Manure Storage and Treatment Systems

John W. Worley

Table of Contents

Goals/Objectives of Manure Storage and Treatment Systems

Animal waste storage and treatment systems have historically been selected and designed to efficiently utilize valuable fertilizer nutrients for crop production while protecting soil, air, and water quality. The primary reason to store manure is to allow the producer to land spread the manure at a time that is compatible with the climatic and cropping characteristics of the land receiving the manure. Manure nutrients can be best utilized when spread near or during the growing season of the crop. Therefore, the type of crop and method of manure application are important considerations in planning manure storage and treatment facilities. The selection of the system also depends on the owner/operator's goals for utilization of waste. If the nutrients in the waste are needed for crop production, a system is designed to conserve and utilize in a timely manner as much of each nutrient as possible. If the nutrients are not needed for crop production, the manure tends to be seen as something that must be disposed of as economically as possible. The goal then is to reduce the waste stream as much as possible. In either case, the waste storage/treatment system is designed to provide storage and/or treatment without allowing surface or ground water to become contaminated with excess nutrients, pathogens, or organic matter which can cause oxygen levels in water to drop below the level needed to sustain aquatic life.

Alternative Storage and Treatment Systems

Most swine and dairy operations and some poultry operations use liquid or slurry manure storage and handling systems. In fact, in Georgia, most of the systems are liquid. The discussion here will therefore focus on liquid systems. However, slurry systems will also be discussed in order to enhance understanding of the difference between the goals and management strategies of the two systems. "Dry" systems (systems where manure is handled as a solid) will also be discussed. Some systems use solids separation devices to remove some of the solids from the liquid stream. These systems are really a combination of liquid and dry systems and must be handled as such.

Liquid Storage Systems (Lagoons)

Lagoons are probably the most common form of liquid manure handling system. A lagoon is a waste treatment system as well as a storage facility for manure, and it represents the most economical means currently available of reducing the waste stream in liquid systems. A properly operating lagoon will reduce odors and convert much of the organic matter into gases which are given off into the air. Odor reduction comes as a result of purple sulfur bacteria which grow near the surface of the lagoon and convert odorous compounds (primarily hydrogen sulfide) into less offensive gases.

Nutrient reduction is primarily in the form of nitrogen which is converted to nitrogen gas and ammonia. Some of the phosphorus and potassium tend to settle to the bottom of the lagoon and are stored in the sludge. Thus the land needed to apply nutrients from a lagoon is reduced since the nutrients in the lagoon are reduced. It must be noted, however that phosphorus and potassium are still in the lagoon and must be accounted for in nutrient management budgets when the sludge is removed. If properly designed, constructed, and managed, a lagoon will minimize seepage of nutrients into the ground below, and will present a minimum risk of overflow into surface waters.

Advantages of lagoon storage of manure may include cost per animal unit, ability to store large amounts of manure and/or runoff, treatment of manure to reduce odors, and potential to handle manure with conventional pumping and irrigating equipment. Disadvantages of lagoons may include lack of appropriate soil materials for construction, the need for solids separation or sludge removal equipment if bedding or other non-biodegradable materials are present, aesthetic appearance and/or public perception. In addition, the effluent from a lagoon is less well balanced with crop needs, since nitrogen is released, and phosphorus and potassium remain in the lagoon.

Manure Slurry Storage Systems

Manure slurry storage systems tend to be used when the need for nutrients for crop growth in the area is high since these systems tend to maintain higher levels of nutrients (particularly nitrogen) than do lagoons. Many types of facilities are used to store manure in the slurry form. One type is the under-floor pit in which manure is deposited directly into the pit (usually 6 ft deep or more) through slatted floors. Other slurry manure storage facilities include fabricated or earthen structures. Fabricated manure storage tanks are usually either concrete or coated metal (glass-lined steel). Such tanks may be above ground, or partially or fully below ground. Manure is usually scraped or flushed from the production buildings and may flow into these tanks by gravity or be pumped into the tank from a collection sump or reception pit. Adequate agitation is necessary to suspend solids and facilitate complete removal of the contents of these manure tanks. Fabricated tanks are usually the least costly to cover, which is sometimes desirable for odor control.

Slurry manure may also be stored in earthen structures or basins. Because storage volume can usually be obtained at less cost in an earthen basin than in a fabricated facility, these facilities are often used when manure and wastewater volumes are relatively large due to wash-water use or lot runoff. Earthen structures require a relatively high degree of planning and preliminary investigation to ensure that proper soil materials are available to create a seal and that the seal is constructed properly. These facilities are basically similar to lagoons, but smaller since less water is added to the manure. Space requirements are greater with earthen structures than fabricated manure storage tanks due to the required berms and front/back slopes that have structural integrity and can be properly maintained. Maintenance requirements may be greater with earthen structures due to the need for maintaining and mowing a vegetative cover on the berm area and keeping it free of weeds, trees, and shrubs. Agitation is equally important in earthen structures, and access points for agitation and pumping should be part of the design plan. Some earthen storage units are partially or completely lined with concrete and built with an access ramp so that loading and hauling equipment can enter the basin. Earthen storage structures are more difficult to cover than tanks if odor control is needed. Odor is generally a greater problem in slurry storage structures than in a properly operating lagoon, but if coverage is necessary, it is less costly in a slurry storage facility because of the smaller size.

Advantages of storing manure in the slurry form may include less volume (higher solids content compared to a lagoon), adaptability to tank storage either under floor or above ground, possibility of covering the manure storage facility to reduce odors, higher nutrient retention, and the potential to collect and transport hydraulically. Disadvantages may include higher odor potential (unless storage unit is covered), increased danger of toxic or combustible gas buildup in enclosed areas, number of loads or trips that must be made when the storage is emptied, and odor and runoff potential if the slurry is spread without injection or incorporation.

Dry Systems and Solids Separators

Dry manure storage can be as simple as using the confinement building itself as storage, as is often done in poultry houses where three or more flocks of chickens are raised before cleaning out the building. In cases where crop needs do not coincide with the need to clean out a broiler house, a dry swine house, or a dairy lot; manure is often stacked either in a building or outside until it can be utilized by a crop. These stacks should always be covered to protect them against runoff in case of rain **or** the runoff should be contained and treated as a liquid waste.

When swine are raised on litter, they tend to dung in limited areas of the building, so that the litter is very non-homogeneous when removed from the building. Some loads contain almost no nutrients, and some are very concentrated. To achieve a homogeneous product, it is necessary to compost, or at least stack and mix the material from these houses. Some producers have experimented with only removing the wet areas which contain most of the nutrients and reusing the dry litter, but it is not clear if this system is sustainable because of concerns about worms and parasites transferring from one batch of pigs to the next.

Another type of "dry" storage is a settling basin used to separate solids from a liquid stream. Typically, these basins are designed to store 3 to 4 weeks of manure, with two or more basins being utilized in order to allow one basin to drain while the other one is being filled. This design allows more flexibility in timing the application of solids onto crops and pastures. These basins are lined with concrete and the runoff from them flows into a lagoon to prevent contamination of surface waters.

Mechanical solid separators are also used. These devices usually produce a dryer product than a settling basin which is better for composting or hauling to remote sites or off the farm. Their main disadvantage is that, being mechanical systems, they do break down and require periodic maintenance. They also have a cost of operation involved since they require energy to operate. The solids fractions from these systems are typically stored on a concrete pad with the runoff going into a lagoon or protected by vegetated buffers.

Basic Design Principles

Lagoons

A lagoon must be sized to provide adequate storage for manure, dilution water so that proper microbial digestion will occur, storage of sludge (indigestible materials that settle to the bottom), storage of rain water and wash water, and a safety margin in case of severe storms. (See Figure 1) If all of these capacities are not accounted for, the lagoon will not function properly, will begin to act like a manure storage facility, and will have to be pumped out much more frequently. Adequate sizing of a lagoon depends upon location, the number and size of animals using the lagoon, whether or not solids separation will be used, and how long sludge will be allowed to build up before removing. In addition, good management practices, such as loading the lagoon on a uniform basis, maintaining proper vegetation on berms, regular inspections and maintaining safe levels in the lagoon are necessary to provide safe, efficient operation.

Lagoons must be designed by a properly trained engineer (NRCS or consulting engineer). The berms (walls) must be designed to be stable under load and the lagoon must be properly lined with either a compacted clay or synthetic liner to prevent leakage into ground water. The owner/operator should understand the limitations of the system, and how the expansion of animal numbers will prevent the lagoon from operating properly. He/she should know the capacity of the lagoon, how many animals it is supposed to handle, how often it should be pumped down, and to what level it should be pumped down. Any major expansion or change in the operation of a facility would require a reassessment by the design engineer.

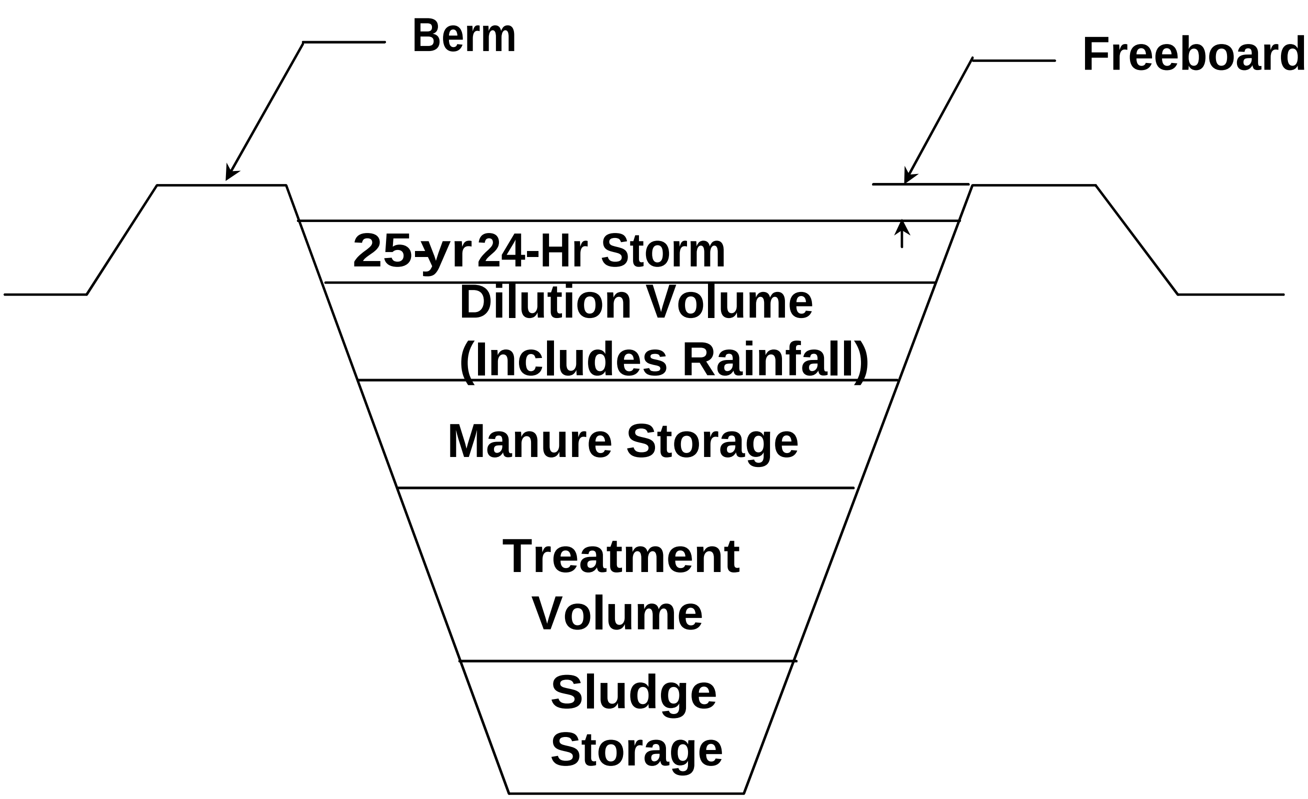


Figure 1. Capacities that must be included in a proper lagoon design.

Manure Slurry Storage

The actual size of a manure slurry storage structure needed depends upon the same factors used in sizing a lagoon with the notable exception that no treatment volume of water must be added since microbial breakdown of manure is not desired. Manure is left in a more solid state, which hinders bacterial growth. Also, sludge accumulation is not accounted for since this facility should be completely emptied one or more times per year. The design storage period plays a significant role in sizing these structures. Storage period needed depends primarily upon cropping system, climatic conditions, and labor/equipment availability. Most operations utilizing a single, full-season annual row crop or small grain crop will need at least six months manure storage to schedule land spreading around cropping operations. Experience has shown that even a full year's storage is beneficial when wet conditions may make fall application difficult and manure needs to be stored until spring. ....

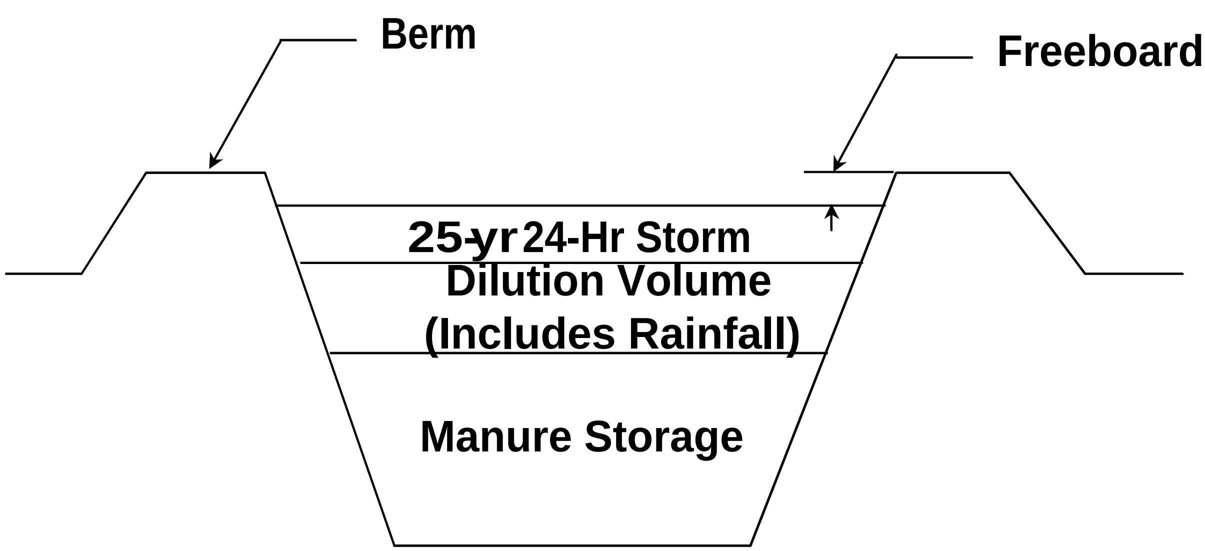


Figure 2. A manure storage facility is smaller than a lagoon, but must still be sized to handle volumes according to the planned management.

A manure storage facility for a given number of animals is much smaller than a lagoon for the same farm (See Figure 2), since no storage space is needed for dilution water. However, adequate size must still be supplied for manure storage, rainwater, and a safety factor for severe storms.

As in the case of lagoons, a manure slurry storage system should be designed by an NRCS or properly trained consulting engineer, whether it is an earthen basin (Figure 2) or a concrete or steel structure. The engineer should also be consulted before any expansion or major change in the operation takes place.

Dry Systems and Solid Separators

If manure is to be stored in a building (commonly called “dry-stack houses” in the poultry industry, the building should be designed to safely handle the loads it will experience, and should be designed to withstand the corrosive atmosphere in which it will exist while manure is stored in it. Assistance on building design is available from the NRCS or the Cooperative Extension Service Plan Service. Concrete floors are recommended, but clay floors are acceptable if mortality composting is not to be done in the facility.

Storage of manure in stacks outside a building should be avoided. Stacks can be covered with plastic which will protect them from leaching while in place, but when the stack is removed and spread on a field, it is almost impossible to remove all of the material, and the remaining manure can leach into the soil. Experience has shown that the most highly contaminated areas on a poultry farm is around old stacks and at the entrance to the houses where spillage occurs when houses are cleaned out.

Settling basins for separating solids should be designed to be structurally sound and to be large enough to provide flexibility in the timing of manure application from the basin. Again, assistance can be gained from the NRCS or Cooperative Extension Service Plan Service.

Effects on Nutrient Management

The amount of nutrients available for use on crops is affected by the method used to store manure, as well as the application method. In estimating the total amount of nutrients available for use annually, the total nutrients excreted must be adjusted for storage and application losses. When applying material from an aerobic lagoon for instance, up to 90% of the excreted nitrogen can be lost during the anaerobic treatment of the waste. This nitrogen is lost to the atmosphere primarily in the forms of nitrogen gas and ammonia. There are also losses of phosphorus and potassium, but unlike nitrogen, these nutrients accumulate in the sludge layer of the lagoon, which must eventually be removed and applied to the land unless some arrangements can be made to remove the sludge from the farm. For this reason, 90 to 95% of excreted phosphorus and potassium should be accounted for in the overall farm nutrient management plan. Five to 10% may be lost in moving the waste material (spillage when loading, leaching when stored outside, etc.) Table 1 shows estimated available nitrogen after storage losses as a percentage of total nitrogen produced for various species and storage methods.

Table 2 illustrates how manure values can vary with system and time and thus result in different recommended or allowable loading rates. The only way to know the exact composition of manure is to have it tested. While the numbers below may represent average values, the variation from one system to another is great, and manure testing is an absolute essential for determining proper application rates.

Table 1. Estimated available nitrogen after storage losses (% of total nitrogen produced) for different systems.

Management System	Dairy	Poultry	Swine
Anaerobic Lagoon	20-35	20-30	20-30
Manure Slurry Storage	65-80		70-75
Manure Stored in Pit Beneath Slats	70-85	80-90	70-85
Manure and Bedding in Covered Storage	65-80	55-70	
Manure stored in open lot	70-85		55-70

Table 2. Average manure accumulation and nutrient values for different swine manure systems .(These values may be used as planning guidelines.)

Nutrient Composition of Swine Manure					
Manure Type	Manure Accumu-lation	Total Nitrogen	Ammonium NH_4-N	Phosphorus P_20_5	Potassium K_20
Fresh	82 lb/1,000 lb of animal/day	12 lb/ton	7 lb/ton	9 lb/ton	9 lb/ton
Scraped[1]	58 lb/1,000 lb of animal/day	13 lb/ton	7 lb/ton	12 lb/ton	9 lb/ton
Liquid Slurry[2]	16.7 gal/1,000 lb of animal/day	31 lb/1,000 gal	7 lb/1,000 gal	12 lb/1,000 gal	17 lb/1,000 gal
Anaerobic Lagoon Sludge	0.74 gal/1,000 lb of animal/day	22 lb/1,000 gal	6 lb/1,000 gal	49 lb/1,000 gal	7 lb/1,000 gal
Anaerobic Lagoon Liquid	20.3 gal/1,000 lb of animal/day	136 lb/acre-inch (5 lb/1,000 gal)	111 lb/acre-inch (4 lb/1,000 gal)	53 lb/acre-inch (2 lb/1,000 gal)	133 lb/acre-inch (5 lb/1,000 gal)

[1]Collected within 1 week.
[2]Six to 12 months accumulation of manure, urine, and excess water usage, which does not include fresh water for flushing or lot runoff.
Source: North Carolina Agricultural Chemicals Manual.

Operation and Monitoring of Lagoons and Slurry Storages

Lagoons combine storage and treatment functions and thus are more sensitive to management inputs than are solid or slurry facilities. The establishment and maintenance of desirable microbiological populations in lagoons requires more specific procedures in the way lagoons are loaded and monitored.

Startup and loading procedures

Lagoon startup is a very important factor in developing a mature lagoon that has an acceptable odor level and will perform in the expected manner over the long term. Lagoons are designed with a “treatment volume” that provides an environment for development and maintenance of a bacterial population that degrades and stabilizes manure. The size of the treatment volume is based on a volatile solids (VS) loading rate, which depends primarily upon temperature. Volatile solids are the "non-mineral" or organic solids in manure that are subject to bacterial degradation. At warmer temperatures, bacteria are more active and VS loading rates are higher. The converse is true for cooler temperatures. For the bacteria to develop and function properly, the actual VS loading rate should be as designed. The proper VS loading rate is achieved only if the lagoon contains a volume of water equal to the treatment volume at startup. A lagoon with only one-tenth of the treatment volume filled at startup will experience an “overload” by a factor of 10 (VS loading rate is ten times greater than designed). Therefore, it is very important to plan a procedure to have sufficient water in a lagoon at startup. The treatment volume should be used as a target. Achieving this goal may require identifying a water source (pond, lake) and implementing the needed pumping procedures to transfer the desired volume of water to the lagoon. Since bacteria are more active at warmer temperatures, consideration should be given to starting a lagoon in the spring or early summer. In this way, bacteria will have a warm season to establish themselves before activity slows during the winter. Spring startup of lagoons often requires special planning of construction schedules and animal procurement.

<u>Problems associated with insufficient volume at startup include excessive odor and high rates of sludge buildup. A lagoon that is started with insufficient volume may take years to recover and may never attain an operating state equal to a lagoon that is started properly.</u>

In addition to startup, long-term loading procedures are critical to lagoon performance. A somewhat common and unfortunate practice in the livestock industry is to expand animal numbers without expanding lagoon size. This results in a proportionate increase in VS loading, and the associated problems can be expected to develop. Volatile solids loading should not be increased beyond the design loading. Alternatives to reduce VS loading (or expand animal numbers) include solids separation, construction of additional lagoon volume, or pretreatment of manure. Lagoons should also receive manure in a consistent manner (no “slug” loading). This is usually accomplished in modern production systems utilizing hydraulic transport of the manure to the lagoon.

Salt and Nutrient Levels, Testing

Bacterial activity is somewhat sensitive to salt levels in the lagoon. Salts are a natural byproduct of the biological degradation of manure. The removal of some salts as the lagoon is pumped and the addition of fresh water via rainfall, runoff, and wash water combine to generally keep salt levels within an acceptable range. However, some conditions can occur that may lead to elevated salt levels. These include extended periods of dry weather, high rates of evaporation, little or no dilution with lot runoff and wash water, and perhaps overloading of the lagoon. Elevated salt levels inhibit bacterial activity, and lagoon performance is characterized by increased odors or “sour” smells and increased sludge buildup rates. A simple field test called “electrical conductivity” (EC) is effective in monitoring salt levels. A University of Missouri study found that EC values in the range of 8,000 to 12,000 μmho/cm (or S/cm) were associated with greatest bacterial activity. If salt levels rise too high in a lagoon, the most effective remediation is to pump the lagoon and add water from a freshwater source (pond or lake). The availability of such a freshwater source is an enhancement to long-term lagoon operation, and consideration should be given to such a source when planning a lagoon.

While overall salt levels are the primary concern in lagoon health, occasionally other more specific compounds may affect lagoon performance. These might include copper, arsenic, (dietary inputs), certain medications, and perhaps excessive use of harsh cleaning agents. If reduced lagoon performance is suspected due to factors such as these, specific testing may be required to isolate the source.

Overall Monitoring Activities

Certain activities are advisable and necessary in maintaining a manure storage structure and ensuring that it is performing as expected. Some of these activities may be required by regulation, but all are evidence of good management and stewardship regardless of regulatory requirements.

Monitoring During Pumping Activities

Experience has shown that unplanned discharges and spills sometimes occur with pumping activities. Sources of such unplanned discharges include burst or ruptured piping, leaking joints, operation of loading pumps past the full point of hauling equipment, and other factors. Hence, pumping activities should be closely monitored, especially in the "start-up" phase, to ensure that no spills or discharges occur. Continuous pumping systems such as drag-hose or irrigation systems can be equipped with automatic shut-off devices (which usually sense pressure) to minimize risk of discharge in the event of pipe failure.

Liners

Liners in earthen manure storage impoundments are designed and constructed to provide an adequate barrier between the potential contaminants in the impoundment and groundwater. Hence, liner integrity is extremely important in maintaining an environmentally sound manure storage facility. To the extent possible, liners should be regularly inspected for signs of damage, erosion, or other compromising factors. Wave action can cause liner erosion at the level of the liquid in the impoundment. If this condition is severe, consideration might be given to the use of riprap or similar mitigation methods to preserve liner integrity. The area around the pipes that discharge into the impoundment is also subject to erosion, especially if the pipes discharge directly onto the liner surface. A better configuration is to install inlet pipes such that they discharge into at least 4 feet of liquid, which may require a supporting structure for the end of the pipe. Concrete or rock chutes should be used with inlet pipes that discharge onto the liner surface. Agitation is also an activity that can damage liners. Care should be taken to operate agitators a sufficient distance above the liner so that liquid velocities are reduced enough to ensure that erosion does not occur. Heavy or unusual rainfall events can also erode liners, and special attention should be given to liner inspection after such storm events.

Logbooks and record keeping

Certain data and record keeping involving manure storage structures can aid in overall maintenance and management, and is also evidence of responsible operation and good record keeping. In addition to the periodic inspections, manure levels in a storage structure should be monitored and recorded. This data can illustrate the effects of excessive rainfall and lot runoff, and help in planning pump-down or other land application activities. Manure levels should be observed and recorded frequently enough to provide a “feel’ for the rate of accumulation, and pumping activities should be scheduled accordingly.

When a lagoon is pumped or other manure storage structure is emptied, the date of the activity should be recorded along with the volume or amount of manure removed, locations where the manure is spread, and the nutrient content (lab analysis) of the manure. Calibration of pumping equipment is necessary to accurately estimate amounts pumped. This information may be required by the regulatory agency for interim or year-end reports, or may be useful in the event of litigation.

Pump-down or Manure-Level Markers

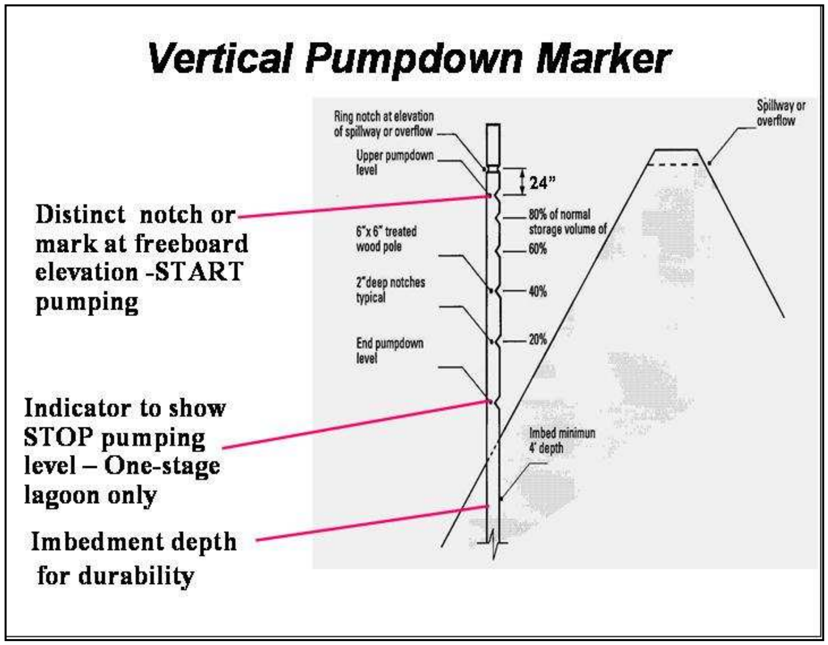
Pump-down or manure-level markers, or indicators, are a simple but important component of a manure storage facility. Such a marker enables the operator to ascertain quickly and easily the degree of fill of the manure storage facility, the point at which pumping or emptying should begin, and the point at which it should end. The presence of a durable, easily read marker gives inspection or regulatory personnel confidence that a manure storage facility is being managed properly.

Experience has shown that pump-down markers must be made of durable materials and properly installed to afford the long life needed. The operator or inspector should be able to ascertain the following information when observing a pump-down marker:

- When pumping operations should begin and end
- Level at which overflow will occur
- Fraction of total storage that is currently filled
- For a multi-stage lagoon or a manure storage basin, the start-pumping level should be indicated, but not necessarily a stop pumping level since the stop pumping level is really the bottom of the lagoon (or as close as it can be pumped.)

A common practice is to install steel fence posts at the upper and lower pump-down levels for earthen impoundments. While this approach provides basic information on beginning and ending pump-down, experience has shown that more knowledge is needed. Also, fence posts installed in this manner are subject to damage and displacement. A good pump-down marker will indicate the level, or elevation, of manure throughout the possible range (from lower pump-down level to overflow, or spillway) in the storage facility. A pump-down marker can be made from PVC pipe with all ends left open to allow water to flow into the pipe. Two examples of how this can be done are shown in Figures 3 and 4. Table 3 gives conversions for sloped to vertical measurements for use in installing level indicators on sloped markers.

Figure 3. Example of Vertical Pumpdown Marker



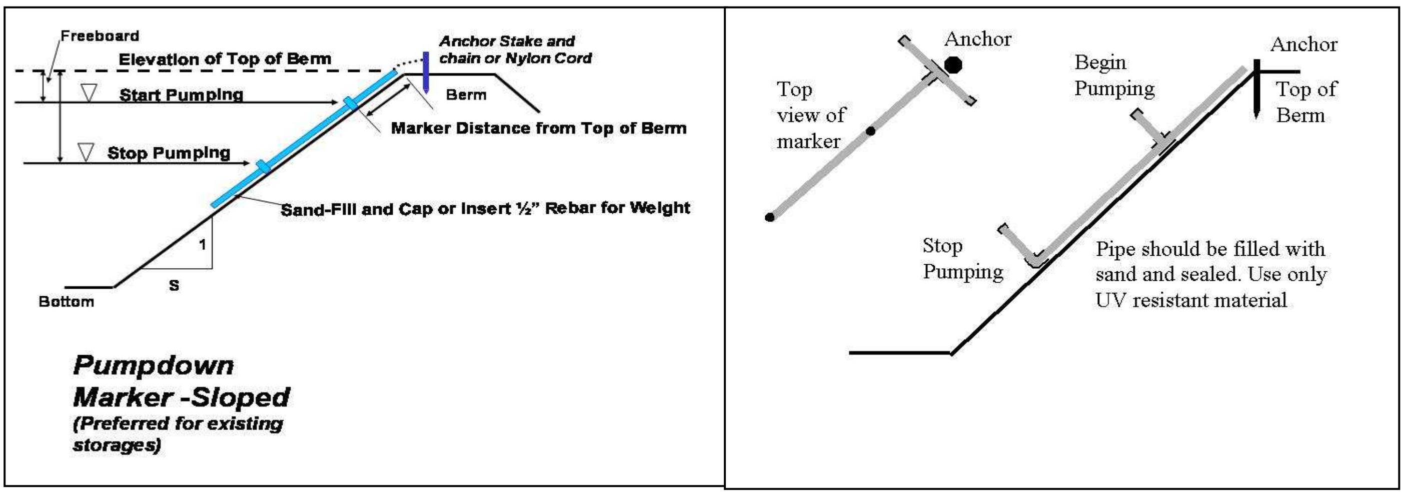


Figure 4. Example of Sloped pump-down marker in earthen impoundment

Table 3. Conversions for sloped to vertical measurements

Vertical Distance, ft	Interior Sideslope, Run:Rise				
	1:1	1.5:1	2:1	2.5:1	3:1
2	2.8	3.6	4.5	5.4	6.3
4	5.7	7.2	8.9	10.8	12.6
6	8.5	10.8	13.4	16.2	19.0
8	11.3	14.4	17.9	21.5	26.3
10	14.1	18.0	22.4	26.9	31.6

Weather stations

A simple weather station that indicates or records rainfall can be a useful tool in maintaining and managing a manure storage structure. Rainfall has a significant impact on open storage structures and structures serving open lots, so knowledge of rainfall amounts can be very useful. Some permits are written that provide for a "legal" discharge under certain climatic events. A weather station can aid in the documentation of such events without resorting to "off-site" data from stations that may not be descriptive of conditions at the storage facility. Recorded rainfall data is also evidence of good stewardship.

Aesthetics and appearance

Aesthetics and appearance may not be critical factors in protecting the environment or complying with environmental regulations. However, these characteristics are major factors in the perceptions formed by the general public, tour groups, regulatory or inspection personnel, and others who may not be intimately associated or familiar with the livestock industry. Therefore, aesthetics and appearance should be given major priority for the overall benefit and viability of animal agriculture.

The general cleanliness and sanitation characteristics of a livestock enterprise are often perceived as a measure of the concern of that enterprise for environmental stewardship and environmental compliance. A clean, well-landscaped production area will project a positive image for the operation, while the presence of debris, litter, and poorly maintained buildings will project a negative image. Typical items of concern for livestock production enterprises include leftover construction debris or refuse; old, unused vehicles; worn-out equipment; rusted equipment from the buildings (farrowing crates, pen dividers, feeders); torn and worn-out ventilation curtains; and loose roofing panels, etc. All livestock production operations experience animal death loss. A specific plan managing animal mortalities should be developed and implemented. The visual and olfactory perceptions generated by the presence of dead animals in or around the production facility are highly offensive and likely will be attributed to the industry as a whole by the general public. Additionally, poorly managed mortalities represent a very real health and disease risk to the enterprise.

Few activities undertaken by the producer are as effective as frequent mowing in conveying a positive image of livestock production. Producers who maintain "front yard quality" around the production and manure storage facilities provide a powerful first impression of pride and responsibility. Conversely, the presence of tall grass, weeds, shrubs, and trees in undesirable locations creates an impression of laxity and disrespect for environmental responsibility. Regulatory personnel inspect most livestock production and manure storage facilities at some interval. If tall grass, weeds, brush, and trees hamper the inspector, a positive report is an unlikely outcome. Routine inspections for seepage, rodent burrowing, erosion, or other damage are much more effective if the areas have been mowed at regular intervals.

Control of Surface Water

As confined production units become larger, control of surface water in the production area is a primary concern. Wider, longer buildings, placed relatively close together, create high rates of discharge from roof and paved areas. Special considerations and landscaping are needed to manage this water in a manner that does not create erosion and unwanted ditches and washedout culverts or waterways. A surface water management plan should be developed based on a design storm event, expected runoff rates, soil types and erosive velocities, and properly designed and vegetated channels for carrying surface water away from the production area. Some states may require that surface water from production areas be contained and/or checked for contaminant levels before discharge to a watercourse.

Closure of Waste Impoundments

Anaerobic lagoons have been used for a number of years to treat and store animal waste from swine, poultry, and dairy cattle. Bacteria in the lagoons treat the waste by digesting organic matter and converting much of the mass to gases (ammonia, nitrogen, methane, and many others). A typical active lagoon consists of a large, dilute layer of fresh manure, water, and partially digested manure; and a layer of thick sludge at the bottom, which is primarily material that cannot be broken down by the anaerobic bacteria. The thickness of the sludge layer depends on the age of the lagoon, and on the loading rate and species of animals whose waste is being processed and stored.

If lagoons cease to be used for waste storage and treatment, the dilute top layer cleans itself up to a degree, but the thick solids layer underneath stabilizes and will remain in tact indefinitely. At some point, the solids will need to be removed. Provisions have been written into rules that would require lagoons on Confined Animal Feeding Operations (CAFO's) greater than 1,000 animal units (new or existing) to be properly closed when no longer in service.

The rule citation is as follows:

Rule 391-3-6-.21 (5) (j)
When the owner or operator ceases operation of the AFO, he must notify the Division (EPD) of that fact within three months, and he must properly close all waste storage lagoons within eighteen months. In the case of voluntary closure, a period of twenty-four months from notification is allowed. Proper closure of a lagoon entails removing all waste from the lagoon and land applying it at agronomic rates, and in a manner so as not to discharge to any surface water.

The regulations also reference the Natural Resources Conservation Service (NRCS) Practice Standards as the guiding document for interpretation of the requirements. The NRCS Conservation Practice Standard that covers this subject is Code 360, Closure of Waste Impoundments. A summary of the document is on the next page.

NRCS Guidance on Lagoon Closure

There are three options for managing the earthen lagoon after closure:

1. ***Complete closure and fill.***
2. ***Breaching the lagoon berm.***
3. ***Conversion to a farm pond or irrigation storage structure.***

In either case, the first steps are the same:

1. Remove all pipes or other structures that convey waste into the structure. Pipes should be dug up and ditches refilled
2. Remove as much of the stored waste and sludge as practical. This can be done by agitating the lagoon and pumping as much material out as possible, refilling with water and repeating until most material has been removed. Alternatively, the effluent (relatively dilute liquid on top) can be pumped out, and the sludge can be removed using a slurry pump or excavation equipment.
3. All material must be land applied at agronomic rates (such that crops can utilize the nutrients).

If the lagoon is to be completely closed, it should then be filled in and the land returned to its approximate original contours. Soil should be mounded slightly in the lagoon area (5% slope) in order to allow for settling and to encourage surface water to run away from the site. Vegetation should be established on the site to prevent erosion.

If the lagoon berm is to be breached, all surface water runoff should first be diverted away from the lagoon. The breach should have sufficient side slope to prevent erosion. (Maximum 3:1 slope.) The NRCS can help with this design. It should be low enough to allow all water to flow from the structure and prevent ponding. Vegetation should be established on the entire site including the sides of the breach to prevent erosion.

If the lagoon is to be used as a farm pond, a watering source for livestock, or an irrigation storage pond, the structure should meet the requirements for these types of structures. A properly designed lagoon will probably meet those requirements without major alterations, but the NRCS should be able to provide technical assistance to assure this requirement is met. Water quality samples should be taken and submitted to assure safety before allowing livestock to drink from a converted lagoon. Dissolved oxygen (DO) levels should be higher than 3 milligrams per liter and nitrate nitrogen should be below 30 milligrams per liter.

Summary

Lagoons, manure slurry storage structures, and dry systems each have advantages and disadvantages. Lagoons reduce the nitrogen and organic matter in the waste stream by volatilizing them (converting them to gases and moving them into the air.) They also reduce the odor released compared to a slurry storage, but they are more expensive because of their larger size and must be carefully managed to maintain a healthy bacterial population. Slurry storage structures are smaller (do not include treatment volume or sludge storage), conserve more nutrients in the waste, and are easier to cover if necessary, but they tend to produce more odor if not covered. Dry systems keep manure in a concentrated form making it more transportable and less likely to flow into surface waters, but it must be handled as a solid which usually requires more labor than liquid systems which can use automated pumps. Solids separation devices remove much of the solids going into a liquid system and thus reduce the required volume for treating the waste, but they do require a large financial investment and require two types of manure handling equipment (liquid and dry). Whichever type of system is used, it is important to understand that it cannot perform as designed unless it is managed properly. For a lagoon, that includes starting it about 1/3 full of water before waste is added, preferably in the Spring, loading it evenly, and maintaining the level between the minimum and maximum levels. For a slurry storage, it includes cleaning it out on a regular schedule, according to crop needs, and minimizing the amount of water entering the storage. Solids separating systems must have the solid fraction removed regularly (within the flexibility provided in the design) in order to keep them operating properly, and mechanical systems must be regularly maintained to avoid break downs.

Regular inspections and records of these inspections are vital to maintaining any manure storage and handling facility and to being able to prove that you are doing a good job managing your facility. Inspections should include investigations of existing or potential leaks, aesthetic appearance of facilities, and variations in odor levels. Regular monitoring and recording of lagoon levels requires the use of an easily read marker that shows **at a minimum** the overflow level, maximum storage level, and minimum pump-down level for the lagoon. Lagoon levels and weather forecasts should be studied so that pumping can be scheduled before it has to be done on an emergency basis. Berms should be checked for leaks, rodent burrows, erosion, and tree growth. Aesthetics include regular mowing and establishing vegetative screens where needed to present a pleasing picture to neighbors and those passing the farm.

If a lagoon is no longer used to store animal waste, it should be properly closed, including removal of all waste material. The structure can be filled in and reclaimed, the berm may be breached, or the structure can be converted for use as a farm pond. In any case all conveyances should be removed and exposed ground should be planted in a cover crop to prevent erosion. Until these steps occur, the lagoon should be managed just as it was before closure.

Appendix A
Monthly Manure Storage Facility Checklist

Farm:_______________________________ Facility ID:_______________________________

Inspected by:____ Date:___________________

Manure Level

Manure level today: (Distance below maximum fill level)____________ft.

Last observation: ________________ft. Date:________

Earthen Storage Facilities

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Are embankments well-sodded with no bare areas?	Yes	No	
Are embankments free of trees or woody shrubs?	Yes	No	
Does the berm or embankment have a consistent elevation (i.e., no low or settled areas other than the planned spillway)?	Yes	No	
Is the spillway free of erosion?	Yes	No	
Are all berms and embankments free of erosion?	Yes	No	
Is the base of the embankment free of soggy, damp areas and other evidence of seepage or leaks?	Yes	No	
Are the embankments free of burrowing or other rodent damage?	Yes	No	
Is the liner free of damage due to rainfall, wind, or wave action?	Yes	No	
Is the liner free of erosion damage around inlet/outlet pipes and agitation points?	Yes	No	
Does the lagoon contain at least the minimum volume for treatment?	Yes	No	

Concrete/Steel Tanks

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Are tanks free of visible cracks or structural damage in walls or foundation?	Yes	No	
Is the area around the tank free of seepage or other evidence of leakage?	Yes	No	
Is the manure loadout area free of spills or accumulations of manure?	Yes	No	
Does surface water properly drain away from the manure tank?	Yes	No	

Diversions

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Is roof water and field runoff diverted?	Yes	No	
Are diversion ditches adequately sized to handle runoff without overtopping?	Yes	No	
Are diversion channels vegetated and free of erosion?	Yes	No	
Is storage available in secondary containment structures if required?	Yes	No	
Is there adequate drainage of surface water around production buildings and manure storage facilities?	Yes	No	

Components

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Are level markers properly installed and easy to read?	Yes	No	
Are manure inlet pipes submerged and properly supported?	Yes	No	
Are drains, sewer lines, and cleanouts in good condition and operating properly?	Yes	No	
Are perimeter drains or tiles open and functioning?	Yes	No	
Are recycle pumps, valves, controls, and pressure lines operating properly?	Yes	No	

Appearance

Item	Low Risk	Potential Problem	Corrective Measures Taken/Planned
Is the manure storage site neat and recently mowed?	Yes	No	
Is the manure storage site free of refuse, debris, unused materials, and junk?	Yes	No	
Is the manure storage site screened by visual barriers, and are these barriers maintained?	Yes	No	
Is the manure storage site free of carcasses, afterbirth, or medical wastes?	Yes	No	
Is the manure storage site properly fenced and marked?	Yes	No	
Is the lagoon purple and actively bubbling?	Yes	No	
Is the manure storage surface free of excessive floating materials or vegetation growth?	Yes	No	