stored per day in cu ft (line 4 × line 3) ___________
6. Contribution of bedding stored with manure in cu ft per day (line 1 × line 2/1,000 × amt from Table 3) ___________
7. Cu ft of manure and bedding per day (line 5 + line 6) ___________
8. Days of storage required ___________
9. Volume of storage required in cu ft (line 8 × line 7) ___________

Given information for example dairy:

- 200 dairy cows, 1,300 pounds average body weight.
- 2 acres unpaved lot area with less than 2 percent slope.
- Runoff is contained in storage facility.
- Winter precipitation is from Twin Falls.
- 25 year, 24 hour storm is 1.8 inches.
- Long straw bedding is used in loose housing.

# Glossary of Animal Waste Management Terms

**Aeration** — Intimate contact between air and a liquid effected by bubbling air through the liquid or by agitation of the liquid to promote surface absorption of air.

**Aerobic** — Living or active only in the presence of oxygen.

**Aerobic bacteria** — Bacteria that require the presence of free (dissolved or molecular) oxygen for their metabolic processes. (Oxygen in chemical combination will not support aerobic organisms.)

**Aerobic decomposition** — Reduction of the net energy level of organic matter by aerobic microorganisms.

**Aerobic lagoon** — See Lagoon.

**Agitation** — The turbulent remixing of liquid and settled solids.

**Agricultural waste** — Wastes that originate from agriculture. Most such wastes are associated with the production of food and fiber on farms, ranges and forests. These wastes normally include animal manure, crop residues, dead animals and agricultural chemicals. Municipal solid wastes, effluents and sludges disposed of in agricultural areas are considered agriculture-related wastes in this publication.

**Algae** — Primitive plants, one or many-celled, usually aquatic and capable of synthesizing their food by photosynthesis.

**Alkalinity** — A quantitative measure of the capacity of liquids or suspensions to neutralize strong acids or to resist the establishment of acidic conditions. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, volatile acids, salts and occasionally borates, silicates and phosphates. Numerically, alkalinity is expressed in terms of the concentration of calcium carbonates that have an equivalent capacity to neutralize strong acids.

**Anaerobic** — Living or active in the absence of oxygen.

**Anaerobic bacteria** — Bacteria that do not require the presence of free or dissolved oxygen for metabolism.

**Anaerobic decomposition** — Reduction of the net energy level and change in chemical composition of organic matter caused by microorganisms in an anaerobic environment.

**Bacteria** — Primitive plants, generally free of pigment, that reproduce by dividing in one, two or three planes. They occur as single cells, chains, filaments, well-oriented groups or amorphous masses. Most bacteria do not require light, but a limited number are photosynthetic and draw upon light for energy. Most bacteria are heterothrophic (utilize organic matter for energy and for growth materials), but a few are autotrophic and derive their bodily needs from inorganic materials.

**Bedding** — Material, usually organic, placed on the floor surface of livestock buildings for animal comfort and to absorb urine and other liquids and promote cleanliness in the building.

**BOD (Biochemical Oxygen Demand)** — An indirect measure of the concentration of biologically degradable material present in organic wastes; the amount of free oxygen used by aerobic organisms when allowed to attack the organic matter in an aerobically maintained environment at a specified temperature (20°C) for a specific time period (5 days). BOD is expressed in milligrams of oxygen used per liter of liquid waste volume (mg/1) or in milligrams of oxygen per kilogram of waste solution (mg/kg = ppm = parts per million).

**Biodegradation (biodegradability)** — The destruction or mineralization of either natural or synthetic organic materials by the microorganisms populating soils, natural bodies of water or wastewater-treatment systems.

**Biological stabilization** — Reduction in the net energy level of organic matter and reduction in its tendency to putrefy, as a result of the metabolic activity of organisms.

**Biological treatment** — Organic waste treatment in which bacterial and/or biochemical action is intensified under controlled conditions.

**Chemical oxidation** — Oxidation of organic substances without benefit of living organisms. Examples are by thermal combustion or by oxidizing agents such as chlorine.

**CAFO** — A concentrated animal feeding operation with potential for pollution of Idaho's surface and ground water.

**COD (Chemical Oxygen Demand)** — An indirect measure of the biochemical load exerted on the oxygen content of a body of water when organic wastes are introduced into the water. COD is determined by the amount of potassium dichromate consumed in a boiling mixture of chromic and sulfuric acids. The amount of oxidizable organic matter is proportional to the potassium dichromate consumed. If the wastes contain only readily available organic bacterial food and no toxic matter, the COD values can be correlated with BOD values obtained from the same wastes.

**Composting** — Present-day composting is the aerobic, thermophilic decomposition of organic waste to relatively stable humus. Humus with no more than 25 percent dead or living organisms is stable enough not to reheat or cause odor or fly problems. It can undergo further, slower decay. In composting, mixing and aeration are provided to maintain aerobic conditions and permit adequate heat development. The decomposition is done by aerobic organisms, primarily bacteria, actinomycetes and fungi.

**Contamination** — A general term signifying the introduction into water of microorganisms, chemical, organic or inorganic wastes or sewage, which renders the water unfit for its intended use.

**Dehydration** — The chemical or physical process whereby water in either chemical or physical combination is removed from other matter.

**Denitrification** — The process by which nitrates or nitrites in the soil or organic deposits are reduced to ammonia or free nitrogen by bacterial action.

**Digestion** — Though aerobic digestion is being used, the term digestion commonly refers to the anaerobic breakdown of organic matter in water solution or suspension into compounds that are simpler or more biologically stable, or both. Organic matter is decomposed to soluble organic acids or alcohols and then converted to gases such as methane and carbon dioxide. Bacterial action alone never completely destroys organic solid materials.

**Dissolved oxygen** — The oxygen dissolved in sewage, water or other liquid and usually expressed as milligrams per liter or as percent of saturation.

**Effluent** — (1) A liquid that flows out of a containing space. (2) Wastewater or other liquid, partly or completely treated or in its natural state, flowing out of a reservoir, basin, treatment plant or part thereof.

**Evaporation rate** — The quantity of water that is evaporated from a specified surface per unit of time, generally expressed in inches or centimeters per day, month or year.

**Facultative bacteria** — Bacteria that can exist and reproduce under aerobic or anaerobic conditions.

**Facultative decomposition** — Reduction of the net energy level of organic matter by facultative microorganisms.

**Fertilizer value** — The worth of plant nutrients contained in wastes and available to plants when the waste is applied to soil. A monetary value assigned to a quantity of organic waste represents the cost of obtaining the same type and amount of plant nutrients in commercial form. The worth of waste as fertilizer can be estimated only for given soil conditions and other pertinent factors such as land availability, time and handling.

**Filtration** — The process of straining a liquid through a porous medium to remove suspended or colloidal material contained in the influent liquid.

**Gasification** — The process or processes whereby solid or liquid matter is converted to gases such as carbon dioxide, methane or ammonia through biological activity.

**Holding pond** — An impoundment made by constructing a dam or embankment or by excavation or a combination thereof, for temporary storage of livestock or other agricultural wastes, waste water or polluted runoff.

**Infiltration rate** — The rate at which water enters the soil. Units are usually inches of water per hour.

**Influent** — A liquid that flows into a containing space.

**Lagoon** — Also see Holding pond. An all-inclusive term commonly given to a water impoundment in which organic wastes are stored or stabilized or both. Lagoons may be described by the predominant biological characteristics (aerobic, anaerobic or facultative), by location (indoor, outdoor), by position in a series (first stage, second stage, etc.) and by the organic material accepted (sewage, sludge, manure or other).

**Liquefication** — Any of several processes whereby solids are converted to liquids. Suspended solids can be liquefied by the biochemical action of microorganisms or by the physical-chemical process of dissolving. Liquefication as a term is often applied to the operation whereby water or agitation or both are used to convert semisolid manure into thick slurries or thinner solid suspensions.

**Liquid manure** — A suspension of livestock manure in water in which the concentration of manure solids is low enough that flow characteristics of the mixture are more like those of Newtonian fluids than of plastic fluids. Synonymous with slurry.

**Manure** — The fecal and urinary defecations of livestock and poultry. Manure may often contain some spilled feed, bedding or litter.

**Manure flume or gutter** — Any restricted passageway, open along its full length to the atmosphere, through which liquid moves by gravity.

**Manure pit or tank** — A storage unit in which accumulations of manure are collected before treatment or disposal. Water may be added in the pit to promote liquefication.

**Manure stack** — A place with an impervious floor and side walls to contain manure and bedding until it may be recycled.

**Milkcenter wastes** — The wastewater containing milk residues, detergents and manure generated in the milkcenter.

**Organic matter** — Chemical substances of animal or vegetable origin, or more correctly, of basically carbon structures, comprising compounds consisting of hydrocarbons and their derivatives.

**Oxidation** — Combining of oxygen with organic waste to produce simple chemical compounds such as carbon dioxide, water, nitrates, etc.

**Oxidation ditch** — A shallow and continuous ditch, often oval in shape, around which liquid wastes are circulated by rotors or propellers which also transfer oxygen from the atmosphere for aerobic treatment.

**Oxidation lagoon or pond** — Synonymous with aerobic lagoon.

**pH** — The symbol for the logarithm of the reciprocal of hydrogen ion concentration, expressed in moles per liter of a solution and used to indicate an acid or alkaline condition. A pH of 7 indicates neutrality; less than 7 is acid; greater than 7 is alkaline.

**Percolation** — The movement of water through soil.

**Percolation rate** — The rate, usually expressed as a velocity, at which water moves through saturated granular material.

**Pesticide** — A chemical substance used to kill or control pests such as weeds, insects, algae, rodents and other undesirable agents.

**Pollution** — The presence in a body of water (or soil or air) of substances of such character and in such quantities that the natural quality of the body of water (or soil or air) is degraded so as to impair its usefulness or render it offensive to the senses.

**Putrefaction** — Biological decomposition of organic matter with the production of ill-smelling products associated with anaerobic conditions.

**Sedimentation basin or tank** — A basin or tank in which a liquid (water, sewage, liquid manure) containing settleable suspended solids is retained until part of the suspended solids settle out by gravity.

**Seepage** — The movement of liquid through the ground surface. Influent seepage is movement of liquid from surface bodies of water into the soil. Effluent seepage is discharge of liquid from within the soil to the surface of the soil or to surface waters.

**Septic** — A putrefactive condition produced by anaerobic decomposition of organic wastes, usually accompanied by production of malodorous gases.

**Settleable solids** — Those suspended solids contained in waste water that separate by settling when the carrier liquid is held in a quiescent condition for a specified time interval.

**Sludge** — The accumulated settled solids deposited from sewage or other raw or treated wastes in lagoons, basins or tanks, and containing enough water to form a semiliquid mass.

**Suspended solids** — Solids either floating or suspended in water, sewage or other liquid wastes and that can be removed by laboratory filtering.

**Solids content** — The residue from water, sewage, other liquids or semi-solid masses when moisture is evaporated and the remainder is dried at a specified temperature (usually 103°C).

**Solid/liquid separation** — See Sedimentation basin or tank and Settleable solids.

**Total solids** — The sum of dissolved and undissolved constituents in water or wastewater, usually stated in milligrams per liter.

**Volatile solids** — That portion of total or suspended solids driven off as volatile (combustible) gases at a specified temperature and time (usually 600°C for 1 hour).


## The Authors

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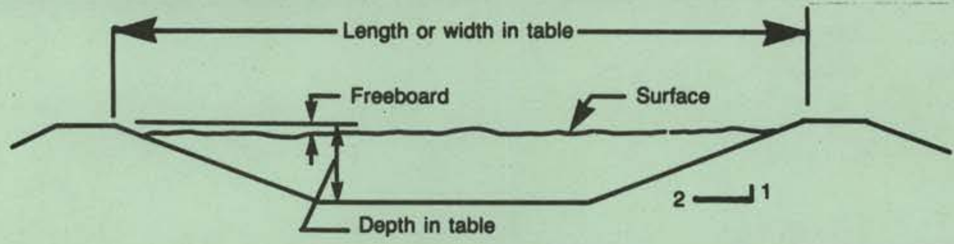
# Appendix A

Appendix A can be used to determine earth basin dimensions, or the volume of rectangular and square earth storages can also be determined from the following formula.

## Earth Basin Holding Pond and Lagoon Capacities

**Bank slope = 2.1. Volume allows for 2 feet of freeboard. All dimensions are in feet.**




| Volume (thousands of $ft^3$) | Depth 8, Interior width | | | | | Depth 10, Interior width | | | | | Depth 12, Interior width | | | | | Depth 15, Interior width | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 150 | 200 | 50 | 75 | 100 | 150 | 200 | 50 | 75 | 100 | 150 | 200 | 50 | 75 | 100 | 150 | 200 |
| | (Interior length, ft) | | | | | | | | | | | | | | | | | | | |
| 4 | 41 | 31 | - | - | - | 40 | 32 | - | - | - | 40 | 34 | - | - | - | 39 | - | - | - | - |
| 6 | 52 | 37 | 32 | - | - | 50 | 37 | - | - | - | 49 | 38 | - | - | - | 49 | 40 | - | - | - |
| 8 | 63 | 43 | 36 | - | - | 59 | 42 | - | - | - | 58 | 42 | 37 | - | - | 58 | 44 | - | - | - |
| 10 | 74 | 49 | 40 | - | - | 69 | 47 | - | - | - | 67 | 46 | 40 | - | - | 68 | 47 | 42 | - | - |
| 15 | 102 | 65 | 51 | - | - | 93 | 59 | 48 | - | - | 90 | 57 | 47 | - | - | 92 | 57 | 48 | - | - |
| 20 | 130 | 80 | 61 | 45 | - | 117 | 71 | 56 | - | - | 113 | 68 | 54 | - | - | 116 | 66 | 54 | - | - |
| 30 | 185 | 110 | 82 | 58 | - | 165 | 96 | 72 | - | - | 158 | 89 | 68 | 51 | - | 164 | 85 | 66 | 52 | - |
| 40 | 241 | 140 | 103 | 71 | - | 213 | 120 | 89 | 63 | - | 204 | 110 | 82 | 60 | - | 212 | 104 | 77 | 59 | - |
| 50 | 296 | 171 | 124 | 84 | 66 | 261 | 145 | 105 | 73 | - | 249 | 132 | 96 | 68 | - | 260 | 122 | 89 | 65 | - |
| 60 | 352 | 201 | 144 | 97 | 75 | 309 | 169 | 122 | 83 | 66 | 295 | 153 | 109 | 76 | 62 | 308 | 141 | 101 | 72 | - |
| 70 | 407 | 231 | 165 | 109 | 85 | 357 | 194 | 138 | 93 | 73 | 340 | 174 | 123 | 84 | 68 | 356 | 160 | 112 | 78 | 65 |
| 80 | 463 | 262 | 186 | 122 | 94 | 405 | 218 | 154 | 103 | 80 | 386 | 195 | 137 | 92 | 74 | 405 | 179 | 124 | 85 | 70 |
| 90 | 518 | 292 | 207 | 135 | 103 | 453 | 243 | 171 | 113 | 87 | 431 | 217 | 151 | 101 | 80 | 453 | 197 | 135 | 92 | 74 |
| 100 | 574 | 322 | 228 | 148 | 112 | 501 | 267 | 187 | 123 | 95 | 476 | 238 | 165 | 109 | 85 | 501 | 216 | 147 | 98 | 79 |
| 110 | 630 | 352 | 249 | 161 | 122 | 550 | 292 | 204 | 132 | 102 | 522 | 259 | 179 | 117 | 91 | 549 | 235 | 159 | 105 | 84 |
| 120 | 685 | 383 | 269 | 173 | 131 | 598 | 316 | 220 | 142 | 109 | 567 | 280 | 193 | 125 | 97 | 597 | 254 | 170 | 112 | 88 |
| 130 | 741 | 413 | 290 | 186 | 140 | 646 | 341 | 237 | 152 | 116 | 613 | 302 | 207 | 133 | 103 | 645 | 272 | 182 | 118 | 93 |
| 140 | 796 | 443 | 311 | 199 | 149 | 694 | 365 | 253 | 162 | 123 | 658 | 323 | 221 | 142 | 109 | 693 | 291 | 194 | 125 | 98 |
| 150 | 852 | 474 | 332 | 212 | 159 | 742 | 390 | 270 | 172 | 130 | 704 | 344 | 234 | 150 | 114 | 741 | 310 | 205 | 132 | 102 |
| 160 | 907 | 504 | 353 | 225 | 168 | 790 | 414 | 286 | 182 | 137 | 749 | 366 | 248 | 158 | 120 | 789 | 329 | 217 | 138 | 107 |
| 170 | - | 534 | 374 | 238 | 177 | 838 | 439 | 302 | 192 | 144 | 795 | 387 | 262 | 166 | 126 | 837 | 347 | 229 | 145 | 111 |
| 180 | - | 565 | 394 | 250 | 186 | 886 | 464 | 319 | 202 | 151 | 840 | 408 | 276 | 174 | 132 | 885 | 366 | 240 | 151 | 116 |
| 190 | - | 595 | 415 | 263 | 196 | 934 | 488 | 335 | 212 | 158 | 886 | 429 | 290 | 183 | 138 | 933 | 385 | 252 | 158 | 121 |
| 200 | - | 625 | 436 | 276 | 205 | 982 | 513 | 352 | 222 | 166 | 931 | 451 | 304 | 191 | 144 | 981 | 404 | 264 | 165 | 125 |
| 225 | - | 701 | 488 | 308 | 228 | - | 574 | 393 | 247 | 183 | - | 504 | 339 | 211 | 158 | - | 451 | 293 | 181 | 137 |
| 250 | - | 777 | 540 | 340 | 251 | - | 635 | 434 | 271 | 201 | - | 557 | 373 | 232 | 173 | - | 498 | 322 | 198 | 148 |
| 275 | - | 852 | 592 | 372 | 274 | - | 696 | 475 | 296 | 219 | - | 610 | 408 | 252 | 187 | - | 544 | 351 | 214 | 160 |

| Volume (thousands of $ft^3$) | Depth 10, Interior width | | | | | Depth 15, Interior width | | | | | Depth 20, Interior width | | | | | Depth 25, Interior width | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | 150 | 200 | 300 | 400 | 100 | 150 | 200 | 300 | 400 | 100 | 150 | 200 | 300 | 400 | 100 | 150 | 200 | 300 | 400 |
| | (Interior length, ft) | | | | | | | | | | | | | | | | | | | |
| 300 | 516 | 321 | 237 | 160 | 124 | 380 | 231 | 172 | 120 | - | 334 | 197 | 148 | - | - | 322 | 183 | 139 | - | - |
| 325 | 557 | 346 | 254 | 171 | 132 | 409 | 248 | 183 | 127 | - | 359 | 210 | 157 | 113 | | 346 | 194 | 146 | 109 | - |
| 350 | 599 | 371 | 272 | 182 | 140 | 439 | 264 | 195 | 134 | - | 384 | 223 | 166 | 118 | - | 369 | 205 | 153 | 113 | - |
| 375 | 640 | 395 | 290 | 194 | 148 | 468 | 281 | 206 | 142 | 112 | 408 | 236 | 175 | 124 | - | 393 | 216 | 161 | 117 | - |
| 400 | 681 | 420 | 308 | 205 | 157 | 497 | 297 | 218 | 149 | 117 | 433 | 250 | 184 | 129 | 105 | 417 | 228 | 168 | 122 | - |
| 425 | 722 | 445 | 325 | 216 | 165 | 526 | 314 | 230 | 156 | 123 | 458 | 263 | 193 | 135 | 109 | 440 | 239 | 176 | 126 | 105 |
| 450 | 763 | 470 | 343 | 227 | 173 | 555 | 330 | 241 | 163 | 128 | 483 | 276 | 201 | 140 | 113 | 464 | 250 | 183 | 131 | 109 |
| 475 | 804 | 495 | 361 | 239 | 182 | 584 | 347 | 253 | 171 | 133 | 508 | 289 | 210 | 145 | 117 | 488 | 262 | 191 | 135 | 112 |
| 500 | 845 | 519 | 379 | 250 | 190 | 613 | 364 | 264 | 178 | 138 | 532 | 302 | 219 | 151 | 121 | 511 | 273 | 198 | 140 | 115 |
| 600 | 1,010 | 619 | 450 | 295 | 223 | 730 | 430 | 311 | 207 | 159 | 632 | 354 | 255 | 173 | 136 | 606 | 318 | 228 | 157 | 127 |
| 700 | - | 718 | 521 | 341 | 256 | 846 | 496 | 357 | 236 | 181 | 731 | 407 | 291 | 194 | 152 | 700 | 364 | 258 | 175 | 140 |
| 800 | - | 817 | 592 | 386 | 290 | 963 | 563 | 403 | 265 | 202 | 830 | 459 | 326 | 216 | 168 | 795 | 409 | 287 | 193 | 152 |
| 900 | - | 916 | 663 | 431 | 323 | 1,080 | 629 | 450 | 293 | 223 | 929 | 512 | 362 | 238 | 183 | 889 | 454 | 317 | 210 | 165 |
| 1,000 | - | 1,015 | 734 | 477 | 356 | - | 695 | 496 | 322 | 244 | 1,028 | 564 | 397 | 259 | 199 | 984 | 500 | 347 | 228 | 178 |

Source: Midwest Plan Service, 1985. Livestock Waste Facilities Handbook.

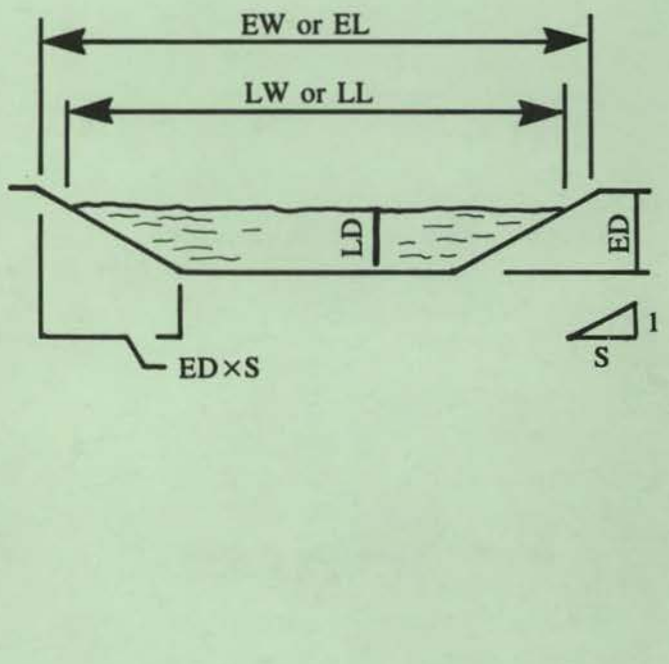
# Appendix B: Conversions

Multiply to the right (cu ft × 7.5 = gal)
Divide to the left (gal ÷ 7.5 = cu ft)

| | | |
|---|---|---|
| Cubic feet | 7.5 | gallons |
| | 1,728 | cubic inches |
| | 62.4 | pounds water |
| Gallons | 231 | cubic inches |
| | 0.134 | cubic feet |
| | 8.3 | pounds water |
| Cubic yards | 27 | cubic feet |
| Acres | 43,560 | square feet |
| | 4,840 | square yards |
| Miles | 5,280 | feet |
| | 1,760 | yards |
| Acre-inch | 27,154 | gallons |
| | 3,621 | cubic feet |
| | 133 | tons |
| Acre-foot | 325,848 | gallons |
| | 43,560 | cubic feet |
| Acre-in/hr | 450 | gpm |
| | 1 | cfs (approx.) |
| psi | 2.31 | feet of water head |
| cfs | 448.8 | gpm |
| | 646,317 | gal/day |
| ppm or mg/1 | 0.0001 | percent |

**Unit Abbreviations**

cfm = cubic feet per minute
cfs = cubic feet per second
cfh = cubic feet per hour
psi = pounds per square inch
gpm = gallons per minute
fps = feet per second
ppm = parts per million




$LW = EW - 2 \times FB \times S$

$LL = EL - 2 \times FB \times S$

$LD = ED - FB$

**Unit Abbreviations:**

LW = liquid width, ft
EW = earth basin width, ft
FB = freeboard, ft
S = sideslope, ft
= amount of run for 1 foot fall
LL = liquid length, ft
EL = earth basin length, ft
LD = liquid depth, ft
ED = earth basin depth, ft

$$V = (LW \times LL \times LD) - [(S \times LD^2) \times (LW + LL)] + (4 \times S^2 \times LD^3 \div 3)$$

V = liquid volume, $ft^3$

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