ENVIRONMENTAL QUALITY

MU Guide

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Beef Manure Management With Dirt Lots

Charles D. Fulhage and Donald L. Pfost, Agricultural Engineering Extension
Troy Chockley, Natural Resources Conservation Service

Many of Missouri's cattle producers background their calves for later sale or feedlot finishing, either in their own lots or at a custom feedlot. Major problems with feedlots in Missouri are due to high rainfall, which produces high volumes of runoff that can pollute streams, and muddy dirt lots, which reduce performance (Figure 1). This publication shows ways to reduce the problem of muddy lots and to prevent stream pollution.

Missouri Clean Water Law

Most beef cattle operations in Missouri are relatively small pasture-based operations and are not "regulated." Permits or letters of approval are not required for the following animal feeding operations: (a) Operations smaller than 300 animal units (AU) in size (except for certain dairy facilities); and (b) Pasture operations, bare feeding areas within a pasture, or barn lot feeding areas when the cattle have free access to pasture. One beef feeder animal or beef slaughter animal equals one AU.

However, the Missouri Clean Water Law, in simple terms, states that "it is a violation to allow the discharge of a pollutant or contaminant to waters of the state" without a discharge permit. The Clean Water Law applies to all production enterprises regardless of size. Therefore, beef producers are urged to maintain vegetation on pastures, especially next to streams and bodies of water, and to follow recommended best management practices when collecting, storing, transporting and applying manure to fields.

Solid, slurry and lagoon systems, or any combination, can be developed to meet Missouri Clean Water Law requirements. Any livestock manure management system, regardless of size, must be designed and operated in a manner that will not pollute surface or ground water. Consult local health and regulatory authorities and have all plans approved before constructing any manure handling system. Contact the Outreach and Assistance Center at the Missouri Department of Natural Resources (Phone 1-800-361-4827) or your local MU Outreach and Extension office or NRCS office for information about permits and assistance in planning manure management systems.

Figure 1. Cattle confined to muddy dirt lots have reduced performance and feed efficiency.

Current regulations are primarily concerned with concentrated animal feeding operations. A concentrated animal feeding operation with 1,000 animal units [AU]) or more is required by state law to obtain a permit from the Missouri Department of Natural Resources (DNR) if it meets each of the following three criteria:

1. Animals are confined for 45 days or more in any 12-month period.
2. A ground cover of vegetation is not sustained over at least 50 percent of the animal confinement area.
3. One of the following size criteria is met:
   a. Class 1A, 1B or 1C operation (greater than 1,000 AU); or
   b. Class II operation (between 300 and 999 AU) that discharges through a man-made conveyance into waters of the state or where pollutants are discharged directly into waters of the state which originate outside of and pass through the facility.

If animals normally on pasture are kept in a concentrated animal feeding area for a portion of the year, the total concentrated animal units will determine the requirements for a letter of approval or permit. For more details, see *Guide to Animal Feeding Operations,* published by the Water Pollution Control Program, Division of Water Protection and Soil Conservation, Department of

Natural Resources, or contact the Outreach and Assistance Center at the Missouri Department of Natural Resources (phone 1-800-361-4827).

Classification of feeding operations

The requirements are based on the number of animals at each operating location. Table 1 shows the number of animal units in each class of concentrated animal feeding operations. Table 2 shows the number of various animals constituting one animal unit.

Table 1. Animal unit and size classification.

Size classification	Number of animal units
Class IA	7,000 or more
Class IB	3,000 to 6,999
Class IC	1,000 to 2,999
Class II	300 to 999

Table 2. Number of various animals constituting one animal unit.

Animal size and species	Number of animals to equal 1 AU
Beef feeder or slaughter animal	1.0
Horse	0.5
Dairy cow	0.7
Swine weighing more than 55 lb	2.5
Swine weighing less than 55 lb	15
Laying hens	30
Pullets	60
Turkeys	55
Broiler chickens	100

Voluntary letters of approval: Operations smaller than those listed in Table 1 may not be required to obtain a letter of approval but must operate in a no-discharge manner in compliance with the Missouri Clean Water Law. Operations that do not require a permit may apply for a letter of approval or a permit on a voluntary basis. Operations smaller than Class II (less than 300 AU) may apply for a letter of approval based on best management practices approved by the DNR. This will allow approval of innovative practices that may be more appropriate for these smaller operations than conventional storage and land application systems. Many of the feedlots in Missouri are smaller 300 animal units, and few are larger than 1,000.

Land area requirements

Approval of an animal manure management system by DNR requires that sufficient land be available to receive the nutrients contained in the manure. If you do not own suitable land, a legally binding agreement must be reached with neighboring landowners to allow spreading the manure on their land. A specific form (M121-F, Spreading Agreement) is available from DNR outlining the requirements.

Beef manure management systems

Missouri beef manure management, usually for feedlots rather than for pasture systems, can be classified into three systems — solid, slurry or liquid — depending on the collection, transportation and distribution of the manure on the fields. Which of these systems is appropriate depends on the amount of bedding and water dilution used by a specific operation or the reduction of moisture content by allowing water to drain off to an approved collection area. Manure can be collected by scraping and transported to a storage area for land application at an appropriate time to make best use of the manure nutrients and when the crop production sequence allows spreading. During storage, water may drain off and reduce the mass of manure to be transported as a solid to the land application area. Runoff from a dirt feedlot may have a substantial portion of the solids separated from the runoff in a settling basin. The settled solids and runoff water remaining in the settling basin may be agitated and handled as slurry. The runoff passing through the basin may proceed to a holding pond (or a lagoon) and be applied to the land by sprinkler or surface irrigation. Thus, dirt lot systems may handle manure using one, two or three systems, based on solids content.

Many beef operations use more than one system. Frequently, most of the manure is spread by the animals while on pasture, thus eliminating the cost of collecting, transporting and distributing the manure on fields. Manure distribution and water quality can be enhanced by such low-cost measures as disbursed salt blocks and mineral feeders and frequent moving of hay feeders, feed bunks and self-feeders. Higher-cost measures include disbursed water supplies to draw cattle away from streamside areas and fencing off buffer strips along streams. A recent trend in beef production is intensively managed grazing, which optimizes forage production as well as manure distribution over a system of paddocks. This method is well suited for cow-calf and backgrounding operations.

Site selection for dirt lots

In the past, many feedlots were located in irregular areas where row-crop farming was not practical. Often the feedlot was located on steep land with high rates of erosion and bordered a ravine or a stream. In other cases, a stream ran through the feedlot and a portion of the land was too flat for good drainage. In these situations, stream pollution was a common occurrence and runoff-control structures were not feasible without compromising the size of the lot.

Feedlots experience problems with both water runoff and air quality. Preliminary site evaluation considers topography, neighbors, present and future livestock numbers and accessibility. See EQ 378, *Selecting a Site for Livestock and Poultry Operations*, for more details. Any livestock waste management system, regardless of size, should be designed and operated in a manner that will not pollute surface or ground water.

A land slope of 2 to 6 percent is recommended for good drainage of dirt lots. Steeper slopes can cause excessive erosion. Grade the site to establish the proper slope, if necessary. Lot space is affected by lot slope. Minimum requirements are 150 to 250 ft^2/head with 4 percent or greater slopes, 250 to 400 ft^2 with 2–4 percent lot slopes and 400 to 800 ft^2 with slopes below 2 percent. Another rule of thumb is a minimum area of about one acre of land per 100 animal units for pen space, alleys and feed roads. Soil with 25 percent or more clay is preferred to sand or fractured rock surfaces. Clay soils can develop a manure pack that will shed surface water. When scraping manure off the lot, do not disturb the manure-soil interface that has developed a seal.

With a sloping site, take advantage of the natural slope to plan drainage and equipment placement. Terrain and drainage determines bunk location. Preferred bunk orientation is in a north-south direction with east-west sloping lots. On a flat site, the topography must be shaped. Move earth from the parts designed for solids settling and runoff control, and build up along fence lines and feed bunks. Additional soil may be needed to achieve the desired slopes and drainage. Plan drainage away from feed bunks, waterers and fence lines. Concrete areas along the feed bunks and around the waterers. A 10- to 20-foot-wide slab connecting the waterer slab to the feed bunk slab is recommended.

Maintenance of dirt lots

Dirt lots should be maintained to eliminate depressions where water will collect. The goal is to maintain a 1- to 2-inch layer of compacted manure to form a seal above the mineral soil and keep the lot as hard, smooth and dry as possible. Lots that shed water rapidly and completely have less potential to create odors. Pay special attention to holes and wallows near water troughs and feed aprons where spilled and excreted water may collect even during dry weather. Fill these areas with compacted soil as soon as possible. Remove manure ridges that may cause water to collect in fence lines and near feed bunks and waterers. Cleaning these areas may require small equipment or manual labor.

Box scrapers and wheeled front-end loaders are commonly used to remove manure and fill depressions. The best equipment for removing manure is either a self-propelled elevating (paddle) scraper or a tractor-towed box scraper. The paddle scraper and road grader are precision excavation machines, which produce a smooth surface in the hands of a good operator, even with deep or well-compacted manure. Box scrapers are best in relatively loose manure, whether moist or dry, and often have an adjustable blade depth. Both box and paddle scrapers are commonly used in western feedlots, where manure is collected relatively frequently for dust management in the summer and for shaping pens to improve drainage before winter. Frequent “harvesting” of loose, dry manure improves manure quality for land application and reduces dust emissions in dry weather and slush in wet times.

Pushed equipment, such as dozers and front-end loaders tend to gouge. It is more difficult to ensure that a pushed scraper blade (e.g., front-end loader) leaves an even, smooth surface than a pulled blade (e.g., box scraper). Blades that gouge and scar the surface of a lot reduce its water-shedding efficiency. A combination of a front-end loader for major manure removal and a scraper for final cleaning and grading would be an effective compromise.

Manure harvesting equipment should permit skilled operators to leave a firm, smooth and evenly graded lot surface with 1 to 2 inches of compacted manure on top of the mineral soil. It is hard to prevent some mixing of wet manure with the underlying soil, especially during prolonged wet weather in winter and spring, even with excellent manure harvesting practices the rest of year. But it’s worth the effort.

Mounds keep animals out of the mud

Mounds improve drainage and provide areas that dry quickly; a dry resting area improves cattle comfort, health and feed utilization. Animals should be able to step off of the mound and onto the concrete feeding apron without having to move through mud. Proper mound construction requires 20 to 40 square feet of mound space per animal unit on each side of the mound. The entire pen of animals should be able to lie on each side of the mound without lying on each other (Figure 2). The mounds should be constructed to allow the animals to lie on the sides of the mound rather than on top. Resting on the top often creates areas where rainwater or urine can accumulate rather than draining off. The top of the mound should be less than 5 feet wide and the side slopes should be at a 5:1 or 4:1 ratio. Mounds oriented east-west allow the animals to use the mound as a windbreak by lying on the south side. Mounds should not impede natural pen drainage and should be constructed so that pen shaping and leveling equipment can travel over and maintain the shape of the

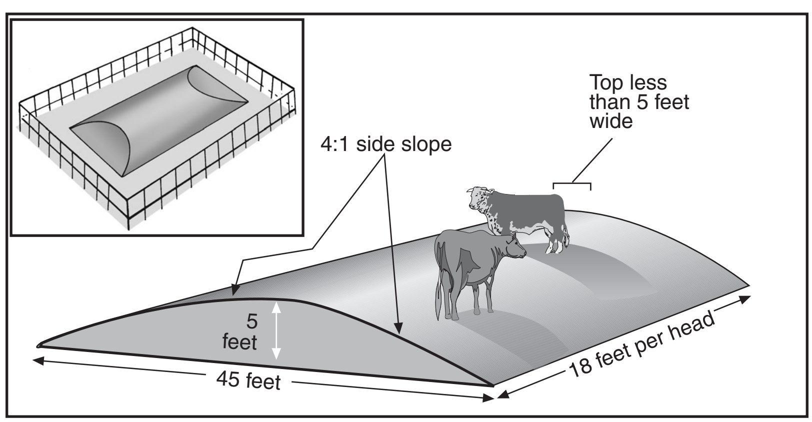

Figure 2. Typical mound construction. Mounds should allow space for all the animals in a pen to lie on the warmest side slope.

mound. For more details, see MWPS-6, *Beef Housing and Equipment Handbook*.

Runoff control methods

Pens should be separated from the nearest flowing water channel by at least 200 feet to allow space for runoff control structures or conservation practices. Water channels include road ditches, streams, waterways and pasture draws. All extraneous runoff needs to be diverted away from the feedlots and roads (keep clean water clean). For new sites, this is most easily accomplished by siting the feedlot on a ridge or elevating the feed road to construct a diversion channel. Runoff control systems usually include diversion channels below the dirt lots to convey the runoff to a solids-separation device, most often a solids settling basin (either earthen or concrete) or a settling terrace. For more details, see MU publication EQ 386, *Settling Basins and Terraces for Cattle Manure*.

If a mechanical separation device is used, pumping may be required to elevate the runoff to the separator inlet. The liquid outflow from the solids separation device is usually routed to a holding pond or a lagoon for later land application. For more details, see MU publications EQ 388 *Earthen Pits (Basins) for Liquid Livestock Manure*; EQ 387 *Anaerobic Lagoons for Storage/Treatment of Livestock Manure;* EQ 383 *Land Application Equipment for Livestock and Poultry Manure Management*; and G1157, *Lagoon Pumping and Irrigating Equipment.*

A holding pond should be designed to hold the runoff for the desired storage period; 180 days minimum storage in Missouri (365 days storage recommended).

The design of a holding pond should include a safety volume adequate to store the runoff expected from the feedlot for a 25-year, 24-hour storm plus storage capacity for at least 180 days of manure production, the expected 10-year return rainfall minus evaporation during the storage time, and any influent from other sources. The manure production (solids volume) includes the manure not settled out in the settling basin plus silt from any dirt lots. At lease 2 feet of liquid must be left in the bottom of an earthen basin to keep the clay seal from drying and cracking.

If the open lot surface area contributing to the holding pond is greater than 70 percent of the pond area (as is likely for dirt cattle lots), the safety volume depth is computed using the following formula:

$$\text{Safety volume depth} = 0.67 + \frac{\text{square foot lot surface x 0.5 ft}}{\text{square foot pit liquid surface area}}$$

For earthen lot areas, the value of 2,800 ft^3/acre/year should be used to calculate the amount of manure and silt solids that would come off the lot area. For concrete lot areas, the amount of manure generated, the percent solids not retained in the settling basin (typically 50%) and the desired storage period should be used to size the holding pond. Beef feeders produce about 7.7 pounds (about 0.15 ft^3) of manure solids per day per 1,000 pounds of body weight, and lactating dairy cows produce about 10.4 pounds (about 0.21 ft^3) of manure solids per day per 1,000 pounds of body weight. For other livestock, see MWPS-18, Manure Management Systems Series, Section 1, *Manure Characteristics*).

The 25-year, 24-hour rainfall varies from about 5.5 inches in northeast Missouri to 7 inches in southwest Missouri (see Figure 3). The runoff for 180 days of storage is 60% (not 50%) of the expected 365-day runoff.

Table 3 lists the runoff and rainfall minus evaporation values for a 1-in-10-year return. Table 4 lists the runoff and rainfall evaporation factors for a 1-in-10-year return, depending on storage time.

Table 3. Runoff and rainfall minus evaporation: 1-in-10-yr return.

		Feet per year for 1-in-10-year return		
		Stormwater runoff		Rainfall minus evaporation
Mean annual rainfall (inches)	1-in-10-yr rainfall (inches)	From earth lot areas (ft/yr)	From concrete lots & roofs (ft/yr)	From basin water surface (ft/yr)
34	44	1.7	2.9	0.9
36	47	1.8	3.1	1.2
38	50	2.0	3.3	1.3
40	52	2.2	3.5	1.6
42	55	2.5	3.6	1.8
44	57	2.7	3.8	2.0
46	60	2.8	4.0	2.3
48	63	3.0	4.2	2.5
50	65	3.2	4.3	2.75
52	68	3.3	4.5	2.9

Table 4. Runoff and rainfall evaporation factors: 1-in-10-year return.

Days storage	Runoff factor for all areas	Rainfall minus evaporation factors for average annual rainfall areas	
		34"–42"	43"–52"
365 days	1.00	1.00	1.00
180 days	0.60	0.70	0.90
120 days	0.50	0.60	0.75
90 days	0.40	0.55	0.65
60 days	0.30	0.50	0.50

Example calculation using the runoff factor: Calculate the runoff to be expected from a 3-acre earth lot for the 1-year-in-10 return period and 180 days of storage in an area with a 46-inch average rainfall as follows:

3 acres x 43,560 ft^2/acre x 2.8 ft/year runoff x 0.60 runoff factor = 219,542 ft^3 of runoff in 180 days.

Note: 219,542 ft^3 x 7.5 gallons/ft^3 = 1,646,568 gallons (This would fill a 100-foot-diameter tank 52.4 feet tall.)

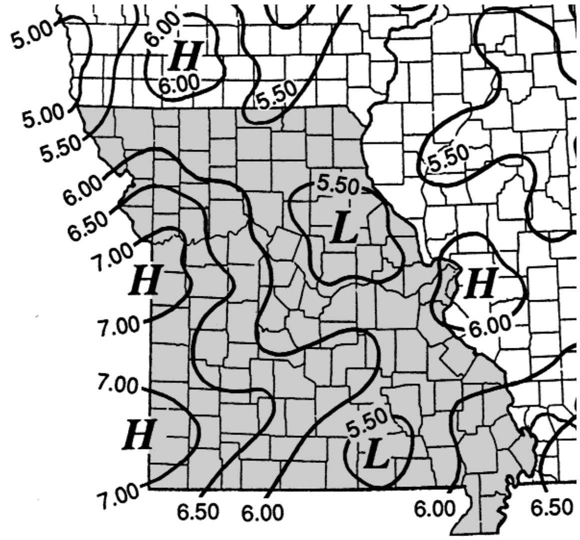

Figure 3. The expected 25-year, 24-hour rainfall in inches.

The storage periods recommended by the MDNR for anaerobic lagoons, runoff ponds and pits are listed in Table 5.

Table 5. Recommended minimum storage periods for design.

Type of storage	Recommended storage period
Lagoons/Runoff ponds	365 days
Liquid manure basin	180 days
Solids	90 days

Example

Calculate the required holding pond volume for 120 head of 1,000-pound beef feeders spending 100 percent of the time on a 220′ x 220′ dirt lot with 1.2 acres draining into the holding pond (based on a rule of thumb for feedlots of 1 acre per 100 head total area) with about 400 ft^2 per head inside the lot). The lot is in Cole County, Missouri, where the mean annual precipitation is 39 inches and the 25-yr, 24-hr rainfall is about 6 inches. The pond must contain the liquid runoff for the wettest year in 10, the solids not settled out in the settling basin, the 25-year, 24-hour rainfall, the rainfall minus evaporation from the pond water surface, and have at least 1 foot of freeboard to allow time to apply the pond contents to the land if the weather is inclement when the pond is to be emptied (1 foot from full). Assume the holding pond is designed as an earthen basin to store 180 days of runoff (the Agricultural Engineering Extension computer program AG0003 can be used for the lagoon and holding pond design).

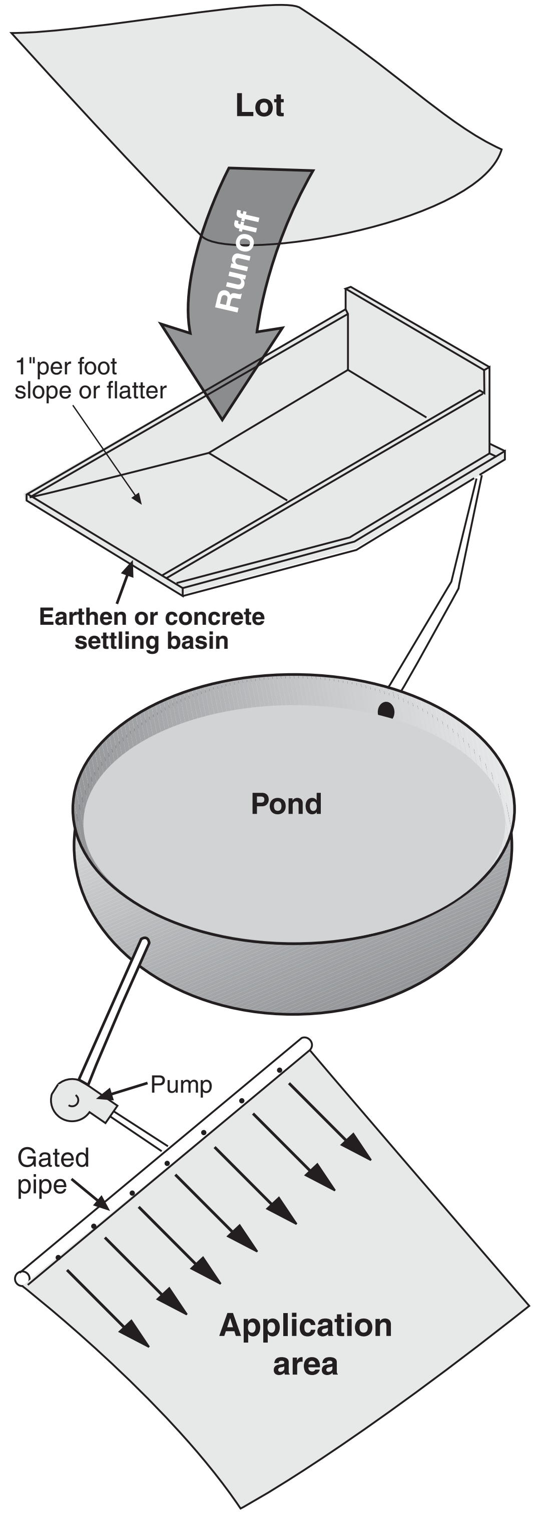

Figure 4. Schematic of an open-lot runoff control/distribution system that uses a pump to convey liquid from the settling basin to the gated-pipe distribution system at the vegetative filter area.

Worksheet to calculate holding pond design volume

1. Normal lot runoff volume for storage period

A. Earth lots

________ acres dirt lot area × 43,560 ft^2/acre × ____*____ feet/year × ____**____ = ________ ft^3

B. Concrete lots

________ ft^2 concrete lot area × ____*____ feet/year × ____**____ = ________ ft^3

* Stormwater runoff from Table 3.

** Runoff factor for 180-day storage from Table 4.

Example: (with dirt lot)

__1.2__ acres dirt lot area × 43,560 ft^2/acre × __2.1 *__ feet/year × __0.6**__ = **__65,863__ ft^3**

2. Solids volume

A. Earth lots

Lot area _______ acres × 2,800 cubic feet/acre-year × ___*___ lot time × ______ days storage ÷ 365 days/yr × ___**___ = ________ ft^3

B. Concrete lots

Total lb animal ______ /1000 lb × ___*___ lot time × 0.0521 × ___***___ lb total solids/day × _______ days storage × ___**___ = ______ ft^3

* Proportion of time cattle spend in open dirt lot (as a decimal).

** Percent of manure solids to storage basin expressed as a decimal fraction, typically assumed to be 50% of the manure produced (the other 50% retained in the settling basin).

*** Total solids per day = 7.7 lb/day for beef cattle and 10.4 lb/day for dairy cattle per 1,000 pounds of animal weight.

Example: (For a 220' × 220' dirt lot)

Dirt lot area 220' × 220'/43,560 ft^2/acre acres × __2,800 *__ × __1.00**__ lot time × __180__ days storage /365 days/yr × __0.50__ not settled out = **__767__ ft^3**

* 2,800 cu ft of solids (manure and silt) per acre per year off open dirt lot.

** Proportion of time cattle spend in open lot.

3. Runoff from the 25-year, 24-hour rainfall event (safety volume)

A. Earth lots

_______ acres dirt lot area × 43,560 ft^2/acre × ___*___ inches ÷ 12 in/ft × __0.8**__ = ________ ft^3

B. Concrete lots

_______ ft^2 concrete lot area × ___*___ inches ÷ 12 in/ft × __1.0 **__ = ______ ft^3

* Inches for the 25-year, 24-hour rainfall event from Figure 3.

** Assumes 80% of rainfall runs off a dirt lot. (Use 100% runoff for concrete lot.)

Example: (For a 420' × 12' concrete slab)

__420 × 12__ ft^2 concrete slab area × __6 *__ inches ÷ 12 in/ft × __1.0 **__ = __2,520__ ft^3

Example: If the open lot surface area contributing to the holding pond is greater than 70% of the pond area, the safety volume depth is computed using the following formula:

$$\text{Safety volume depth} = 0.67 + \frac{\text{square foot lot surface} \times 0.5 \text{ feet}}{\text{square foot pit liquid surface area}}$$

Calculate the safety volume depth for a 1.2-acre area draining into a 150’ × 150’ pit liquid surface area:

$$\text{Safety volume depth} = 0.67 + \frac{1.2 \text{ acres} \times 43{,}560 \text{ ft}^2 \text{ lot surface area} \times 0.5 \text{ feet}}{150' \times 150' \text{ pit liquid surface area}} = \frac{52{,}272 \text{ ft}^2 \text{ area} \times 0.5 \text{ feet}}{22{,}500 \text{ ft}^2} = 1.83 \text{ ft}$$

Calculate the safety volume for the 1.83 ft safety volume depth:

150' × 150' × 1.83' = **41,175 ft^3**

4. Rainfall minus evaporation from holding pond surface

_________ ft^2 water surface area × ___*___ ft × ___**___ = _______ ft^3

* Rainfall minus evaporation from Table 3.

** Rainfall minus evaporation factor from Table 4.

Example: Calculate the rainfall minus evaporation volume for a 150' × 150' water surface area in a 39" rainfall area for a 180-day storage period.

150' × 150' ft^2 water surface area × 1.45 ft × 0.7 = **22,838 ft^3**

5. Runoff from the berm surrounding the 150’ × 150’ water surface

_________ ft^2 berm surface area × ___*___ ft × ___**___ = _______ ft^3

* Stormwater runoff from earth lot areas from Table 3.

** Runoff factor for 180 days storage from Table 4.

Example: Calculate the berm runoff volume for a 150' × 150' water surface area in a 39-inch rainfall area for a 180-day storage period assuming that the berm centerline is 8 feet out from the water surface.

Assuming that the water falling on the water side of the berm centerline runs into the pond basin, the area for the example can be calculated as follows (the berm centerline is a square 166' × 166'):

Area = (166' × 166') − (150' × 150') = 5,056 ft^2

5,056 ft^2 berm surface area × 2.1 * feet/year × 0.6** = **6,370 ft^3**

6. Total volume

Total volume = Sum of 1 + 2 + 3 + 4 + 5

Example: Total the “boldface” volumes from above.

Total volume = 65,863 ft^3 + 767 ft^3 + 41,175 ft^3 + 22,838 ft^3 + 6,370 ft^3 = **137,013 ft^3**

Use this volume to size the holding pond.

7. Final basin (holding pond) dimensions

(Sized to hold 180 days of lot runoff for the wettest year in ten. University of Missouri Extension computer program AG0003 was used to calculate the basin data below.)

Maximum water area = 22,500 ft^2 Depth = 7.5 ft

Water area dimensions = 150 ft × 150 ft

Embankment CL to CL dimensions = 166 ft × 166 ft

Average 180-day pump down volume = 59,897 ft^3 (includes rainfall minus evaporation on storage basin) = 16.5 acre-inches and a maximum annual pump down volume of 159,174 ft^3.

(Have assumed a square basin with 10 ft runoff storage depth, 1 ft freeboard, 1.8 ft safety volume depth, 10 ft embankment top width, 3:1 berm slopes and calculated 2,455 cut yards to construct with 1.20 cut/fill ratio on a 3% slope in one direction and a 2% slope in the other direction.) Depth includes a 2-foot permanent volume in the bottom to keep the clay liner from drying and cracking.

For further information

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EQ 202, *Land Application Considerations for Animal Manure.*

EQ 383, *Land Application Equipment for Livestock and Poultry Manure Management.*

EQ 386, *Settling Basins and Terraces for Cattle Manure.*

EQ 387, *Anaerobic Lagoons for Storage/Treatment of Livestock Manure.*

EQ 388, *Earthen Pits (Basins) for Liquid Livestock Manure.*

G 1157, *Lagoon Pumping and Irrigating Equipment.*

M 115, *Animal Waste Management - Planning and Designing Guidelines.*

Midwest Plan Service Publications

LPES Lesson 42: *Controlling Dust and Odor from Open Lot Livestock Facilities.*

MWPS-6, *Beef Housing and Equipment Handbook.*

MWPS-18, *Livestock Waste Facilities Handbook.*

MWPS-18, Manure Management Systems Series, Section 1, *Manure Characteristics.*

Northeast Regional Agricultural Engineering Service Publications

NRAES-31. Proceedings from the Dairy Waste Management Symposium, Syracuse, New York, February 22-24, 1989.

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