Gutter Flushing Systems for Swine Buildings

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- How Flushing Works
- Who Should Consider Using It
- Advantages and Drawbacks
- Basic Parts of a Flushing System
- Questions and References
- Design and Equipment Worksheet

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In Indiana, most hogs are raised in confinement—either in drylot or enclosed buildings. One of the major management considerations (and problem areas) in confinement rearing is how to best handle the swine waste. Today’s high-intensity production systems, labor cost and availability, plus stiffer pollution control regulations only serve to underscore the need for proper and efficient waste handling.

Present methods of handling manure in the confinement area include: (1) storing as a solid on a slab floor and periodically scraping and hauling to the field, (2) storing in a manure pit underneath a slatted floor and periodically scraping and hauling to the field, and (3) temporarily storing in a manure pit which overflows to a lagoon or holding pond and eventually irrigating onto cropland.

However, a relatively new concept—flushing—has been receiving increased attention among Indiana swine producers. This concept calls for use of a sloped, shallow gutter that is flushed periodically to remove waste from the building to a lagoon. The two types of flushing systems in swine production facilities are: open-gutter flushing which has been used successfully in finishing buildings and open concrete lots, and under-slat flushing which works best in farrowing, nursery and gestation confinement buildings.

This publication is a design and operating manual for gutter flushing systems in hog buildings. Its purpose is three-fold: (1) to explain the concept and how it works, (2) to provide a basis for evaluating its potential to your swine operation, and (3) to help you develop a system tailored to your production program. Worksheets, drawings, design tables and sources of additional information have been provided to guide you in determining your particular flushing system requirements.

A word of advice: Before going too far in contemplating a change in present facilities or construction of new ones to accommodate flushing, check with your Extension animal production agent for waste management information and with a professional engineer or farm building contractor for construction suggestions. Also consider visiting some swine operations where gutter flushing is used, and find out what each operator likes—and doesn’t like—about his system.

HOW DOES GUTTER FLUSHING WORK?

Gutter flushing does more than just wash away manure that happens to collect in the gutter of a confinement building. Periodic flushing actually attracts the hogs to the gutter and induces dunging, essentially “toilet training” them. Basically, here’s how a flushing system operates:

A small-capacity pump transports treated lagoon effluent to the high end of the gutter in the building. There it fills a flush tank, which periodically dumps the water into the gutter. Frequency of flush is determined by the rate at which water is pumped into the tank, and the tank is sized to contain enough water to “scour” wastes from the gutter. The spent flush water then re-enters the lagoon where it is treated and later reused for flushing.

In open-gutter systems, flushing should be done at least every 2 hours, and preferably every hour, to maintain proper dunging habits. Under-slat gutters should be flushed at least three times a day, but preferably every hour. To insure cleaner pens, have hogs sufficiently crowded (4 sq.ft. per cwt. of animal) so that no other dunging habits are started. This is especially important for younger pigs.
Swine usually dung in areas that are damp and drafty and bed where it’s drier and stiller. Pen partitions should be solid except for the area over the gutter, which should be wire-partitioned. This will also aid dunging habits.

WHO SHOULD CONSIDER USING FLUSHING SYSTEMS?

No one waste handling system is “best” for all swine production operations. Therefore, the feasibility of gutter flushing can only be determined by the individual operator accurately assessing his own particular situation. Economic conditions, management skills and preferences, type of operation and location considerations must all enter into the evaluation. The discussion that follows will focus on the latter two considerations.

Type of Operation

The flushing principle of waste handling probably has greatest appeal to those with farrow-to-finish operations who feel they must handle swine waste as a liquid. A feeder pig producer, on the other hand, would probably not find this system as beneficial, since volume of waste to be handled is usually much less than that in a finishing operation. One who buys feeder pigs for finishing to market weight may also have some reservations about open gutter flushing because of the possibility of disease transmission.

Keeping the above in mind—if you are now using bedding and have a plentiful supply, and if you can conveniently handle swine waste as a solid, and if you have no immediate plans for expanding your operation, there is little reason to convert to a gutter flushing system. However, the producer who is planning either to expand or to convert to liquid waste handling should give serious consideration. If expansion calls for converting an old building to hog production, chances are that installing an open gutter or a shallow-flushed under-slat gutter will be less expensive than installing a deep pit and slats.

Location Considerations

Because a lagoon is a necessary component of the flush system, a good lagoon site with low water-table and suitable soil is needed. From the landowner’s standpoint, an area containing poor soil is a good site for a lagoon; whereas fertile, level land is obviously the most expensive location.

For longer, trouble-free performance of pumps and piping as well as protection against disease organisms getting into open gutters, a two-stage lagoon is recommended over a single stage for flushing operations. A clay or silty loam soil is preferred for the second stage, although research indicates that lagoons receiving raw waste seal even in medium and coarse sand within a few months. To prevent pollution of ground water, avoid any site that is underlain by fractured limestone or gravel layers.

ADVANTAGES AND DISADVANTAGES OF GUTTER FLUSHING

Assuming your present or proposed hog operation could accommodate a flushing system, what specifically are its advantages and drawbacks compared to other liquid swine waste handling systems?

Advantages

- **Lowers initial cost.** Open-gutter flushing can reduce building cost by as much as 30 percent over a comparably-sized, fully-slatted deep pit facility. Because there are no slats, pitwalls or pit excavation, the floor consists of only a poured concrete slab. However, since flushing requires a large lagoon, this savings would be reduced to about 10-15 percent (based on an average two-stage lagoon volume of 450 cu. ft. per finishing hog). An under-slat flushing system is probably comparable in cost to a conventional deep pit building.

- **Can reduce odor problems.** Compared to the standard liquid manure pit, a properly designed and managed lagoon can reduce odors both during storage and while spreading or irrigating. If complete odor control is necessary, a floating aerator can be added to the lagoon to make the surface layer of water aerobic. Frequent flushing of the waste can significantly reduce the characteristic “clinging” odor inside the confinement building itself.

- **Requires less frequent waste disposal.** Because anaerobic lagoons, to operate properly, require a relatively large volume of waste, much more manure can be stored before disposal is necessary. In fact, waste spreading can be limited to twice or even once per year.

- **Accommodates waste irrigation.** Irrigation, a low-labor method of waste disposal, is easily adapted to the gutter flushing concept, especially if the waste lagoon is divided into two stages. Waste irrigated from the second stage contains little solid matter, thus permitting use of almost any type of irrigation equipment. It may also be possible to irrigate onto growing crops. (For more information on waste irrigation, see “Related Publications,” page 17.)

- **Adapts to building conversion.** Some older buildings and especially dirt floor poultry buildings can be easily converted to include gutter flushing systems because a deep pit is not required. The reverse is also true; a flushing system building can be more easily converted to other uses than can a slatted-floor deep pit building.

- **Allows construction flexibility.** Since deep pits are not required, the roof of a flushing system building can be put up before the floor is poured. This means that construction is less weather dependent.
Disadvantages

- **Greater nutrient loss.** Animal waste that has been lagoon-treated shows greater nutrient loss than that stored in a liquid manure pit under slatted floor. The “fertilizer value” of animal waste varies depending on storage time and temperature, time and method of application, type of soil at the disposal site, current fertilizer prices, etc. To illustrate the extent of nutrient loss in lagoon-treated swine waste—fresh manure, if injected into the soil, can be worth up to three times more than the same amount of waste treated in a lagoon and then irrigated onto cropland.

For an accurate estimate of the value of wastes, a laboratory test must be made (see Purdue Extension Publication ID-101, “Utilization of Animal Waste as Fertilizer,” listed on page 17). About half of the fertilizer value lost in a lagoon can be saved by placing a settling tank between the building and lagoon.

- **Requires careful management.** The waste treatment lagoon, which is essential to a flushing system, is a living biological system, not a passive storage area. If the bacteria population is properly maintained, the lagoon should be relatively odor free most of the year. If not designed and operated correctly, there will be odor and solids build-up problems.

- **Requires a relatively large land area.** The lagoon designed for a flushing building takes up 4 to 6 times more land area than the building itself. Although cost of this land was taken into account when comparing the economics of a flushing building to a deep-pit slatted-floor building, some producers may still have reservations about using land this way.

- **Interuptions to give medication.** If medication is occasionally added to the drinking water, open gutter flushing systems may have to be turned off for extended periods to force hogs to drink the medicated water, since they can and do drink some of the flushing water.

- **Open gutters not practical for farrowing and nursery buildings.** Open-gutter flushing is not feasible in the farrowing house because the dampness and cooling effect from the flush water might endanger health of the young pigs. Neither is it practical for the nursery building, since the pigs are too young to be trained in proper dunging habits. Under-slat flushing, however, would be a workable alternative in these cases.

- **Subject to mechanical problems.** A flushing system has two mechanical components—flush tank and return pump—that must operate continuously. Like all mechanical devices, they are subject to breakdown. (A standby return pump is suggested to improve reliability of the system.)

- **Possibility of disease transmission.** Although to date there have been no confirmed cases of disease transmitted by flushing systems since being introduced in the early 1960’s, there is still debate among veterinarians and animal scientists concerning this problem. Producers with SPF herds who already have good disease control programs should not expect abnormal disease problems. In fact, the frequent and thorough removal of waste from the building may actually lessen the threat of disease, especially respiratory ailments since there are no strong pit gases. Also remember that lagoons with two stages are several times more effective in destroying disease organisms than single-stage lagoons.

Basic Parts of a Flushing System
—Their Design and Operation

Up to this point, our purpose has been to help you assess the feasibility and practicality of gutter flushing to your particular swine operation. This section will now deal in some detail with the four basic parts of a flushing system—floor and gutter, flush tank, waste treatment lagoon, and circulation pump and pipes. The worksheet on page 18 should help you determine your particular needs in each of these areas.

The design and operation recommendations made are based on the best information presently available. Further research and farmer experience will undoubtedly change some of these recommendations. Therefore, you are cautioned again to check with those who have access to the latest information, such as your Extension agent, before installing a flushing system.

FLOOR AND GUTTER

In farrowing and nursery buildings, the flush gutter should be under fully-slatted floors (Figure 1). In finishing facilities, open-type gutters can be located either along one side of the building, on both sides or in the middle (Figures 2, 3 and 4).

Gutter and Sump Pit Design

Gutter design is extremely important to the system’s success. How completely the waste is removed depends on velocity, depth and duration of the flush; and these factors are determined by the dimensions and slope of the gutter. To adequately clean the gutters, flush velocity must be maintained at 2.0 feet per second or better.
In an open gutter, initial depth of flow should be at least 1½ inches with at least a 10-second flush. (For channels less than 125 feet, a 1-inch depth may be satisfactory with a longer flush duration. For channels longer than 125 feet, a flush volume 50 percent larger than the volume for which channel slope was designed, provides additional cleaning ability.) In an underslat gutter, a 3-inch depth of flow is recommended.

In most cases, the flushing device determines depth of water flow. For instance, a 3-inch siphon will provide only enough water for a 1-inch depth of flow in a 30-inch wide gutter, whereas 4- and 6-inch siphons allow for greater depths and will work in wider gutters. (Most siphons release water to give a flush duration of about 30 seconds.) A “tipping bucket” flush tank can be designed to deliver a 3-inch depth of flow in almost any width gutter with a 5- to 10-second release; while the opening in a “trap door” tank can be designed to provide almost any depth and flush duration.

Depth of flow must be considered in selecting slope of the gutter. To achieve the same cleaning action, a steeper slope is required when depth of flow is shallow. Remodeled facilities can be designed for deeper channels (use 2x6’s as forms) to increase depth of flow (e.g., 3-4 inches), thus permitting shallower slope. This minimizes excavation and construction problems in an existing building.

Tables 1-4 present the recommended slopes for gutters of various lengths, configurations and initial water flow depths.

Various gutter configurations have been used successfully. Most gutters are a constant width—usually 30 or 40 inches (Figure 5). For open gutters, preferred minimum channel width is 40 inches and depth is usually 3½ inches (height of a 2x4 form). Channel depth should be at least 1 inch (preferably 1½ inches) deeper than initial depth of flow.

However, because flush water picks up solids, it tends to slow down as it moves through the gutter. To overcome this, the gutter can be narrowed and/or its slope increased (Figure 6). Research at the University of Missouri showed that, in a 132-foot building, cleaning action was improved when the gutter was narrowed from 6 feet at the upper end to 3 feet at the lower end and slope was varied down the length of the channel, instead of a constant width and slope. Table 4 shows the appropriate slopes to maintain various depths of flow in tapered channels.

For open gutters shorter than 125 feet, a constant-slope gutter will probably suffice. For one over 125 feet, a tapered, variable-slope gutter improves cleaning. For a facility much longer than 150 feet, both ends should be sloped such that it flushes toward the middle.

A sump pit should be located at the discharge (or runoff) end of the flushing gutter. Volume of the sump should at least equal volume of the flush tank at the high end of the gutter. This allows all the water from the flush tank to pass through the gutter and empty without backing up—thus insuring maximum cleaning benefit from the flush.

If waste is pumped from the sump to the lagoon, the sump should have a float switch to stop the recycling of water from the lagoon in case of sump pump malfunction. A sump cover is necessary to keep rats out of the building. If gravity is used to carry waste to the lagoon, the tile line from sump to lagoon should be at least 8 inches in diameter and have at least a ½ percent slope.

**Floor and Building Construction**

Construction of a swine building to accommodate gutter flushing is rather straightforward. First, the approximate grade for the building floor is established. (Simply average the gutter slopes if a variable-slope gutter is to be used.) Next comes placement of the footings. Using an engineer’s level, exact grade of the gutter is then established along the length of the building. It is simplest and cheapest to slope the entire building the same as the gutter slope (Figure 7). However, if constant ceiling height is desired, the foundation can be poured level at the sill, but with various depths as required by the sloping floor.

With pole-type construction, the poles can be set, truss locations marked and then the girders put in place. If the entire building is set at the gutter slope, the sidewalks are not perpendicular to the poles; however, this should not pose any significant problems since floor slope is not very great.
Figure 2. Cross-section of building with open flushing gutter on one side.

Figure 3. Cross-section of building with open flushing gutters on both sides.

Figure 4. Cross-section of building with open flushing gutters in the middle. Probably more applicable to remodeled buildings where construction restricted and floor space less expensive than in a new building.
### Table 1. Minimum percent slope for constant width, constant slope under-slat gutter.*

<table>
<thead>
<tr>
<th>Initial depth of flow</th>
<th>Gutter width 10 in.</th>
<th>20 in.</th>
<th>30 in.</th>
<th>40 in.</th>
<th>50 in.</th>
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<th>80 in.</th>
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<th>100 in.</th>
<th>110 in.</th>
<th>120 in.</th>
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<td>3.5</td>
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*Gutter configurations not shown are not usually recommended; consult a competent agricultural engineer for these special cases. The data here assume that velocity = 2 fps and Manning's n = 0.025, unless otherwise noted.

**Recommended depth.

### Table 2. Minimum percent slope for constant width, constant slope open gutter (flushed at least every 120 minutes).*

<table>
<thead>
<tr>
<th>Initial depth of flow</th>
<th>Gutter width 10 in.</th>
<th>20 in.</th>
<th>30 in.</th>
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<td>1.5**</td>
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*See Table 1 footnote.

**Recommended depth.

### Table 3. Minimum percent slope for constant width, constant slope open gutter (flushed only 2-3 times a day or in remodeled building where slope is restricted).*

<table>
<thead>
<tr>
<th>Initial depth of flow</th>
<th>Gutter width 10 in.</th>
<th>20 in.</th>
<th>30 in.</th>
<th>40 in.</th>
<th>50 in.</th>
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*See Table 1 footnote.

### Table 4. Minimum percent slope for tapered open gutter (5' width to 3' width).*

<table>
<thead>
<tr>
<th>Initial depth of flow</th>
<th>Final depth of flow</th>
<th>Percent of gutter length</th>
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<tbody>
<tr>
<td>in.</td>
<td>in.</td>
<td>0-25% (n = 0.0175)</td>
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<td>1.7</td>
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<tr>
<td>1.5**</td>
<td>2.5</td>
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<tr>
<td>2.0</td>
<td>3.3</td>
<td>0.75</td>
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</table>

*See Table 1 footnote.

**Recommended depth.
After girders, trusses and roof are in place, the floor can be formed and poured in any weather. Again, use an engineer's level to place the forms for the gutter floor to insure proper slope.

Form and pour the entire length of gutter first. Then pour the aisleway and floor slab in sections at the same slope as the gutter. (In a variable-slope, open-gutter building, it is usually easiest to change lengthwise slope of the entire floor when slope of the gutter changes.) Slope the floor laterally toward the gutter at a slope of 1/3 inch per foot (Figure 2). For guidance in construction of a gutter building with a horizontal roof line, see Purdue Farm Building Plan Service Plan No. 72682, referenced at the end of this publication.

The floor slab and slats in an under-slat gutter building may either be level or have the same slope as the gutter. If slats are to be level, pour the pit sidewalls first, then place fill along the gutter bottom to grade and finally pour the gutter floor, using the sidewalls as the form. If the slats are to slope with the gutter, form and pour the gutter floor first, then the pit sidewalls. (See MSU Extension Bulletin E-777, referenced on page 17, for more information on pouring under-slat gutters.)

Two important construction features that influence animal behavior and, thus, success of a flushing system are: pen configuration and type and arrangement of partitions. Pen length (as measured across width of the building) should be less than three times the width (as measured along gutter length), with a minimum of 1 square foot open gutter per pig with hourly flushing. It has also been found that hogs will tend to defecate in the gutter if solid partitions separate pens at the feeding and loafing area but open partitions, (e.g., welded wire panels) are used at the gutter area (Figure 2). When partitions are either entirely solid or entirely open, random dunging is more likely to occur.

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*Figure 5. Floor plan of finishing building with constant width open gutter.*

*Figure 6. Floor plan of finishing building with variable width open gutter.*

*Figure 7. Side view of finishing building sloped same percent as the flushing gutter.*
FLUSHING METHODS AND FLUSH TANKS

There are essentially two approaches to transporting manure down the gutter and out of the building. One is to provide a constant flow of water down the gutter. The second is to periodically release a large amount of water to completely “scour” the gutter.

Constant-Flow Flushing

The constant-flow method has been used with some degree of success in open-gutter buildings for a number of years. However, it is not recommended for gutters flushed under slats. Although the constant-flow approach eliminates need for a flush tank, there are some rather important drawbacks to consider.

- Since gutters cannot be kept as clean, potential for odor in the building is increased as is the humidity.
- Because wastewater is constantly in the gutter, the hogs themselves may not stay as clean, particularly if they lie in the gutter then track manure into the loafing area.
- Continuous flow also requires greater quantities of water, which means larger capacity pumps and conduits, thus higher power costs. (Pump and capacity can be approximated by multiplying gutter width in inches by 2 to determine gallons per minute. This type of gutter should be laid on a slope of about 1.5 percent.)

For a constant-flow system to operate successfully, there should be hogs in each pen to agitate the manure and keep it moving along the gutter. If any pen is empty, settling may occur in the gutter area of that pen. Therefore, it is important that either all pens be full or the empty ones be at the inlet end of the building.

Periodic Flushing

This method of flushing has several advantages over constant flow, but its design and operation is somewhat more complicated. How often to flush, if one uses the periodic flushing method, is determined by two factors—animal behavior characteristics and the solids carrying capacity of the water.

- As to animal behavior, experience to date indicates that young hogs tend to lose the “toilet training” characteristics if flushes are more than 2 hours apart; whereas, a 1-hour flushing interval works extremely well. In addition, the diversion provided by more frequent flushing may help decrease boredom and, therefore, reduce tailbiting and cannibalism.

In the summer there is a tendency for the hogs to occasionally lie in the gutter and block the flow of water, but this does not seem to affect the efficiency of the flushing operation.

- Concerning solids carrying capacity, the smaller the volume of water per flush, the more frequent the flushes should be. When too little water must pick up too much waste, the fluid characteristics change greatly and a dirty gutter will result. If for some reason flushes must be less frequent, then the volume of water must be increased.

In cases where the interval might be as great as 12 hours (such as in a gestation house where tanks are dumped manually after checking for sows in labor), the flush tank should be designed to overflow continuously. This small constant flow down the gutter will help keep the manure in a partially liquefied state and easier to pick up and transport when the gutter is flushed.

Flush Tanks

Total volume of flush water required per day for adequate cleaning is about 15 gallons per finishing pig (100 gallons per 1000 pounds liveweight). The required volume per flush, depending on gutter width and desired depth of flow, is shown in Table 5 or can be calculated as follows:

\[
\text{Flush volume (gallons)} = 1.67 \times \text{gutter width (inches)} \times \text{depth of flow (inches)}.
\]

Three types of flush tanks have been developed to provide the required flush volumes—(1) the automatic siphon tank, (2) the tipping bucket and (3) the trap door tank.

<table>
<thead>
<tr>
<th>Initial depth of flow</th>
<th>10 in.</th>
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<th>Gutter width</th>
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<td>gals. water</td>
</tr>
<tr>
<td>1.0</td>
<td>20</td>
<td>35</td>
<td>50</td>
<td>65</td>
<td>85</td>
<td>100</td>
<td>115</td>
<td>135</td>
<td>150</td>
<td>165</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>100</td>
<td>125</td>
<td>150</td>
<td>175</td>
<td>200</td>
<td>225</td>
<td>250</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>35</td>
<td>65</td>
<td>100</td>
<td>135</td>
<td>165</td>
<td>200</td>
<td>235</td>
<td>265</td>
<td>300</td>
<td>355</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>45</td>
<td>85</td>
<td>125</td>
<td>165</td>
<td>210</td>
<td>250</td>
<td>290</td>
<td>330</td>
<td>375</td>
<td>415</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
<td>350</td>
<td>400</td>
<td>450</td>
<td>500</td>
<td>550</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>60</td>
<td>120</td>
<td>175</td>
<td>235</td>
<td>300</td>
<td>350</td>
<td>410</td>
<td>470</td>
<td>530</td>
<td>590</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>70</td>
<td>135</td>
<td>200</td>
<td>265</td>
<td>335</td>
<td>400</td>
<td>470</td>
<td>535</td>
<td>600</td>
<td>670</td>
<td>800</td>
<td></td>
</tr>
</tbody>
</table>
**Automatic siphon tank.** Designed and in use at Iowa State University since 1969, this type of tank has the singular advantage of no moving parts (Figure 8). As the tank slowly fills with water, an air bubble trapped under the bell is forced through a siphon trap until it triggers the siphoning action. An automatic siphon tank can be placed above the pens, thus eliminating floor space requirements.

Siphon devices are available commercially at prices ranging from $250 to over $800, or they can be constructed using a stock watering tank.* Pipe size depends on the necessary discharge opening area (from Table 6). Multiple pipes can also be used, if put under the same bell, to increase the discharge rate. To keep from having to use impractically large siphon pipes, it may be necessary to plan on a narrower gutter and a shallower depth of flow. For adequate cleaning, design tank discharge for those conditions, then double tank volume to obtain a longer flush duration.

**Tipping bucket tank.** Figure 9 shows a tipping bucket, which dumps when it fills to the place where the center of gravity of the water volume overbalances the pivot point. Because the water discharges all at once, flushing velocity is high and can cover a wide gutter, if necessary. This type of flush tank has been successfully used for under-slat flushing at Michigan State University. (For details, see MSU Extension Bulletin E-777, listed on page 17.)

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*For a list of known siphon tank manufacturers, contact the authors of this publication. Several patents have been obtained concerning design of the automatic siphon tank; contact the Agricultural Engineering Department, Iowa State University, Ames, Iowa, for construction details.

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**Figure 8.** Design of a typical automatic siphon flush tank, with construction detail of siphon bell housing 3- or 4-inch diameter pipe.

**Figure 9.** Design of a tipping bucket flush tank (left), and dimensions for a 150-gallon tank (right).
One problem with conventional-designed tipping buckets is that they are subject to mechanical failure, unless "cushioned" by bumpers both when dumping and when returning empty. However, agricultural engineers at Kansas State University have now developed a modified tank with a pivot point located such that it empties and rights itself without use of bumpers (Figure 10).

**Trap door tank.** A University of Missouri innovation, this flush tank has more moving parts than either of the above, but allows greater design flexibility because both tank and trap door can be modified to meet individual circumstances (Figure 11). Table 7 gives proper door size for flush volume needed.

The trap door is held shut by a latch mechanism at the rear of the tank which holds the counterbalance arm in the down position. The door is activated by a float connected to a lever which trips the latch. Weight of the water then pivots the door open and, at the same time, raises the counterbalance arm. After discharge, the counterbalance arm forces the door closed and falls with enough force to latch it again. Proper seal around the door is important. The practical limit on depth of the tank is 4 feet; otherwise it is too hard to get a good seal around the tank door due to water pressure.

### Table 6. Suggested diameters of automatic siphon tank discharge pipes for various width gutters (to provide 1-2 inch depth-of-flow).

<table>
<thead>
<tr>
<th>Initial gutter width</th>
<th>Siphon pipe diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 in.</td>
<td>3 in. adequate, 4 in. recommended</td>
</tr>
<tr>
<td>30 in.</td>
<td>3 in. adequate, 4 in. recommended</td>
</tr>
<tr>
<td>40 in.</td>
<td>4 in. adequate, 6 in. recommended</td>
</tr>
<tr>
<td>50 in.</td>
<td>6 in. adequate, 8 in. recommended</td>
</tr>
</tbody>
</table>

### Table 7. Suggested discharge opening areas for various capacity trap door tanks.*

<table>
<thead>
<tr>
<th>Flush volume</th>
<th>Door opening area</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 gals.</td>
<td>20 sq. in.</td>
</tr>
<tr>
<td>100 gals.</td>
<td>40 sq. in.</td>
</tr>
<tr>
<td>150 gals.</td>
<td>60 sq. in.</td>
</tr>
<tr>
<td>200 gals.</td>
<td>80 sq. in.</td>
</tr>
<tr>
<td>250 gals.</td>
<td>100 sq. in.</td>
</tr>
<tr>
<td>300 gals.</td>
<td>125 sq. in.</td>
</tr>
<tr>
<td>400 gals.</td>
<td>165 sq. in.</td>
</tr>
<tr>
<td>500 gals.</td>
<td>215 sq. in.</td>
</tr>
</tbody>
</table>

* Rough approximation from the equation, opening (sq. in.) = volume (gals.) x 0.4. Actual relationship between opening size, tank volume and tank height is:

a = 0.735 \( \frac{V}{\sqrt{h}} \)

where:
- a = opening size (sq. in.)
- V = tank volume (gals.)
- h = water depth in tank (ft.)

Figure 10. Dimensions of the modified Kansas State University tipping bucket tank. (For details, write Pat Murphy, Agricultural Engineering Department, Kansas State University, Manhattan, Kansas 66506.)

Figure 11. Perspective view of a modified University of Missouri trap door flush tank.
WASTE TREATMENT LAGOONS

A properly designed and operated lagoon is essential to the success of a flushing system. The design criteria for lagoons used with flushing systems are the same as for conventional swine waste lagoons. Under no circumstances may the contents of these lagoons be discharged into streams, open ditches or field tile.

Type of Lagoon

Although a single-stage lagoon may operate satisfactorily in a flushing system, a two-stage lagoon is preferred for a number of reasons.

1. The primary stage stays at a constant volume, minimizing odor generation.

2. Overflow to the second stage is relatively free of solid matter. Since this is the water recycled for flushing, the pump used for conveying it back to the flush tank can be of simpler design and will operate more reliably.

3. Threat of disease transmission in open gutters is minimized since two-stage lagoons are several times more effective in destroying pathogenic bacteria.

4. The recycled water is less corrosive and has less odor since two stages provides better treatment than a single stage.

Design of the Lagoon

A two-stage lagoon system should hold a total of 2 cubic feet of waste water per pound of live animal weight. Total volume of the first stage should be 1.25 cubic feet per pound of swine, while total volume of the second stage should be 0.75 cubic feet. This 0.75 cubic foot required capacity for the second stage includes: (1) a minimum design volume of 0.35 cubic feet to provide treatment for incoming waste, (2) a storage volume of 0.2 cubic feet to hold the waste produced over a 6-month period, and (3) a dilution volume of 0.2 cubic feet. Figure 12 shows the proper design volumes of a two-stage lagoon system. Tables 8 and 9 can then be used to determine the lagoon dimensions that fit your needs.

The single-stage lagoon must have a minimum design volume of 1.33 cubic feet per pound of swine. In addition, 0.2 cubic foot of manure will be produced in 6 months for each pound of swine, and 0.2 cubic foot of dilution water should be added for each pound of hog, making total volume about 1½ cubic feet per pound of swine. Figure 13 illustrates the volume needs of a one-stage lagoon. Again, use Tables 8 and 9 to determine the dimensions of such a lagoon on your farm.

The design volume of both single-stage and two-stage lagoon systems can be reduced if a settling basin or tank is constructed to receive the waste.

![Figure 12. A properly-designed two-stage anaerobic lagoon for treating swine waste. (Values used assume twice-a-year pumping.)](image)

![Figure 13. A properly-designed single-stage anaerobic lagoon for treating waste. (Values used assume twice-a-year pumping.)](image)
Table 8. Total lagoon volumes required per pound of live animal weight loading the lagoon.

<table>
<thead>
<tr>
<th>Type of lagoon</th>
<th>Once-a-year dewatering</th>
<th>Twice-a-year dewatering</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cu. ft./lb. liveweight</td>
<td></td>
</tr>
<tr>
<td>Two-stage lagoon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First stage</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Second stage</td>
<td>1.15</td>
<td>0.75</td>
</tr>
<tr>
<td>One-stage lagoon</td>
<td>2.15</td>
<td>1.75</td>
</tr>
</tbody>
</table>

from the flushing gutters. (Design information about settling units is available from the authors.) However, if located in an area where hog odors may cause a problem, increase dilution volume in the one-stage lagoon or second stage of a two-stage lagoon by an additional 0.2 cubic foot per pound of swine (see worksheet on page 18).

A below-surface lagoon inlet works best for flushing systems because it will not freeze shut in winter.

**Location of the Lagoon**

If possible, a lagoon should be located well back from any roads, downwind and at least ½ mile from dwellings, at least 100 feet from water wells or water

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Table 9. Holding capacities of various size earthen waste storage structures.

<table>
<thead>
<tr>
<th>Side slopes*</th>
<th>Depth</th>
<th>Length of side</th>
<th>Capacity of Square Storage</th>
<th>Volume of 10-Foot Length of Earth Storages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft.</td>
<td>40 ft.</td>
<td>60 ft.</td>
<td>80 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Refer to the ratio of horizontal distance to vertical rise or fall. For example, a 2:1 side slope is 1 ft. rise or fall in each 2-ft. horizontal.

To add 1-ft. depth for freeboard, add 2½ ft. more of bank on each side. 1 ft. freeboard x (2½ ft. horizontal + 1 ft. vertical). This means 5 ft. additional length and 5 ft. additional width for each 1 ft. freeboard.
courses, preferably in or around trees or woods, and on a non-tillable site. Shallow soils with fractured limestone less than 10 feet below the lagoon bottom should not be used because of the danger of ground water pollution. In an area of gravel or sand, it may be necessary to line the lagoon with a soil sealant, a plastic liner or raw manure. In most cases, raw manure will seal the soil effectively.

Ground water table is also a factor in selecting a lagoon site. Even if it were not a problem after the lagoon had been constructed, level of the water table can determine whether the lagoon is built at all. High water tables can increase construction costs, decrease effective storage due to ground water infiltration, and require more surface area and shallower depth, which will take more land out of production.

If the swine building is at an elevation higher than the lagoon, flushed water can be gravity-fed from the sump to the primary lagoon, with overflow to the second stage then pumped back to the flush tank. If building is below the lagoon, the flushing water can be pumped from sump to primary lagoon, overflowing to the second stage then flowing by gravity back to the flush tank for recirculation. The gravity-flow concept from building to lagoon is preferred, since a larger, more expensive pump is required to handle water containing manure solids than to pump lagoon water back to the building.

On land having no slope, consider the cut-and-fill approach illustrated in Figure 14. Here, the dirt excavated from the lagoon is mound and used as the building site. Not only is the effective volume of the lagoon increased, but gravity flow from building to lagoon is insured. Of course, the lagoon "cut" must be material that can be adequately compacted before a building is constructed. Also remember that construction of the building may have to be delayed for several months so the fill can settle and compact to insure a firm foundation.

Before Constructing a Lagoon

Several things must be considered when constructing a lagoon. If the number of hogs on the farm will exceed 600 at any one time, construction approval must be obtained from the Indiana State Board of Health (see Purdue Extension Publication ID-89, "Steps in Complying with the Indiana Confined Feeding Control Law", listed on page 17. Approval requires soil boring data at the lagoon site.

If Agricultural Stabilization and Conservation Service (ASCS) cost-sharing is involved, the Soil Conservation Service (SCS) must be consulted. Even when size of operation or cost-sharing is not a factor, SCS will provide assistance, if requested.

Operation of the Lagoon

Starting up a two-stage lagoon system. On most farms, the flush system must be started with fresh water from a well. If well supply is limited, the flushed water (and waste) should be routed to the second-stage lagoon first. Fresh well water should be used until this second stage is full and overflowing to the first-stage lagoon, a period of approximately 3-4 months. The fresh water supply can then be shut off and the recirculation system started—i.e., pumping the water from second-stage lagoon to flush tanks. During this time, the second-stage lagoon will continue to overflow to the first stage. After about 6-8 months of operation, this first stage should be nearly half full. At that point, waste from the building should then be routed to the first stage lagoon and normal operation began.

If surface water can be diverted into the lagoon, well water may not be needed to get the flush system started. Still, it is a good idea to route the waste water to the second stage for the first 6 months or until second-stage overflow has filled the first stage lagoon at least half way. This will insure an adequate supply of water for the flushing system from the second stage lagoon, and may give needed extra bottom sealing in the lagoons by addition of raw waste to both stages.

Starting up a single-stage lagoon. For a single-stage lagoon, dilution water from either surface drainage or wells should be diverted into the lagoon until approximately half full. The flushing water can then be recirculated from lagoon to flush tanks.

Dilution water. Properly operating lagoons must have dilution water added. And one of the best sources is surface runoff. At least 130 square feet should be diverted to the lagoon per 1,000 pounds of liveweight capacity in the buildings to insure the required 0.2-cubic-feet-per-pound dilution volume. Part of this drainage area can be obtained by diverting roof gutters to the flush channel. If drainage area cannot be diverted, another source of dilution water must be found. As a rule of thumb, 7.5 gallons of well water every 6 months substitutes for each square foot of drainage area.

Figure 14. Cut-and-fill construction for a two-stage swine waste lagoon system.
Pumping waste from the lagoon. Small irrigation pumps can be used to pump the waste from the lagoon to adjacent farmland. This should be done twice a year. Pump only to the minimum design volumes shown in Figures 12 and 13.

PUMPS ANDPIPES

Pumps are used to transport effluent either from the lagoon to the flush tank or from the sump at the end of the gutter to the lagoon. If the lagoon is located some distance from the building, pumps may be required for both jobs.

Lagoon-to-Flush-Tank Pump

The pump used to fill the flush tank is generally very small. For example, a 10-gallon-per-minute pump is sufficient for two 300-gallon tanks that are flushed every hour. The worksheet on page 18 can be used to calculate the size of pump you need.

Types. Two types of pumps can be used for returning lagoon water to the building—centrifugal and rubber impeller or rubber roller types. A self-priming centrifugal pump with semi-enclosed or enclosed impellers works well for pumping from a swine waste lagoon. Where possible, semi-enclosed impellers are preferred since they won’t clog as readily. Although the flow in a centrifugal pump can be valved down to control flush interval, avoid using valves if possible, since they tend to collect hair at the fitting and can plug. Select a motor large enough to drive the pump at its recommended revolutions per minute (rpm). Slower-speed pumps (1725 rpm or less) cost more initially but last much longer than high-speed pumps (3450 rpm or more).

A rubber impeller or roller pump is capable of higher pressure than a small centrifugal pump, because it is a positive-displacement type. Service life can be extended by using a larger capacity pump than required, then selecting pulleys so it operates at slower speed. The rubber impeller pump must not be operated dry. One disadvantage of this type of pump is the frequent service required when operated continuously. If needed, use a valve bypass from the outlet end of the pump back to the sump to control pumping rate, since a positive-displacement pump should not be valved down.

Regardless of the pump used, a plastic fitted, non-clogging type of pump with high quality seals that can be easily serviced is recommended. Because of their seemingly short service life, it’s a good idea to keep on hand several spare replacement seals and impellers and a replacement motor. Cost of pump plus motor should be less than $200 (1975 prices) for a 20-gallons-per-minute (gpm) unit.*

*In their experimental work, the agricultural engineers at Iowa State and Purdue Universities have used successfully the 20-gpm capacity Jabsco Model #14540-0001 flexible impeller pumps, operated at 1725 rpm by a ½ hp motor. Since there are several recycle pumps adequate for lagoon-to-flush-tank purposes, this is not an endorsement of a particular brand.

Do not use pumps with either metal impellers or any metal parts in contact with the water being pumped. The salts in lagoon water will precipitate on the metal and eventually plug the pump.

Location. A lagoon-to-flush-tank pump can be placed on the lagoon bank in an insulated enclosure or in a wet well sunk in the bank. The pump must be protected from freezing weather at all times. A submersible pump can also be used.

The wet-well approach with all piping below frost line is usually the best method (Figure 15). If the pump is located in the dry well, the well should be large enough for a man to work in (at least 3½ feet in diameter), and there should be some means of shutting off inlet water flow to facilitate pump repair.

The intake pipe from lagoon to wet well should be at least 1 inch greater in diameter than the outlet on the return pump. It should be suspended about 18 inches below the lagoon surface, with inlet opening at least 20 feet from the bank and as far away as practical from where the waste enters the lagoon.

Figure 15. Diagrams of wet well and combination dry well-wet well installation used for swine waste systems at Iowa State University and Purdue University.
lagoon. (Flexible pipe suspended from a float anchored to the lagoon bank is suggested.) Either the intake pipe from lagoon to wet well should be covered with ¼-inch mesh nylon, or galvanized metal screen or such screening should be used in the wet well.

Use a flow switch to stop the pump if the inlet becomes plugged. Vacuum switches are also available to shut off the pump should the wet well be pumped dry; but flow switches are better, since they also shut off the pump if the pump inlet becomes plugged.

Sump-to-Lagoon Pump

If a pump is needed to lift the effluent from building to lagoon, it should be a commercial-grade sewage lift type activated with a float switch (Figure 16). A mercury switch enclosed in a rubberized float is very dependable and can usually be purchased for less than $40 (1975 prices) for most sump pumps. Some pumps come equipped with a diaphragm pressure switch built into the pump body which has the same function as a float switch.

Although a 2-inch pump might be satisfactory, a 3-inch pump will probably give more trouble-free operation. Size of the line from pump to lagoon should be the same as the pump discharge to prevent solids from settling in the pipe. The pump should be able to handle 1½-inch diameter solids and be sized to empty the sump in a minimum of 5-10 minutes to prevent excess solids from settling to the bottom.

Most sump pumps are open-impeller trash types and thus have limited lifting ability. For instance, a 3-inch sump pump operating at 1725 rpm can pump 200 gpm at 20 feet of head, 100 gpm at 30 feet of head and 20 gpm at 50 feet of head. Therefore, lift should be limited to about 20 feet. In addition to the difference in elevation between sump and lagoon, the friction loss in a 3-inch line will add about 8 feet of head for every 100 feet of pipe.

Also, when a sump pump is used, it's important to provide a separate liquid level shut-off switch to shut off the pump that fills the flush tank in case the sump pump fails. This prevents overflow or flush water backing up into the building.

Pipes

The pipe from lagoon to flush tank can be relatively inexpensive polyethylene and, if possible, should be one continuous piece. Its diameter depends upon flow rate, the length of pipe, and the height the water must be lifted. See the worksheet and Table 10 for determining the size you will need.

<table>
<thead>
<tr>
<th>Table 10. Pipe size and friction head loss for 160# plastic pipe at various flow rates.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump capacity</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>gals./min.</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
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<td>15</td>
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<td>20</td>
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<td>80</td>
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<tr>
<td>100</td>
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<tr>
<td>125</td>
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<tr>
<td>150</td>
</tr>
<tr>
<td>175</td>
</tr>
<tr>
<td>200</td>
</tr>
</tbody>
</table>

*Pipe sizes other than these for the given flow rates are not recommended. If smaller sizes are used, flow velocities will be too high and water hammer can loosen joints and break pipes. Pipe sizes larger than recommended here result in flow velocities too low and solids may settle out.
QUESTIONS FREQUENTLY ASKED ABOUT GUTTER FLUSHING

1. Will hogs lie in an open gutter, and does this hamper cleaning ability? Yes, hogs will lie in the gutter during hot weather; however, this does not materially reduce cleaning ability. If it should become a problem, two possible solutions are: (a) to flush more often, or (b) to install a sprinkler system over the edge of the gutter.

2. Isn’t pumping all that water day and night expensive? Not really! For a 2000-head hog building, a 20-gpm pump would supply all the water necessary. A ½ hp motor could supply that water at a 10-foot head. Cost of running the motor year-round is approximately $50 or, if the building is fully utilized, about 1 cent per hog marketed.

3. Doesn’t all that flushing water add greatly to the humidity during the winter? There has been no evidence of excess humidity in the flush buildings constructed to date. Greatest cause of excess humidity is when the hogs lie in the manure thus wetting their body surface; their body heat then evaporates this moisture. With a flushed gutter, the wastes are placed in the gutter and periodically removed from the building.

4. If block or poured walls are used instead of poles, should the roof line follow the gutter slope? Not necessarily. Construction may be easier if the roof is stepped in one or two places thus allowing the roof line to remain level.

5. What about disease transmission in a feeder pig operation? A closed herd, good management and an adequate disease control program should reduce the possibility of a major disease outbreak. On the other hand, regularly introducing new hogs to the building without a disease control program is asking for trouble, regardless of the waste handling system.

6. What about loss of fertilizer nutrient value with this method of waste handling? Between 60 and 80 percent of the nitrogen in swine manure can be lost in a lagoon system. It is possible, however, to place a settling unit between flush gutter and lagoon to recover much of the fertilizer in a concentrated form. A settling unit has the added benefit of allowing the use of a smaller lagoon treatment system. (Consult the authors for design details.)

7. Is an automatic flush tank always necessary in a building where periodic flushing is used? All tanks discussed here have been set to flush automatically. But many times it is practical to use manually flushed tanks in buildings flushed only 2-3 times a day. These tanks can be constructed from locally available materials. One such apparatus simply uses a stock watering tank and 4-inch sewer pipe with bathroom stool plunger for the tank seal. Consult the authors for construction details.

RELATED PUBLICATIONS

Under-Slat Flushing

"Flushing" (Ext. Bul. E-777). E. C. Miller and C. M. Hanson, Agricultural Engineering Department, Michigan State University, East Lansing, Michigan 48824.

Open-Gutter Flushing

"Design of Gutter Flushing Systems for Swine" (ASAE Paper 73-4569). R. George and C. E. Browning, Agricultural Engineering Department, University of Missouri, Columbia, Missouri 65201.

"Proceedings of the 1973 Livestock Waste Management Conference". Agricultural Engineering Department, University of Illinois, Urbana, Illinois 51801 (Cost: approx. $3.00).

"Livestock Waste Facilities Handbook" (MWPS-18). Available from Agricultural Engineering Departments of 12 North Central Regional Land-Grant Universities or from Midwest Plan Service, Iowa State University, Ames, Iowa 50010 (Cost: $2.00).

"Selecting a Swine Waste Management System" (ID-107). Cooperative Extension Service Mailing Room, AGAD Building, Purdue University, West Lafayette, Indiana 47907.

Plans

"Finishing House Gutter Flushing for Hogs—Sloped Building Roofline and Variable Slope, Variable Width Open Gutter" (Plan No. P72681). Farm Building Plan Service, Agricultural Engineering Building, Purdue University, West Lafayette, Indiana 47907 (Cost: $1.00).

"Curtain-Sided Finishing House—Level Building Roofline and Constant Slope, Constant Width Open Gutter" (Plan No. 72682). Farm Building Plan Service, Agricultural Engineering Building, Purdue University, West Lafayette, Indiana 47907 (Cost: $2.00).

Fertilizer Value


Legal Aspects

"Steps in Complying with the Indiana Confined Feeding Control Law" (ID-89). Cooperative Extension Service Mailing Room, AGAD Building, Purdue University, West Lafayette, Indiana 47907.

Irrigation Waste

"Irrigation for Land Application of Animal Waste" (ID-88). Cooperative Extension Service Mailing Room, AGAD Building, Purdue University, West Lafayette, Indiana 47907.
WORKSHEET FOR DESIGNING AND EQUIPPING
A GUTTER FLUSHING SYSTEM FOR SWINE

Example Situation
Farmer A wants to construct a new 600-head hog finishing unit to accommodate open gutter
flushing. The building will be 145 feet long with a constant-width gutter on each side. The waste will
be flushed to a two-stage lagoon. The surface of the second stage will be at the same elevation as
the top of the flush tanks when the lagoon is full and 6 feet below the top of the flush tanks at its lowest
level. This means the waste must be pumped from sump pit to lagoon, and the recycled water
pumped from lagoon to flush tanks. The pump station at the lagoon will be 320 feet from the tanks.
An offset center aisle will divide the finishing building into 12-foot pens on one side and 18-footers
on the other, with pigs started in the smaller pens and moved across the aisle as they grow. To hold
20-22 animals, each pen will be 10 feet wide.

From the above assumptions and the information given in this publication, help Farmer A design
his open-gutter system and determine the types and sizes of flushing equipment needed.

<table>
<thead>
<tr>
<th>Calculations</th>
<th>Our example</th>
<th>Your situation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Determine dimensions of gutters</strong></td>
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<tr>
<td>a. <strong>Gutter width</strong>: Recommended gutter area/hog (1 sq. ft.) x no. hogs/pen (22) ÷ pen width (10 ft.). (This is a minimum; to insure better cleaning, Farmer A decides on a 40-in. width.)</td>
<td>(Min.-27 in.)</td>
<td>40-in.</td>
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<tr>
<td>b. <strong>Initial depth of flow</strong>: Your preference; see appropriate Tables 1-4 (example uses Table 2).</td>
<td></td>
<td>1.5 in.</td>
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<tr>
<td>c. <strong>Gutter slope</strong>: From appropriate Tables 1-4 (example uses Table 2).</td>
<td></td>
<td>2 pct.</td>
</tr>
<tr>
<td><strong>2. Determine flush tank capacity and channel depth</strong></td>
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<tr>
<td>a. <strong>Flush volume for 2-hr. flush interval</strong>: From Table 5 (100 gals.). If channel longer than 125 ft., increase volume by 50 pct.</td>
<td></td>
<td>150 gals.</td>
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<tr>
<td>b. <strong>Flush volume for longer flush intervals</strong>: If time between flushes must be longer than 2 hrs., size tank accordingly — e.g., if tank can be flushed only twice a day, tank capacity should be half daily total flush volume (Step 4 a).</td>
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<tr>
<td>c. <strong>Gutter depth</strong>: Again using Table 5, find actual depth of flow based on flush volume in Step 2 a or 2 b (150 gals.). Gutter depth should be at least 1 in. deeper than actual depth of flow. (If required gutter depth is too deep, select a shallower initial depth of flow in Step 1 b and redesign channel accordingly.)</td>
<td></td>
<td>3.5 in.</td>
</tr>
<tr>
<td><strong>3. Determine size of flush tank discharge opening</strong></td>
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<tr>
<td>a. <strong>For automatic siphon tank</strong>: See Table 6 for siphon discharge pipe diameter (40-in. gutter).</td>
<td>6-in. pipe</td>
<td></td>
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<tr>
<td>b. <strong>For trap door tank</strong>: See Table 7 (150-gal. flush volume).</td>
<td>60 sq. in.</td>
<td></td>
</tr>
<tr>
<td><strong>4. Determine size of return pump (lagoon to flush tanks)</strong></td>
<td></td>
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<tr>
<td>a. <strong>Required daily flush volume</strong>: No. hogs (600) x avg. wt./hog* (150 lbs.) ÷ 10 gals. water/100 lbs. liveweight</td>
<td>9000 gals.</td>
<td></td>
</tr>
<tr>
<td>b. <strong>Pump capacity to supply required flush volume</strong>: Step 4 a (9000 gals.) ÷ 1440 min./day.</td>
<td>6.25 gpm</td>
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<tr>
<td>c. <strong>Minutes between flushes</strong>**: Step 2 a (150 gals.) x no. tanks/pump (2) ÷ Step 4 b (6.25 gpm).</td>
<td>48 min.</td>
<td></td>
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</tbody>
</table>

*If actual weight unknown, use the following estimates: finishing hogs, 150 lbs.; sow and litter, 400 lbs.; nursery pig, 25 lbs.; and gestating sow, 300 lbs.
**If flush interval is greater than 120 min., increase pumping rate such that interval will be less than 120 min. (except for systems where flushing is done manually). As a check: flush tank (150 gals.) ÷ 120 min. = needed pump size (1.25 gpm) — OK if less than Step 4 b (6.25 gpm).
5. Determine size of return pipe (lagoon to flush tanks)
   a. **Estimated diameter and head loss:** From Table 10, select pipe diameter and
      associated head loss for needed pump capacity, using the pump capacity
      figure closest to that in Step 4.b.
      - Pipe diameter = 3/4 in.
      - Head loss/100 ft. = 2.7 ft.
   b. **Total head loss:** Maximum difference in elevation from pump to tank*** (6 ft.) +
      \[
      \frac{\text{distance from pump to tank/100} \times (320 \text{ ft.}/100) \times \text{Step 5.a (2.7 ft.)}}{}
      \]
      = 14.6 ft.
   c. **Adjusting pump size to head loss:** Select a return pump that will handle the
      capacity needed (Step 4.b) against the total head loss in the piping system (Step
      5.b). For most flushing operations, a positive displacement pump that delivers a
      capacity of 10-20 gpm against 40 ft. of head will be adequate.

6. Determine size of sump pump (sump to lagoon)
   a. **Size of sump pit:** Step 2.a (150 gals.) x no. tanks (2)
      = 300 gals.
   b. **Minimum pump size:** Step 6.a (300 gals.) ÷ desired pumping time (5 min.)
      = 60 gpm

7. Determine total lbs. liveweight loading the lagoon*
   a. **Total wt. of finishing hogs:** No. hogs (600) x avg. wt./hog (150 lbs.)
      = 90,000 lbs.
   b. **Total wt. of sows + litters:** No. litters x avg. wt./litter
      =
   c. **Total wt. of nursery pigs:** No. pigs x avg. wt./pig
      =
   d. **Total wt. of gestating sows:** No. sows x avg. wt./sow
      =
   e. **Total wt. loading the lagoon:** Step 7.a (90,000 lbs.) + 7.b + 7.c + 7.d
      = 90,000 lbs.

8. Determine required capacity of a single-stage or first cell of a
   two-stage lagoon
   a. **Dewatering frequency:** Times per year.
      = Twice
   b. **Lagoon volume required per lb. of hog:** From Table 8.
      = 1.25 cu. ft.
   c. **Total lagoon volume required:** Step 7.a (90,000 lbs.) x Step 8.a (1.25 cu.ft.).
      = 112,500 cu. ft.

9. Determine dimensions of the single-stage or first cell of a two-
   stage lagoon
   a. **Side slope and depth:** Determined, in part, by location and soil type.
      - Side slope = 2.5:1
      - Depth = 12 ft.
   b. **Length of side of square lagoon having largest volume which is still less
      than required total lagoon volume (Step 8.c):** From top part of Table 9, read
      across line for selected side slope (2.5:1) and depth (12 ft.).
      = 100 ft.
   c. **Lagoon volume for selected length of side:** From top part of Table 9 (for 100
      ft.)
      = 62,300 cu. ft.
   d. **Lagoon volume still needed:** Step 8.c(112,500 cu.ft.) - Step 9.c(62,300 cu.ft.).
      = 50,200 cu. ft.
   e. **Added volume for each added 10-ft. length of side:** From bottom part of
      Table 9, for selected side slope, depth and initial length of side.
      = 8,400 cu. ft.
   f. **No. of 10-ft. lengths of side to provide for volume still needed:** Step 9.d
      (50,200 cu.ft.) ÷ Step 9.e (8,400 cu.ft.).
      = Six 10-ft. lengths
   g. **Total length of side at waterline (when full):** Step 9.b (100 ft.) + [Step 9.f (6
      lengths) x 10 ft.].
      = 160 ft.

***Difference in elevation is the vertical distance from surface of the lagoon from which water is recycled (at its lowest level after pumping down) to top of flush tank — 6 ft. in our example. It is measured accurately only with an engineer’s level.
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<tr>
<td><strong>h. Freeboard needed:</strong> Depends on annual rainfall. In Indiana, use at least 1 ft.</td>
<td>1.5 ft.</td>
<td></td>
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<tr>
<td><strong>i. Berm width:</strong> Plan on at least 8 ft. for maintenance equipment.</td>
<td>8 ft.</td>
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<tr>
<td><strong>j. Lagoon width (outside of berm to outside of berm):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[ (2 \times \text{Step 9.i}) + (2 \times \text{Step 9.a-side slope}) \times \text{Step 9.h} ]</td>
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<td></td>
</tr>
<tr>
<td>Ex: [ (2 \times 8 \text{ ft.}) + 100 \text{ ft.}) + ((2 \times 2.5) \times 1.5 \text{ ft.}) = 116 \text{ ft.} + 7.5 \text{ ft.} ]</td>
<td></td>
<td></td>
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<tr>
<td>= 123.5 ft.</td>
<td></td>
<td></td>
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<tr>
<td><strong>k. Lagoon length (outside of berm to outside of berm):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[ (2 \times \text{Step 9.i}) + (2 \times \text{Step 9.a-side slope}) \times \text{Step 9.h} ]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex: [ (2 \times 8 \text{ ft.}) + 160 \text{ ft.}) + ((2 \times 2.5) \times 1.5 \text{ ft.}) = 176 \text{ ft.} + 7.5 \text{ ft.} ]</td>
<td></td>
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<tr>
<td>= 183.5 ft.</td>
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<td></td>
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<tr>
<td><strong>l. Final dimensions (to outside of berms):</strong></td>
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<td></td>
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<tr>
<td>Step 9.k, 9.j, &amp; 9.a</td>
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</table>

10. **Determine dimensions of second cell of a two-stage lagoon (if used)**
    Same procedure as for first stage lagoon (Steps 9.a-9.i).

    = 147.5 ft. long
    123.5 ft. wide
    8 ft. deep