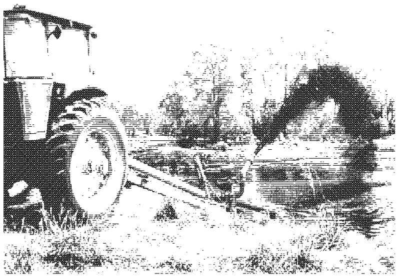

Sludge Management & Closure Procedures for Anaerobic Lagoons

Sludge is a natural byproduct of anaerobic biological digestion. This dead microbial material, which accumulates over many years in the bottom of anaerobic lagoons and is rich in nutrients and organic matter, periodically must be removed from the lagoon. Typically, it is land-applied to crops. Improperly managing the sludge volume in a lagoon will result in higher concentrations of nitrogen in lagoon effluent, a faster rate of sludge buildup, and a greater potential for odors from the lagoon surface. This document discusses several options for removing sludge from anaerobic lagoons. It also outlines the procedures that should be followed to properly "close" a lagoon or take it out of service.

Sludge (also known as biosolids or residuals) is a thick, black, viscous substance that is rich in organic material and nutrients. It is comprised of the dead and degraded microbial cells that anaerobically digested the manure influent and of any other materials (excess feed, debris, rocks, etc.) that were placed in the manure collection system and have settled to the bottom of the lagoon.

Over 10 to 15 years in the life of a lagoon, the volume of sludge will accumulate until it reaches a level at which it should be removed. At this point, it is typically taken from the lagoon and land-applied. Table 1 lists the volume units of sludge that can be expected to accumulate in anaerobic lagoons on various types of farms. If the amount of sludge becomes too large, the Permanent Liquid Treatment volume (Figure 1) will effectively be reduced. The loss of treatment volume will, in turn, adversely affect the overall treatment ability of the lagoon, causing the nitrogen content of the effluent to increase, more sludge to be produced, and more odors to be released from the lagoon's surface.

Since 1996, the state has required earthen lagoons to be designed with a Sludge Accumulation zone (Figure 1). Lagoons built before 1996 may or may not have a zone for sludge accumulation. Thus, older lagoons may not have adequate treatment volume, are prone to emit more odors, and contain high nutrient values in irrigated lagoon effluent.

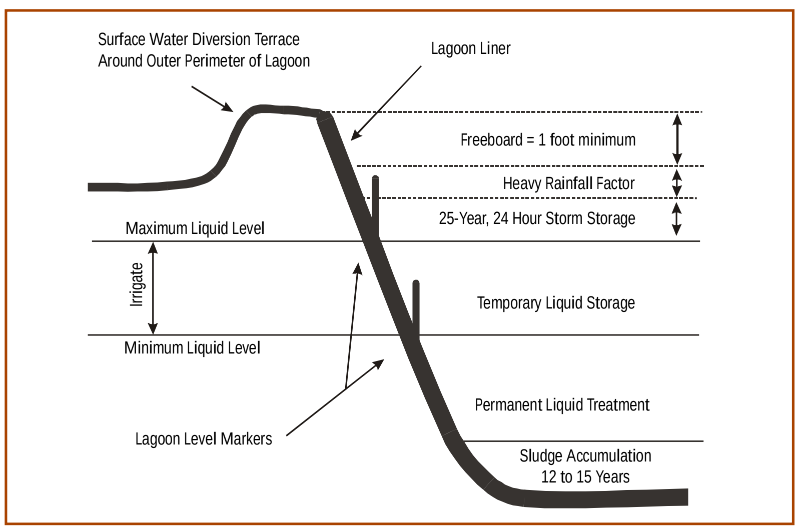

Figure 1. An anaerobic waste treatment lagoon (drawing is not to scale).

NC STATE UNIVERSITY
A&T STATE UNIVERSITY
COOPERATIVE EXTENSION
Helping People Put Knowledge to Work

College of Agriculture & Life Sciences • NC State University
School of Agriculture • NC A&T State University

Table 1. Average Animal Waste Generation Values for Different Production Units

Production Unit	Animal Unit Equivalent: Animal Unit	Animal Unit Equivalent: Live Weight	Lagoon Sludge [1]
		pounds	*gallons per animal unit/year*
Swine			
Weanling-to-feeder [2]	Per head capacity	30	6.7
Feeder-to-finish [2]	Per head capacity	135	33.0
Farrow-to-weanling [2]	Per active sow	433	78.0
Farrow-to-feeder [2]	Per active sow	522	94.0
Farrow-to-finish [2]	Per active sow	1,417	382.0
Poultry			
Pullet (nonlaying)	Per bird	1.5	*No data*
Pullet (laying)	Per bird	6.5	4.0
Layer	Per bird	4.0	4.7
Dairy			
Calf	Per head	350	395.0
Heifer	Per head	1,000	1,387.0
Milk cow	Per head	1,400	1,935.0

[1] No solids removal before lagoon input. [2] Assumes 400-pound sow and boar on limited feed, 3-week-old weanling, 50-pound feeder pig, 220-pound market hog, and 20 pigs/sow/year.

It is important to review current knowledge of sludge in earthen structures and lagoon dynamics prior to sludge removal. This knowledge will help producers and technical specialists prepare plans to safely remove sludge from a lagoon. The following summary lists some critical factors to consider when planning.

Two distinctly different zones are to be found within an anaerobic lagoon. First is the sludge accumulation zone at the bottom of the lagoon, comprised of inert materials and the biologically active sludge itself (Figure 1, “Sludge Accumulation”). Inert materials—rocks, sand, excess feed, debris (pens, plastic bottles, etc.)—accumulate near the inflow pipe(s) from the animal housing and drift to the very bottom of lagoons. This sediment is high in phosphorus, dense in nature, and easily identifiable from the sludge above it (applesauce consistency). Sludge, which is the likely source of much of the anaerobic degradation occurring in a lagoon, is black, moderately viscous, and high in nutrients, bacteria, and organic matter. It can be handled by pumps designed for higher solids applications (*e.g.*, dairy manure slurry).

The second distinct zone in the lagoon is the liquid layer above the sludge (Figure 1, “Permanent Liquid Treatment”). This liquid, typically called lagoon supernatent or effluent, is low in solids, moderately rich in nutrients, and easily pumpable with irrigation pumps.

Sludge is rich in nutrients. Like all animal waste, it must be applied at a rate that does not exceed the nitrogen requirement for a given crop. Sludge has much more phosphorus and heavy metals (copper and zinc) than lagoon liquid. Because of this, it should be applied to land with low phosphorus and metal levels, as indicated by a soil test, and incorporated to reduce the chance of runoff and odor. Note that if sludge is applied to fields with very high soil-test phosphorus, it should be applied only at rates equal to the crop removal of phosphorus. An estimate of the available nutrients in sludge from an active anaerobic lagoon is given in Table 2. Some sludge should be removed every 10 to 15 years so that phosphorus does not accumulate beyond what can be agronomically applied to cropland. However, during regular sludge removals, some sludge should be left behind because of its contribution to the biological treatment processes of the lagoon.

Protecting the lagoon liner integrity is essential during sludge and solids removal. Earthen manure storage structures with well-designed, well-constructed, and well-maintained liners seep less. Manure also reduces seepage rates in most situations due to the physical, chemical, and biological processes that contribute to the clogging of soil pores. Preventing mechanical damage or liner erosion during sludge removal is critical.

Table 2. Average Nutrient Composition of Sludge from Active* Anaerobic Lagoons

Sludge Type	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Copper (Cu)	Zinc (Zn)
	pounds/1,000 gallons				
Swine Anaerobic Lagoon	**22**	**49**	**7**	**0.78**	**0.30**
Poultry Layer Anaerobic Lagoon	**26**	**92**	**13**	**0.14**	**1.14**
Dairy Anaerobic Lagoon	**15**	**22**	**8**	**0.36**	**0.74**

** Refers to lagoons that are currently in operation and receiving manure from production houses. Site-specific sludge samples should be taken to estimate nutrient content from “inactive” lagoons.*

Principles of sludge management

Regular sludge and solids removal should be part of the management of any anaerobic lagoon. The following suggestions will help producers and technical specialists to manage sludge from these facilities:

1. *Identify and use practices that minimize sludge accumulation*. Settling basins and mechanical separators can substantially reduce sludge buildup in a lagoon. Efforts to minimize sludge accumulation should be noted in the farm’s Certified Waste Management Plan. Additional information on liquid/solid separation is available from the N.C. Cooperative Extension Service or from other sources, such as the *Livestock Waste Facilities Handbook*, produced by the Midwest Plan Service *(MWPS #18)*.
2. *Identify the trigger point at which accumulated sludge should be pumped out*. The lagoon design should include

an indicator by depth or volume showing what the maximum accumulation of sludge may be. The Permanent Liquid Treatment volume (Figure 1) in most lagoons should provide at least 1 cubic foot of liquid for every pound of steady state live weight (SSLW) of animals on the farm. Farms with more than 1 cubic foot per pound SSLW may accumulate more sludge than farms with only 1 cubic foot per pound SSLW before the volume will begin to harm lagoon performance. Once calculated, this indicator depth or volume should serve as the trigger point for sludge removal. If not defined in this manner, the trigger point should be set at a depth that is less than the lagoon's Permanent Liquid Treatment pool depth. Worksheet 1 shows how to calculate sludge storage volume for anaerobic lagoons.

3. *Monitor the sludge accumulation relative to the trigger point*. This can be done in two ways. First, sludge accumulation can be predicted using the volumes presented in Table 1. When the predicted accumulation nears the trigger point, make a direct measurement. For an anaerobic lagoon, use a 12- to 14-foot rigid, lightweight pole to check the depth of sludge accumulation. Detailed directions on how to measure sludge depth are provided in the "Estimating sludge volume" section below. The depth of sludge in the lagoon should then be compared to the trigger point to determine if sludge should be removed.

   An alternative method for monitoring sludge accumulation is to visually check when the lagoon is pumped to its lowest seasonal level (Figure 1, "Minimum Liquid Level"). A visual check of the lagoon surface after drawdown or after the last lagoon liquid is pumped would confirm whether accumulated sludge is occupying a large portion of the lagoon's permanent pool. The appearance of sludge at this time should trigger sludge removal.

4. *Do not remove the last foot of accumulated sludge*. Sludge represents the biologically active portion of the lagoon with significant bacteria population for anaerobic processes. Removal of significantly more sludge will adversely affect the odor control benefits of the lagoon.

5. *Protect the integrity of the earthen liner*. Liner integrity can be compromised by both aggressive agitation and use of front-end loaders or backhoes for removal of solids. Agitator/loaders or agitator/pumps are very efficient for suspending, mixing, and removing sludge. However, special care should be taken to prevent scouring of the lagoon walls when using the recirculation nozzle.

6. *Land-apply the sludge and solids to cropland at agronomic rates*. Sludge and solids have significant quantities of nutrients, especially phosphorus and metals such as copper and zinc. Procedures should be defined for nutrient analysis, estimating desired application rate, and field measurement of actual application rate.

   As discussed earlier, sludge removed from lagoons has a much higher phosphorus and heavy metal content than lagoon liquid. You will need to work with a certified technical specialist to develop a Manure Utilization Plan (MUP) to properly remove and apply lagoon sludge. If possible, sludge should be applied to land with low phosphorus and metal levels, as indicated by a soil test, and incorporated to reduce the chance of runoff. If the sludge is applied to fields with very high soil-test phosphorus, it should be applied only at rates equal to the crop removal of phosphorus.

7. *Limit odor production during land application of sludge*. Depending on the age and condition of the lagoon, sludge may or may not release significant odor during land application. Immediate incorporation of sludge into the soil is the preferred land-application method to minimize odor. If surface application or irrigation is to be used, carefully consider wind direction, time of day, and potential effects on neighbors when scheduling sludge removal. Odors dissipate most quickly at midday on warm, sunny days. Avoid applications in the evening or at night or on days of little or no wind.

Sludge sampling

There are two components of sludge sampling: estimating sludge volume and taking sludge samples for analysis. Unlike effluent, sludge cannot be sampled from the edge of the lagoon. Thus, when either estimating or analyzing, sludge must be sampled from a boat on the lagoon. Special care should be taken when going onto a lagoon in a boat. For safety reasons, at least three people should be present: two in the boat and one on the lagoon bank. The extra person on the boat assists with entering and getting out of the craft, and the extra person(s) on shore may be needed as a rescuer(s), should anything go awry. Flat-bottom or johnboats are preferred over canoes or V-bottom boats. As with any watercraft, appropriate flotation devices should be used by everyone in the boat.

Estimating sludge volume

Once on the lagoon, an estimation of sludge volume can easily be made. First, bring a lightweight, rigid, wooden or capped aluminum pole (0.5–1 inch thick by 14 feet long). The pole should be lowered **slowly** into the lagoon until the liquid seems to become denser and thicker (Figure 2). At this point mark (or record) the water level on the pole. Continue to push the pole down until you feel you have reached the bottom of the lagoon. Mark (or record) the water level on the rod, and pull it out of the lagoon. The difference between these two readings is the depth of the

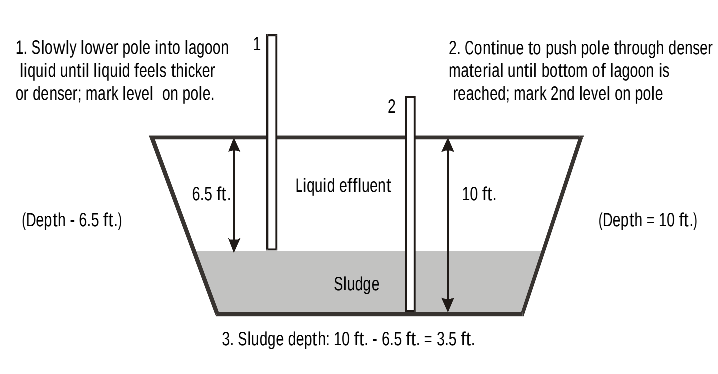

Figure 2. Measuring sludge depth.

sludge. Due to the density of anaerobic lagoon sludge, commercially available "sludge judges" should not be used to estimate sludge volume, but they can be useful when collecting sludge samples.

The sludge layer in a lagoon is a "mobile" fluid that forms peaks and valleys within the lagoon. For this reason, at least 10 depth measurements should be taken randomly. Avoid areas that may be affected by the slope of the lagoon embankments and the inlets of irrigation and recycle pumps. Taking more readings will provide a more accurate estimate of volume as well as highlight "hot spots" of accumulated sludge, which may need more attention during sludge removal. Next, average all of the sludge depths. Use steps E through L in Worksheet 1 to estimate the sludge volume in the lagoon.

For a more detailed assessment of sludge volume, a formal grid should be established around the lagoon. Then plot depth measurements at grid points to develop a contour map. Last, calculate an accurate sludge volume from this map. Consult your local Natural Resources Conservation Service office or surveyor for assistance.

Taking a sludge sample

The best time to take a sludge sample is while measuring for volume of sludge in a lagoon. This allows samples to be collected from several points around the interior of the lagoon. How the sample is collected depends on how the sludge will be removed. Depending on the density and nutrient concentration of the lagoon effluent, the samples may differ by up to 100 percent from point to point. To draw a sample, insert a ½-inch or ¾-inch PVC pipe into the lagoon sludge until the pipe almost reaches the bottom (Figure 3). Wearing plastic or latex gloves, place your thumb over the end of the pipe to create a vacuum and slowly pull the pipe from the lagoon. This will capture a core or profile of lagoon effluent and sludge. Once the pipe is over a clean 5-gallon bucket, **slowly** break the vacuum by removing your finger from the end of the pipe. If the entire lagoon is going to be agitated during sludge removal, the entire core of collected sludge and effluent should be sent to the laboratory. If the lagoon effluent is going to be drawn down and primarily only sludge pumped out, then just the collected sludge should be sent to the lab. If you are unsure on how the sludge will be removed, take samples using both methods, label them separately, and have them analyzed.

Place several samples in the bucket and mix thoroughly before removing a sub-sample for analysis. Consider using a plastic, wide-mouth bottle when shipping samples to the laboratory. For more information on preparing samples, consult Chapter 4, "Tools for the Plan," of the *Certification Training Manual for Operators of Animal Waste Management Systems* (AG-538) or *Soil Facts: Waste Analysis* (AG-439-33).

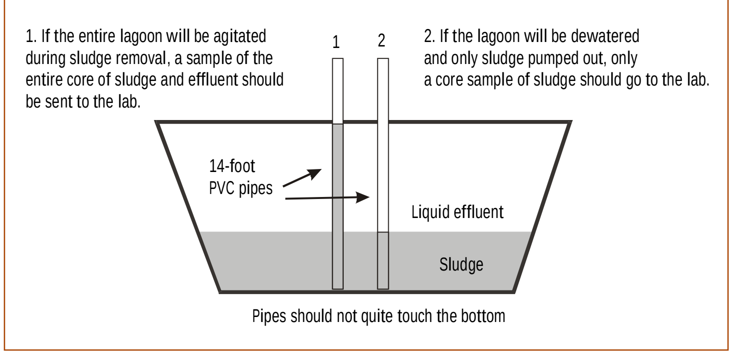

Figure 3. Taking a sludge sample.

Sludge removal

Removing sludge from anaerobic lagoons can be accomplished by several methods:

- Hire a custom applicator.
- Agitate the lagoon and irrigate/land-apply.
- Dewater lagoon, agitate sludge, and land-apply.
- Dewater lagoon, dredge lagoon, and land-apply sludge.

Hiring a custom applicator

This is the most common method for managing sludge in North Carolina for two main reasons. First, many lagoons can properly accumulate sludge for up to 10 years or more before their treatment ability declines. Second, the cost of removal equipment is prohibitive for most producers, especially due to the infrequency of sludge removal. The cost of hiring a contractor is largely based on the amount of sludge to be removed. A recent survey of custom applicators in eastern North Carolina showed that prices ranged from 1.5 cents to 5 cents per gallon of sludge. The difference in cost depends on the size of lagoon to be pumped; lagoon accessibility; distance to available application fields; and a decision on whether the sludge is to be irrigated, broadcast, or injected.

Custom applicators should be selected using these criteria:

- Ability to assist you in developing a Manure Utilization Plan to properly manage the removed sludge.
- Ability to provide appropriate agitation and pumping equipment for high-solid sludge.
- Ability to immediately incorporate sludge into the soil to minimize odor.
- Ability to transport sludge the required distance.
- Cost. Lower costs mean good lagoon access, irrigated applications, and nearby application fields. Higher costs mean poor lagoon access or that sludge must be hauled several miles before being applied. Direct injection or immediate soil incorporation of sludge also costs more.

Agitate the lagoon, and irrigate/land-apply

In this method, lagoon liquid and sludge are mixed with an agitator or a chopper-agitator impeller pump (Figure 4). High-volume pumps (3,000 to 5,000 gallons per minute) specifically designed for agitation and loading provide the

Figure 4. Agitator pumps are very efficient for suspending, mixing, and removing sludge from a lagoon to a tanker or irrigation pump. Special care should be taken to prevent erosion of the lagoon walls when operating the recirculation nozzle.

best suspension of solids. However, agitation equipment is generally effective in suspending solids only within a limited area (within about 50 feet of the agitator). Because agitation equipment also can erode earthen liners, it should be used cautiously. The mixed liquid then can be pumped through a large-bore sprinkler irrigation system onto nearby cropland. The liquid should be soil-incorporated to minimize odor, nitrogen volatilization, and runoff potential.

Dewater lagoon, agitate sludge, and land-apply

The upper part of the lagoon can be dewatered by irrigation onto nearby cropland or forageland. The remaining sludge is agitated and pumped into a liquid sludge applicator. The liquid sludge can be spread onto cropland or forageland and soil-incorporated or injected (Figures 5 and 6).

Figure 5. Tankers reduce the cost and time of applying sludge to fields that may be miles from the lagoon.

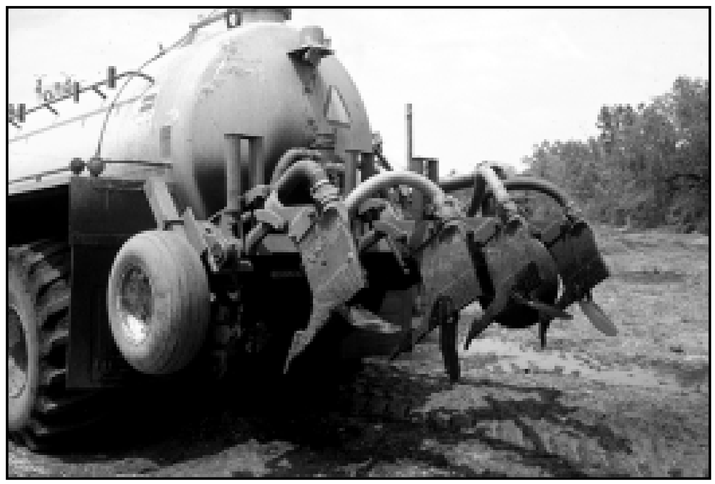

Figure 6. Injecting sludge directly into the soil reduces odors but increases the cost and time of application.

Dewater lagoon, dredge sludge, and land-apply

The upper part of the lagoon is dewatered by irrigation onto nearby cropland or forageland. Sludge is then dredged from the lagoon with a dragline or sludge barge. A bermed area should be created beside the lagoon to receive the sludge so that liquids can drain back into the lagoon. Removed sludge is then placed in the berm and allowed to dewater. Finally, the drier material is hauled and spread with a manure spreader onto cropland or forageland and soil-incorporated. Consult your waste management plan, farm conservation plan, or local Soil and Water Conservation district office to see if the specific fields used for sludge application can be disturbed with soil-incorporation equipment.

When removing sludge, the pumper or drag-line operator should pay close attention to ensure that the lagoon liner remains intact. If the soil material or the synthetic liner material is being disturbed, stop the activity immediately and do not resume operations until the sludge can be removed without liner injury. If the liner is damaged, it must be repaired as soon as possible.

Sludge reduction alternatives

Several companies in North Carolina offer various lagoon additives intended to reduce the volume of sludge in anaerobic lagoons. These products provide a mix of various microorganisms, enzymes, proteins, or catalysts to stimulate the microbial degradation of accumulated sludge. The Animal and Poultry Waste Management Center at North Carolina State University has evaluated several of these products since 1997. To date, these studies have been unable to demonstrate significant reductions in sludge volume similar to those estimated by product representatives and producers who have been using the products for several years. This may be due to differences in the dosage of product, method of application, type of disinfectant used, or the type of operation where the products were tested. However, because the cost of conventional sludge removal is high, research continues at NC State University into the use of lagoon additives to reduce sludge volume.

Numerous commercial products are available for suspending sludge and solids in the lagoon's liquid. Producers in the Midwest say some of these products are effective. Baker's yeast also can be an effective means of suspending solids. Spread 1 pound of fresh baker's yeast mixed with 1 gallon of lukewarm water (90°–100°F) at a rate of 1 gallon per 75 square feet of liquid surface. After two weeks, agitate and pump the lagoon.

Lagoon closure

Sludge removal is a major consideration when an anaerobic lagoon is to be closed or taken out of service. In addition to the removal of collected solids, the future use of the lagoon must be carefully considered before it can be closed. North Carolina producers should contact their technical specialist, local conservation district, or the Natural Resources Conservation Service (NRCS) for assistance in developing a plan to close a lagoon and in completing an Animal Waste Storage Pond and Lagoon Closure Report Form. As part of this process, the local office of the North Carolina Division of Water Quality (DWQ) must be notified of the scheduled closure two days before sludge is removed. The date and name of the DWQ representative who is notified are required on the Lagoon Closure Report Form. After liquids and sludge are removed, the closure form must be completed and signed by the landowner and a technical specialist, then mailed to DWQ within 15 days of closure. Once the form is received and processed, the lagoon will be removed from DWQ's lagoon registration database, and inspections will no longer be required by representatives from DWQ or the N.C. Division of Soil and Water Conservation.

Lagoon closures must meet the requirements established in the NRCS Technical Guide Standard 709, which states that all reasonable efforts must be made to agitate and remove all waste materials from the lagoon before it can be closed. If the bottom of the lagoon/structure is above the water table at the time of closure, it must be scraped to remove the final amount of sludge. If the lagoon's integrity during scraping comes into question, a qualified technical specialist must determine if the soil stability is suitable to support earth-moving equipment. In the case of lagoons that are not to be scraped and those with bottoms documented to be below the water table at the time of closure, a maximum depth of "agitated" waste material may be left in the lagoon at the time of closure. Contact your local NRCS office or technical specialist for a copy of the standard.

There are three options for managing the earthen lagoon:

- Complete closure and fill.
- Breaching the lagoon berm.
- Conversion to a farm pond.

Complete closure or elimination of earthen storage structure

1. *Contact DWQ within 48 hours of beginning closure.*
2. *Remove lagoon effluent and accumulated sludge.* Effluent and sludge should be pumped from the lagoon and applied to crops according to an approved Waste Utilization Plan.
3. *Remove or plug the outlets of any pipes adding runoff or manure to the lagoon.*
4. *Divert all surface water runoff from the lagoon.* All runoff should be directed away from the lagoon, including water from building roofs, abandoned feedlots, and cropland.
5. *Fill the lagoon with soil.* After pumping away as much liquid and sludge as possible, allow the remaining sludge and solids to dry. If more than about 12 inches of solids remain after pumping, remove them while making every effort to maintain liner integrity. This can be done by agitating and removing liquids at a time when the solids can dry sufficiently to allow earth-moving equipment access to the storage, or by refilling with water, agitating, and emptying again and again, until most of the solids are removed. The lagoon can then be filled with soil by pushing in existing dams or berms and bringing in additional fill as needed. The fill should be mounded in the storage cavity and graded to a 4 percent slope or greater (after allowing for settling) to ensure surface runoff from the lagoon site.

6. *Establish a growing crop or sod.* The final surface should be tilled and planted with vegetation to minimize soil erosion. A crop with a deep root zone, such as alfalfa, is preferred because it can harvest some remaining nutrients.
7. *Complete Lagoon Closure Report Form*. The producer, technical specialist, and a representative of the NRCS or local Conservation District must sign this form. Once all parties sign the form and it is sent to DWQ, within 15 days the lagoon will no longer be recognized as a "permitted" facility.

Breaching the lagoon berm.

1. *Contact DWQ within 48 hours of beginning closure.*
2. *Remove lagoon effluent and accumulated sludge.* Lagoon effluent and sludge should be pumped from the lagoon and applied to crops according to an approved Waste Utilization Plan.
3. *Remove or plug the outlets of any pipes adding runoff or manure to the lagoon.*
4. *Divert all surface water runoff from the lagoon.* All runoff should be directed away from the lagoon, including water from building roofs, abandoned feedlots, and cropland.
5. *Breach the lagoon berm.* After pumping away as much liquid and sludge as possible, allow the remaining sludge and solids to dry. If more than about 12 inches of solids remain after pumping, remove them while making every effort to maintain liner integrity. This can be done by agitating and removing liquids at a time when the solids can dry sufficiently to allow earth-moving equipment access to the storage, or by refilling with water, agitating, and emptying again and again, until most of the solids are removed. A section of the existing lagoon berm or dam can then be removed. The lagoon breach should be low enough on the slope of the dam to allow rainwater to flow from the impoundment and not pond.
6. *Establish a growing crop or sod.* The final surface should be tilled and planted with vegetation to minimize soil erosion.
7. *Complete Lagoon Closure Report Form*. The producer, technical specialist, and a representative of the NRCS or local Conservation District must sign this form. Once all parties sign the form and it is sent to DWQ, within 15 days the lagoon will no longer be recognized as a "permitted" facility.

Conversion to a farm pond

1. *Contact DWQ within 48 hours of beginning closure.*
2. *Remove lagoon effluent and accumulated sludge.* Lagoon effluent and sludge should be pumped from the lagoon and applied to crops according to an approved Waste Utilization Plan.
3. *Remove or plug the outlets of any pipes adding runoff or manure to the lagoon.*
4. *Divert all surface water runoff from the lagoon.* All runoff should be directed away from the lagoon, including water from building roofs, abandoned feedlots, and cropland.
5. *Add an emergency spillway.* A spillway (if one does not currently exist) is required if the pond has an embankment of 3 feet or more. If required, a principal and emergency spillway must be installed according to NRCS Conservation Practice Standard 378 (Ponds).
6. *Complete Lagoon Closure Report Form*. The producer, technical specialist, and a representative of the NRCS or local Conservation District must sign this form. Once all parties sign the form and it is sent to DWQ, within 15 days the lagoon will no longer be recognized as a "permitted" facility.
7. *Rinse the lagoon with water*. Refill the lagoon with water after pumping out all sludge and liquid, and allow it to sit for several months. During the next growing season, agitate and completely empty the lagoon, applying the water based on crop water needs. Nutrient concentration should be minimal by this time and will not be a factor in determining the application rate.
8. *Refill lagoon with water.* Although not required, check the dissolved oxygen (DO) level after the second refill. If levels are less than 3 milligrams per liter of DO, continue the rinsing cycles. If DO levels are higher than 3 milligrams per liter, the earthen structure can be managed as a farm pond. Alternatively, available nitrogen levels can be checked and rinsing continued until available nitrogen levels as measured by a laboratory or a nitrogen meter are less than 30 milligrams per liter of nitrate-nitrogen. Runoff should be allowed to enter the lagoon or fresh water added to maintain the pond nearly full. A high water level is necessary to minimize liner degradation due to burrowing animals or vegetative growth. Water from the new pond should not be used for watering livestock without testing it for pathogens and consulting a veterinarian.

Prepared by
Ronald E. Sheffield, Animal Waste Extension Specialist, Department of Biological and Agricultural Engineering, North Carolina State University
James C. Barker, Professor and Extension Specialist, Department of Biological and Agricultural Engineering, North Carolina State University
Karl A. Shaffer, Extension Associate, Department of Soil Science, North Carolina State University

Worksheet 1. Calculating sludge storage volume for existing lagoons.

Example: *A 3,720-head hog finishing farm has a lagoon that is 600 feet long, 205 feet wide, and 12 feet deep. The average weight of each hog is 135 pounds. The Waste Utilization Plan states that 753,300 cubic feet are allocated as the permanent treatment volume. The lagoon has an inside slope of 3:1. The producer takes 10 sludge depth measurements from various points around the lagoon. The average sludge depth is 3.8 feet. Is it time to remove sludge from the lagoon?*

	Example	Your Lagoon
A. Permitted ***Steady State Live Weight*** (SSLW) or Average Live Weight (ALW). (Multiply number of animals by average weight.)	***502,200 (lbs.)***	***(lbs.)***
B. ***Permanent Treatment Volume*** (cubic feet) (Divide gallons by 7.481 to get cubic feet, if needed.)	***753,300 (cu.ft.)***	***(cu.ft.)***
C. Divide **A** into **B**. If **C** is more than 1.0, then go to **D**. If **C** is less than 1.0, the Permanent Treatment Volume is less than recommended levels. Contact your technical specialist or NRCS representative to discuss options.	***1.5***	
D. Subtract **A** from **B**. This is the volume of Available Sludge Storage for minimal manure treatment.	***251,100 (cu.ft.)***	***(cu.ft.)***
E. ***Average Sludge Depth***. Average of a minimum of 10 random depth measurements from around the lagoon.	***3.8 (ft.)***	***(ft.)***
F. ***Inside Slope of the lagoon***.	***3***	
G. ***Lagoon Depth***. Measured from the top of the embankment to the bottom of the lagoon.	***12 (ft.)***	***(ft.)***
H. ***Lagoon Length***.	***600 (ft.)***	***(ft.)***
I. ***Lagoon Width***.	***205 (ft.)***	***(ft.)***
J. ***Bottom Length***. Calculate: (**H** - 2 * **F** * **G**)	***528 (ft.)***	***(ft.)***
K. ***Bottom Width***. Calculate: (**I** - 2 * **F** * **G**)	***133 (ft.)***	***(ft.)***

L. ***Average Sludge Volume.*** Calculate using the equation below.

$$V_{sludge} = {}^{4}/_{3} F^2E^3 + (FJE^2) + (FKE^2) + (JKE)$$

Hint

1. Multiply: (4 * **F** * **F** * **E** * **E** * **E**) then divide by 3.	***658.46*** *1*		
2. Multiply: (**F** * **J** * **E** * **E**)	***22,872.96*** *2*		
3. Multiply: (**F** * **K** * **E** * **E**)	***5,761.56*** *3*		
4. Multiply: (**J** * **K** * **E**)	***266,851.20*** *4*		
5. Add: 1 + 2 + 3 + 4	***296,144.18*** *5*	***296,144 (cu.ft.)***	***(cu.ft.)***
M. Compute D minus L.		***-45,044 (cu.ft.)***	***(cu.ft.)***

Negative values in step **M** indicate that sludge accumulation may be compromising lagoon treatment efficiency and sludge should be removed.
Positive values in step **M** indicate that sludge volume has not exceeded available storage. Monitor sludge depth and recalculate step **L** annually.

5,000 copies of this public document were printed at a cost of $1,455.00 or $.29 per copy.

Published by
NORTH CAROLINA COOPERATIVE EXTENSION SERVICE

5/00—5M—JL/GM AG-604

E00 38814