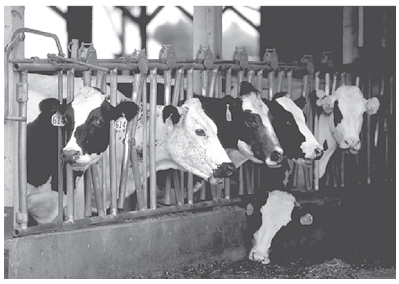
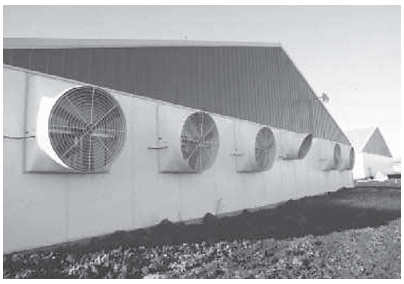
Lesson 23

Manure Storage Construction and Safety, New Facility Considerations

By Charles Fulhage and John Hoehne, University of Missouri





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Intended Outcomes

The participants will

- Understand the sealing concepts, compaction, and practices necessary to obtain a target permeability rate in earthen manure storage structures.
- Understand the basic structural considerations for constructed manure storage.
- Appreciate the need for safety plans and considerations in manure storage.

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Activities

- Review/identify acceptable soil types for earthen impoundments.
- Identify applicable NRCS soil permeability groups.
- Identify and discuss standard practices and testing to obtain sealing and structural integrity.
- Complete a compliance checklist for applicable seepage/permeability requirements, safety aspects, fencing, and signage requirements.

PROJECT STATEMENT

This educational program, Livestock and Poultry Environmental Stewardship, consists of lessons arranged into the following six modules:

- Introduction
- Animal Dietary Strategies
- Manure Storage and Treatment
- Land Application and Nutrient Management
- Outdoor Air Quality
- Related Issues

Note: Page numbers highlighted in green are linked to corresponding text.

Introduction

Decisions made during the design and construction of a manure storage are critical to the environmental risk associated with such a facility. Sound decisions relative to siting a facility and selection of soil materials to be used in the liner of an earthen structure are essential to minimizing the environmental impact of a storage structure. It is important to obtain good advice relative to these critical geological and engineering issues. In many circumstances, the services of a professional engineer or consultant should be used to address these questions. The following lesson provides an overview of these issues. In addition, producers can evaluate their own existing or proposed facility with the aid of the Environmental Stewardship Assessment for design and construction (Appendix C, Lesson 20).

Regulatory Considerations for Siting and Constructing Manure Storage Facilities

Many states have regulations that impact the siting and constructing of manure storage facilities. Become familiar with the regulations in your state as they apply to these considerations for manure storage structures. Table 23A-1 in Appendix A contains some typical manure storage facility siting and construction issues that regulations in your state may address.

Check for state regulations that may influence the location and construction of your manure storage facility.

Siting Considerations for Earthen Impoundments

The use of soils to construct earthen impoundments for manure storage requires investigation and evaluation procedures beyond those that might be used in siting a facility constructed of concrete or steel. To preserve environmental integrity, the variability of soil materials and the need for the soil itself to provide an essentially impermeable barrier requires that an extensive examination be made of the geological characteristics of the proposed site.

Geological investigation

Siting of an earthen manure storage facility should begin with a geological investigation. Such an investigation will assess the surface and subsurface geological characteristics that might negatively impact groundwater. These characteristics may include land slope, topography (i.e., upland, alluvial plain), bedrock, soil types, streams and aquifers, collapse potential, and others deemed pertinent by the investigator. The report will outline any applicable site limitations and may include construction recommendations such as compaction procedures, rock excavation, more detailed soils investigation, or other recommendations. Appendix B contains sample report forms for a geological investigation.

Many states have a Division of Geology and Land Survey staffed by geologists qualified to perform site investigations for manure storage facilities. This service may be available at no cost to the producer. Contact the state regulatory agency for information regarding geologic investigations. Qualified professional geologists or engineers may also perform geologic investigations.

Separation distance requirements

Earthen manure storage impoundments may be subject to regulatory separation distances that might impact a proposed site. Check local and state requirements to ensure that a particular site satisfies separation distance requirements.

Buffer distances. Buffer distances, if required, are usually intended to reduce the impact of a manure storage facility on non-owned dwellings, businesses, and public entities such as parks and churches. The magnitude of these distances is usually dependent upon the size of the livestock enterprise (animal units), and the distance is usually measured from the manure storage structure to the nearest non-owned residence, public building, or entity. Public notice to neighbors within a certain distance (for example, within 1.5 times the applicable buffer distance) may be required by the regulatory agency if an operation is required to obtain a permit.

Groundwater and surface water. Separation distances may be required for groundwater and surface water features. A given vertical separation (for example, 4 ft) may be required between the bottom of an earthen storage facility and the seasonally high water table. Separation requirements may also exist for manure storage structures and water supply facilities such as wells, reservoirs, or ponds. Check applicable local or state codes for any required separation distances.

Flood plain. Locating a manure storage structure in a flood plain presents several potential hazards. The facility may be inundated and structurally compromised due to flooding. Manure may be displaced from the facility by floodwater and become an environmental liability. Floodwater can exert unbalanced hydraulic pressure inward on earthen impoundments if the manure level inside the basin is lower than the water level outside the basin. Such unbalanced pressure may impair seal integrity and compromise the structural integrity of the impoundment.

A geological investigation, along with test borings, provides important information on the suitability of a manure storage site.

Test borings

Conducting test borings may be the most important pre-construction activity in siting and constructing an earthen manure storage facility. Some states may require that test borings be taken and analyzed as a condition for issuance of a construction permit. Test borings yield important information on subsurface soil type, depth to groundwater, depth to bedrock, presence of sand or gravel, and other geological characteristics. Test borings are usually taken to the proposed excavated depth of the impoundment plus some additional distance (for example, excavated depth plus 4 ft) to ensure sufficient material is available between the impoundment bottom and any unknown sensitive geologic feature or condition.

The number of test borings necessary depends upon facility size and the inherent variability of geologic features (varying soil types, presence of rock, sand lenses) at a particular site. Generally, a minimum of four test borings is recommended. Test borings may be performed by Natural Resources Conservation Service (NRCS) personnel as a service to the landowner. Geotechnical firms in the private sector also have expertise and equipment to conduct test borings. Soil samples acquired through test borings may be analyzed in the laboratory for more detailed information such as soil classification, sieve analysis, maximum density, Atterburg limits, plasticity index, and permeability.

Soils Considerations for Earthen Impoundments

Many natural soils will tend to partly seal due to manure solids plugging pore spaces between soil particles. Chemicals (salts) in manure tend to disperse soil particles, which reduces permeability. Soil structure may be altered by biological processes as manure is degraded. Although manure does provide some sealing in most soils, this effect should not be expected to provide sufficient sealing to protect groundwater or to attain a target permeability rate by itself. The allowable seepage rate for waste storage impoundments is regulated in most states. A soil permeability coefficient of 10^{-7} cm/s (1.25 inches/year) is commonly used in state regulations. Many technical considerations are necessary for a complete evaluation of a soil material for earthen manure storage impoundments. The NRCS, through extensive laboratory research and field experience, has developed standards and recommendations for earthen storage impoundments. The following discussion outlines some of these standards and recommendations.

Seepage, permeability, Darcy's law

Darcy's law is the primary model used to design and evaluate the effectiveness of liners in earthen manure storage facilities. Darcy's law relates the amount of seepage expected to occur to particular soil characteristics (permeability), liner thickness, and depth of manure in the impoundment. In simple terms, Darcy's law can be described as follows:

$$v = k\,(H + d)/d$$

v = Amount of seepage through unit area of liner
k = Permeability coefficient of soil liner (often required to be 10^{-7} cm/s)
H = Depth of manure in impoundment
d = Thickness of liner

As can be seen in the above equation, increasing the liquid depth (H) increases the amount of seepage (v) through the liner. Conversely, increasing liner thickness (d) decreases the amount of seepage through the liner. A larger permeability coefficient (k) results in greater seepage, while a smaller (k) reduces seepage. The permeability coefficient depends on the particular characteristics of the soil material used for the liner. Soils in Group I (see next section) generally have a high permeability coefficient, while soils in Group IV have a low permeability coefficient. The permeability coefficient can often be modified (reduced), if needed, by adjusting soil moisture, increasing compaction, and/or adding an amendment such as bentonite or soda ash to the soil liner.

In using Darcy's law to design a liner for a manure storage structure, the engineer will usually assume an acceptable seepage (v), and the depth of liquid in the impoundment is known or assumed from other design and site conditions. A value of (k) is determined by analysis of the soil to be used for the liner. This analysis is usually performed by a qualified soil scientist, and in some cases, may be performed in a more detailed manner by a soil mechanics laboratory. The engineer then uses this information to calculate a minimum liner thickness to achieve the acceptable seepage rate.

Manure impoundment liners constructed of soil may be tested after

Required liner thickness depends on acceptable seepage rate, soil permeability characteristics, and manure depth according to Darcy's Law.

construction to ensure that the design goals are achieved. A core sample of the constructed liner can be removed and tested for permeability by a qualified soils laboratory. Alternatively, "in-place" tests may be used as an indicator of the permeability rate of the completed liner. In-place tests commonly include one of the following:

- Drive cylinder
- Sand cone
- Rubber balloon
- Nuclear density
- Barrel

The first three tests involve removing a precisely measured volume of soil from the liner and determining its in-place density. This density is an indicator of the degree of compaction and attainment of the acceptable seepage rate based on liner design and construction practices. The nuclear density test utilizes radioactive methods to determine in-place density. No soil is removed from the liner, although a probe is inserted into the liner to perform the test. The nuclear density test is more convenient to perform than the test involving removal of a volume of soil from the liner. The barrel test is a water-balance test in which the impoundment is filled with water and a barrel filled with water is placed within the impoundment. Water levels in the impoundment and barrel are closely monitored to determine if excess seepage is occurring. An advantage of the barrel test is that it is a direct measurement of seepage. Disadvantages include the requirement that the impoundment be filled to run the test. Additionally, climatic conditions such as high temperatures (evaporation effects) and rainfall/runoff can complicate the water balance. Also, the barrel test may require a relatively long period (30 days or more) to obtain meaningful data.

Group I and II soils may not have enough clay for a suitable liner, while Group III and IV soils can usually attain the target permeability rate with proper construction practices.

Soil permeability groups

The NRCS groups soils into four categories according to the permeability of the particular soil. Table 23-1 shows the four permeability groups and the particle size characteristics of each group. Group I soils (most often

Table 23-1. Grouping of soils according to their estimated permeability.

Group	Description	Potential for Constructing a Liner
I	Soils that have less than 20% passing a no. 200 sieve and have a plasticity index (PI) less than 5.	Poor
II	Soils that have 20% or more passing a no. 200 sieve and have PI less than or equal to 15. Also included in this group are soils with less than 20% passing the no. 200 sieve with fines having a PI of 5 or greater.	Poor to fair. May be possible to construct a liner with special practices.
III	Soils that have 20% or more passing a no. 200 sieve and have PI of 16 to 30.	Fair to good with a few possible exceptions. May require some special construction practices.
IV	Soils that have 20% or more passing a no. 200 sieve and have a PI of more than 30.	Good, with a few possible exceptions.

associated with sands) have high permeability and may not attain the target permeability rate, even with the sealing effects of manure. Group II soils (most often associated with silt loams) are less permeable than Group I but do not have sufficient clay content to be classed with Group III. Group III soils have low permeability, and with a few exceptions, can attain the target permeability rate. Group IV soils are the least permeable and can usually easily attain the target permeability rate. However, their blocky and fissured structure can result in cracks if allowed to dry. Seek the assistance of a qualified individual to classify a particular soil into the proper soil permeability group. The county soil survey reports available from NRCS can provide general information on the suitability of soils for earthen manure impoundments (see activity at the end of this lesson).

Most soils in Groups III and IV will attain a permeability of 10^{-6} cm/s or less with proper construction practices. The sealing effect of manure will typically further decrease permeability at least one order of magnitude (to 10^{-7} cm/s), which is acceptable in most cases.

Soil tests and specifications

Some states may require certain tests for soils used in liner construction for earthen impoundments. These tests may provide the regulatory agency with information deemed necessary in issuing permits or other documentation verifying that adequate facilities will be constructed. Table 23A-2 in Appendix A contains shows some of the soil tests commonly used in constructing earthen liners.

The tests and analyses described in this table may or may not be required in your state. Contact your regulatory agency or a qualified professional for assistance in determining what tests and analyses are required. The tests should be performed by a qualified soil laboratory so that the results are acceptable to the regulatory agency.

Some states have certain specifications for soils to qualify as liner material. Table 23-2 lists some specifications commonly used for accepting a soil as a liner material.

All, some, or none of the tests and specifications described in the tables may be required by your state regulatory agency. Regardless of regulatory requirements, these tests and specifications represent good practice in the design of earthen manure impoundments, and consideration should be given to performing at least some of these tests to ensure that water quality will be protected. If questions, controversy, or litigation arises concerning the integrity of a manure storage structure, a documented record of these tests can be valuable in demonstrating that proper design and construction practices were followed.

Plasticity index, Proctor density, permeability coefficient, particle size analysis, and Unified Soil Class are characteristics and specifications often used in determining a soil's suitability as a liner.

Table 23-2. Some specifications commonly used to qualify soils as acceptable liner materials.

Specification	Required in my State	
Soil classified as CS, CL, CH, GC, or SC according to the Unified Soil Classification System	__Yes	__No
More than 50% of soil particles pass through a no. 200 sieve	__Yes	__No
Liquid Limit greater than or equal to 30	__Yes	__No
Plasticity Index greater than or equal to 20	__Yes	__No
Coefficient of permeability less than or equal to 10^{-7} cm/sec when compacted to 90% of Proctor density	__Yes	__No
Minimum liner thickness of 12 inches	__Yes	__No

For earthen manure impoundments, the presence of shallow groundwater, fractured bedrock, or excessively porous soils may dictate that a liner be constructed.

Clay liners constructed with suitable clay soils are the most common method of providing reduced seepage in earthen impoundments.

Evaluation of the soil profile for earthen impoundments

The attainment of a target permeability rate requires a careful evaluation of the soil material available at the construction site. The natural soil at the excavated boundary of an earthen impoundment may possess suitable properties that will provide adequate sealing or may require some processing or amendment to provide adequate sealing. The following conditions suggest the need to consider potential seepage reduction through implementation of an impoundment liner:

- An underlying aquifer is at a shallow depth and not confined, or the aquifer is a water supply via a well or spring.
- The excavation boundary of the impoundment is underlain by less than 2 ft of soil over bedrock. Bedrock near the surface is often fractured or jointed, and these openings can provide nearly direct conveyance of pollutants to groundwater. Even soil liners may not be adequate to ensure against seepage in extreme cases of fractured bedrock. Some types of bedrock (low permeability, structurally sound) may not pose a seepage hazard, but these characteristics may be difficult to determine.
- The excavation boundary is underlain by soils in Group I. The sealing effect of manure will likely not be sufficient for soils in Group I, and a liner should be used.
- The excavation boundary is underlain by some soils in Group II or problem soils in Groups III or IV. Group II soils may or may not require a liner. Testing of the soil or correlation with performance at other sites in the area can determine the need for a liner. Excessively flocculated, blocky, and highly plastic clay soils in Groups III and IV may require a liner. Often a liner may be constructed by treating a determined thickness of undesirable soils occurring at the excavation boundary.

Some states may require the construction of a liner of specified thickness and permeability regardless of the profile conditions noted above.

Clay liners. Compacted clay liners are the most common method of providing seepage reduction and ensuring that a target permeability rate is attained in earthen impoundments. Such liners can often be developed using the soils existing at the excavated grade. The thickness of a compacted clay liner is determined based on the permeability of the soil material and the hydraulic pressure (head) of water in the impoundment. Often, a minimum thickness of 1 ft is recommended for clay liners.

Since a clay liner represents a seepage barrier of only finite thickness, consideration must be given to conditions and practices that might cause this thickness to be compromised.

1. Underlying soil. The underlying soil must be capable of supporting the liner without piping, or movement of the liner material into the soil below. This condition can occur if underlying material is very coarse, such as poorly graded gravels or sand.
2. Mechanical damage. Clay liners in manure impoundments must be protected against possible damage by agitation of the manure, excessive velocities at inlet pipes, or other practices that might compromise the integrity of the seal.
3. Collapse potential. In extreme cases (karst, sinkhole regions), bedrock fractures may be large enough to allow the overlying soil to collapse

when sufficient hydraulic pressure is applied, as might be the case with a manure impoundment. This represents, perhaps, the most hazardous possibility for groundwater contamination because large amounts of manure can flow into the groundwater in a very short length of time. Some states do not permit earthen manure impoundments, regardless of design, in areas with collapse potential.

4. Puncture. Since a liner is relatively thin, it must be protected from puncture during and after construction. Animal traffic, rocks, stumps, and roots can cause puncture opening in a clay liner. Carefully clearing the subgrade of these materials prior to liner construction is necessary.
5. Drying. If a clay liner is allowed to dry out, shrinkage cracks may occur, and permeability will be compromised. Measures should be taken after a liner is constructed to maintain proper moisture content until the liner is submerged. Consideration might be given to placing an "insulating" soil cover over the liner to minimize drying. Some states require a minimum liquid depth to be maintained over the liner to prevent drying.

Soil amendments. Some manure storage sites may not have suitable on-site soil materials for constructing a clay liner. In these cases, a soil amendment that modifies the existing soil properties may provide a means to attain the required permeability.

The most common soil amendment used in such cases is sodium bentonite. Sodium bentonite is a volcanic clay that swells to about 15 times its original volume when placed in water. When properly mixed with non-clay soils, the resulting mixture will exhibit properties of a clay soil and can attain the required permeability. When a liner is constructed using bentonite as a soil amendment, the bentonite is usually mixed with existing soil at the excavation boundary at the rate of 1 to 3 lbs/sq ft. Minimum recommended thickness for a bentonite liner is 6 inches.

Some soils in Group III containing high amounts of calcium may not attain the required permeability. Soil dispersants containing sodium (soda ash, tetrasodium pyrophosphate, and sodium tetraphosphate) may be used to disperse the blocky structure of such soils so that they attain the required permeability. Recommended rates of dispersant use are 10 to 20 lbs/100 sq ft for soda ash and 5 to 10 lbs/100 sq ft for the phosphates. Minimum recommended thickness for a dispersant liner is 6 inches.

Synthetic liners. Synthetic liners made of reinforced plastics, HDPE, or other synthetic materials may be used as a seepage barrier in some cases. Usually these liners are not as cost effective as a clay liner or liner constructed with soil amendments. However, in some cases soil with the necessary characteristics may simply not be available on-site or within a practical hauling distance. In such cases, a synthetic liner may offer a solution. Installation of such liners may require special procedures such as providing a geotextile or layer of sand below the liner to prevent puncture or tearing by the underlying material. Synthetic liners are usually installed with seams that must be closed by heating or vulcanizing as the liner is installed. The performance characteristics, installation procedures, and maintenance of synthetic liners are highly specific to the particular liner. If you anticipate using a synthetic liner, consult with the liner manufacturer or a qualified individual experienced in synthetic liner selection and installation.

Soil amendments such as bentonite can be used to modify existing soil properties, reducing seepage to target levels.

When soils with the needed permeability characteristics are not available, a synthetic liner may be required.

Construction practices for earthen impoundments

After soils evaluation, construction practices are the most important factor in developing an earthen manure storage facility that will be effective in protecting groundwater. Good construction practices require knowledge of equipment and compaction procedures.

Equipment. Typical earthmoving equipment used in constructing earthen manure storage facilities includes bulldozers and scrapers. Conventional disks or rototillers may be used for reducing soil structure and mixing soil amendments. Compaction equipment includes the hauling equipment, sheepsfoot or tamping rollers, and perhaps smooth rollers.

Liner construction and compaction procedures. Liners are constructed by laying down "lifts" of the desired soil material. A lift is a layer deposited (usually by a hauling scraper) on the bottom or sides of the impoundment. The thickness of a lift is an important factor in developing a liner with the necessary permeability characteristics. The thickness of a lift should allow nearly complete penetration of the teeth on a tamping roller to the compacted lift or soil below. If smooth rollers or wheeled compaction equipment is being used, the lift thickness should allow complete compaction through the vertical profile of the lift. A "loose lift" thickness of 9 inches compacted to a thickness of 6 inches is typically effective in providing the desired compaction.

Liners should be constructed in "lifts," and each lift should be compacted with the appropriate equipment to attain the target permeability rate.

Lifts are usually placed using one of two approaches. With the "bathtub" approach, a continuous thickness of liner material is compacted up and down or across the inside slopes and bottom of the impoundment. With the "stair-step" approach, the liner material is compacted in a series of horizontal lifts on the inside slopes of the impoundment. Figure 23-1 illustrates these two approaches. The bathtub approach is preferred due to the fewer lifts required but is limited to slopes of 3:1 or less. Steeper slopes result in shearing of the soil because equipment tends to slide on the slope. The stair-step approach can be used on a steeper slope, but the greater number of lifts may provide more pathways for seepage between lifts if adequate bonding is not present.

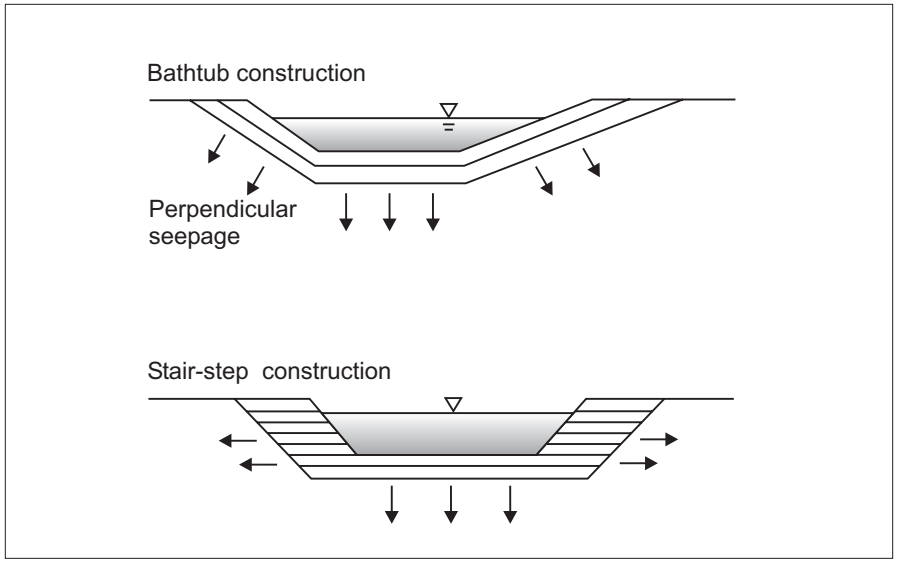

Figure 23-1. Methods of linear construction.
Source: Adapted from the NRCS Agricultural Waste Management Field Handbook 1996.

Lifts should be staggered and/or placed in alternate directions to minimize the possibility of creating preferential flow paths where lift edges coincide.

Compaction procedures are perhaps the most important mechanical operation in construction of an earthen manure storage impoundment. The combination of proper soil types or amendments along with compaction provides confidence that the desired permeability goal will be reached. Compactive energy depends upon the number of passes made, weight of the roller, thickness of the lift, and other factors. Roller weight should be sufficient to provide penetration of the tamping teeth to the compacted lift. Enough passes should be made to attain coverage, break up soil structure or clods if needed, and provide full compaction of the lift. Additional passes cannot substitute for a tamping roller of insufficient weight.

Tamping rollers, depending on size, typically provide contact pressures of 200 to 400 lbs per square inch. The number of passes required to attain the desired compaction depends upon many site-specific factors. Generally, four to eight passes with contact pressures in the 200 to 400 lbs per square inch range will provide sufficient compaction. The length and "footprint" shape of tamping roller teeth should be appropriate for the roller size and weight. Teeth should be long enough to penetrate to the compacted lift below with the weight of roller used. Tamping rollers operated at excessive speed can cause shearing of the soil being compacted, resulting in higher permeability. Rubber-tired or smooth wheeled rollers rather than tamping rollers should be used for compacting bentonite-treated liners. Tamping rollers can cause dimpling and reduced thickness on this type of liner.

A qualified professional should supervise the construction, ensuring that the contractor follows the proper and specified construction practices, providing evidence, if needed at a later date, that proper procedures were followed.

Constructed Manure Storage Facilities

Constructed manure storage facilities include stackhouses for poultry litter, concrete or steel manure tanks, and other possibilities. These types of storage facilities are more likely to be "pre-engineered" packages, and thus may be less subject to specific design and/or construction procedures by the livestock producer. If a constructed manure storage facility is contemplated, the producer should identify potential suppliers who have a proven product and have demonstrated expertise in the necessary sizing and construction procedures. Constructed manure storage facilities may be an alternative where severe geological limitations (gravel, permeable soils, collapse potential) would preclude an earthen impoundment. Constructed facilities are usually not intended to store highly dilute manure or manure containing runoff from lots due to their higher cost per unit of storage compared to earthen impoundments.

Constructed manure storage facilities are usually used to store slurry manure, which contains minimal lot runoff or dilution water. Constructed facilities may be required if soil characteristics are not suitable for an earthen impoundment.

Concrete structures

Manure storage facilities are often constructed using concrete as a material due to its strength and durability. A professional engineer or other qualified consultant should be engaged to assist in the design of concrete manure storage structures. Structural considerations and specific construction techniques and procedures require extensive technical knowledge and expertise. The MidWest Plan Service publication *MWPS-36, Concrete*

Manure Storages Handbook is an excellent reference on concrete manure storage structures.

Below-ground concrete structures must be designed to withstand the inward pressure of saturated soil when that pressure is unbalanced, i.e., the tank is empty and there is no outward pressure by manure. Additionally, surcharge loading due to heavy equipment operating in close proximity to the tank wall must be considered. Below-ground tanks can experience unbalanced uplift forces when the soil outside the tank is saturated and the tank is empty. Provide adequate foundation and perimeter drainage around the tank to minimize this possibility. In selecting a tank configuration, consider agitation and pumpout requirements, and the possible need for partitions or supporting walls within the tank itself. Vigorous agitation of slurry manure tanks is usually necessary for complete cleanout. Such agitation may not be achievable at distances greater than 40 ft to 60 ft from the agitating device. Provide adequate safety barriers such as grills over tank openings to prevent accidental entry of humans or animals into the tank.

Concrete manure tanks may be an ideal alternative when earthen storages are not suitable. The tanks must be designed to withstand the pressure from the manure inside and from the soil outside.

Aboveground concrete tanks may be of poured, stave, or precast panel construction. A circular configuration is the most efficient structural design, and circular tanks may be constructed up to 120 ft in diameter and 20 ft deep. Rectangular tanks are generally limited to 8 ft to 12 ft depths and unbraced wall lengths of 40 ft to 50 ft due to structural requirements.

Steel structures

Pre-engineered manure tanks made of plastic or glass-coated steel are an alternative to concrete tanks. Such tanks are usually circular and are available only in certain sizes. The size should be selected to provide the storage period desired according to the methods outlined earlier. Consult with a qualified manufacturer or design expert when selecting and constructing a steel tank.

Accessories

Constructed tanks may require certain accessories for loading, agitation, and unloading. Some tanks may be loaded (top or bottom) via a pump in an adjacent reception pit. Dedicated ports, or openings, may be required to properly agitate a constructed manure tank. Tanks in buildings (slatted underfloor pit) will require special consideration for agitation and emptying. Open tanks exposed to rainfall will be required to store the extra volume. A roof or covered tank will divert this extra "clean" water and reduce the amount to be handled in the manure management system.

Accessories to facilitate loading, agitating, and unloading must always be considered in implementing a constructed manure storage facility.

Safety in Manure Storage Facilities

As livestock operations become larger and numbers of employees more numerous, safety becomes a critical issue in manure storage.

Signage and fencing

Manure storage facilities should always be equipped with a fence or other barrier to prevent accidental animal or human entry. Earthen impoundments should be fenced to exclude animal traffic but still permit entry with pumping equipment. Install signs that will alert uninformed individuals that a potential hazard exists. Removable grills should be installed over pumping and

agitation openings. Railings around pump docks and access points will provide protection during agitation and cleanout.

Toxic gases

Stored manure generates toxic gases such as hydrogen sulfide that can accumulate to hazardous levels under certain conditions. When stored manure is agitated, these gases are released at potentially toxic concentrations. Humans or animals should not be near a tank or in a building where manure is being agitated. If removal of animals is not possible, provide maximum ventilation of the building either by operating all ventilating fans or opening all doors and ventilating curtains. ***Do not allow anyone to enter a manure tank without a self-contained breathing apparatus and use the "buddy system."***

Secondary containment

Secondary containment structures can reduce the possibility of environmental impact due to a "spill," or malfunction of the manure collection transport system. Examples of possible malfunctions include plugged or broken sewer lines, discharge of manure through cleanouts, and broken recycle lines. A secondary containment system designed to catch runoff from the building and manure storage area offers increased protection in the event of a malfunction. Accumulated runoff in the secondary containment facility is tested for contaminant levels. If levels are below a certain threshold, the accumulated runoff may be discharged from the facility. If contaminant levels are above the threshold level, the effluent must be handled through the manure management system. Some states may require secondary containment structures, depending on the size of the facility.

Safety is an extremely important consideration in the design and operation of a manure storage facility.

Using County Soil Surveys to Evaluate Suitability of Soils for Earthen Impoundments

The NRCS in many states has completed soil surveys on a county-by-county basis. As the following example illustrates, these soil surveys contain information that can be useful in evaluating soils for earthen impoundments.

In summary, the soil survey indicates that this soil may be suitable for an earthen manure impoundment. The sieve analyses and plasticity indices place the soil in the NRCS Groups III and IV, and a liner can likely be constructed that will meet the target permeability rate for earthen manure impoundments. Possible limitations include poor internal drainage, perched water table, and slope.

The soil survey offers general information that may be useful in preliminary evaluation of an area for an earthen manure storage facility. Due to limitations in the depth of the survey profile and the size of the mapping units, the survey cannot substitute for a site-specific investigation. Such an investigation should include a geologic evaluation and soil borings and analyses at the specific location.

A county soil survey report can provide much information needed to evaluate a site's suitability for a manure storage facility.

Participant Activity

Use the soil survey for your county and proposed site to complete the following table and evaluate the soil for an earthen manure impoundment. Discuss the information found in the soil survey.

EXAMPLE

Use the soil survey data for Randolph County, Missouri, to evaluate soil for an earthen impoundment in the southwest quarter of Section 13, Township 54 North, Range 15 West. Discuss the information available in the soil survey as it relates to an earthen impoundment for manure storage.

Step	Information Found		
1. Find general location of site on index to map sheets in soil survey.	Proposed site is on map sheet #6		
2. Find specific location of site on proper map sheet and note soil legend.	Soil legend at proposed site is 26B2		
3. Note soil association or series and general soil properties from soil legend and classification.	Leonard series, silt loam, 2 to 6 percent slope, eroded, deep, poorly drained, slowly permeable soils on uplands.		
4. Determine general clay content of soil from Table 16-Physical and Chemical Properties of the Soils in the soil survey report.	**Depth, inches** 0 - 7 7 - 11 11 - 28 28 - 60	**Percent clay** 20 - 35 35 - 45 35 - 45 32 - 45	
5. Determine general susceptibility of this soil to flooding, high water table, and presence of bedrock from Table 17-Soil and Water Features in the survey report.	**Flooding** Frequency—None Duration—N/A Months—N/A **High Water Table** Depth, ft—0.5 to 2.0 Type—perched Months—Nov to May **Bedrock** Depth, in.—> 60 Hardness—N/A		
6. Determine general soil suitability for ponds and embankments from Table 14-Water Management in the survey report.	**Limitations** Pond/reservoir Embankments	Moderate: slope Severe: wetness	
7. Determine USDA soil texture and class according to the Unified Soil Classification System from Table 15-Engineering Index Properties in the survey report.	**Depth, in.** 0 - 7 7 - 11 11 - 28 28 - 60	**Texture** Silt loam Silty clay loam, Silty clay Silty clay, clay silty clay loam Silty clay, clay loam, silty clay loam	**Unified Class** CL CL CH CL, CH
8. Determine percent passing No. 200 sieve and plasticity index from Table 15-Engineering Index Properties in the survey report.	**Depth, in.** 0 - 7 7 - 11 11 - 28 20 - 60	**% Passing no. 200** 85 - 100 85 - 100 80 - 100 75 - 90	**Plasticity Index** 15 - 25 20 - 30 30 - 40 25 - 35
9. Determine the NRCS Soil Permeability Group for this soil as described in Table 23-1 in this lesson.	**Depth, in.** 0 - 7 7 - 11 11 - 28 28 - 60	**NRCS Soil Permeability Group** III III IV III or IV	

Discussion: The soil survey indicates that a deep, poorly drained, slowly permeable silt loam soil with slopes in the 2% to 6% range exists at the proposed site (Step 3). Clay content (Step 4) ranges from 20% to 45% with lower percentages near the surface and higher percentages in the lower profiles. Flooding and bedrock (to a depth of 60 inches) limitations are not likely at this location, although a perched water table may be present during some part of the year (Step 5). Limitations for pond construction are moderate due to slope and may be severe for embankments due to excessive wetness (Step 6). As noted in Step 7, the soil contains a significant clay component throughout the surveyed profile (60 inches). More than 75% of the soil in the surveyed profile passes a no. 200 sieve and plasticity index ranges from 15 to 40.

Step	Information Found
1. Find general location of site on index to map sheets in soil survey.	Proposed site is on map sheet _____
2. Find specific location of site on proper map sheet and note soil legend.	Soil legend at proposed site is _____
3. Note soil association or series and general soil properties from soil legend and classification.	_____
4. Determine general clay content of soil from table of Physical and Chemical Properties of the soil survey report.	**Depth, inches** / **Percent clay**
5. Determine general susceptibility of this soil to flooding, high water table, and presence of bedrock from table of Soil and Water Features in the survey report.	**Flooding** Frequency _____ Duration _____ Months _____ **High Water Table** Depth, ft _____ Type _____ Months _____ **Bedrock** Depth, inches _____ Hardness _____
6. Determine general soil suitability for ponds and embankments from table of Water Management in the survey report.	**Limitations** Pond/reservoir _____ Embankments _____
7. Determine USDA soil texture and class according to the Unified Soil Classification System from table of Engineering Index Properties in the survey report.	**Depth, in.** / **Texture** / **Unified Class**
8. Determine percent passing no. 200 sieve and plasticity index from table of Engineering Index Properties in the survey report.	**Depth, in.** / **% passing no. 200** / **Plasticity Index**
9. As described in Table 23-1 in this lesson, determine the NRCS Soil Permeability Group for this soil.	**Depth, in.** / **NRCS Soil Permeability Group**

Discussion:

APPENDIX A
Regulatory Compliance Assessment Tools

Table 23A-1. Regulatory compliance assessment: Design and construction considerations for manure storage systems.

Regulatory Issue	Is this issue addressed by regulations? If "Yes," summarize those regulations.	Is my livestock/poultry operation in compliance?
Siting Issues		
Are regulatory buffer distances required for a manure storage facility?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are separation distances required to wells, sinkholes, or surface water supplies?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are there required flood plain or water table considerations in siting a manure storage facility?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are there regulated site conditions specific to construction of an earthen manure impoundment?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___Don't Know
Soil and Geology Considerations		
Is a soil evaluation required to construct a manure storage facility?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Is a geologic evaluation below the storage structure required for a manure storage site?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Design/Construction Documents Required		
Are engineering design and construction plans required for a manure storage facility?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are engineering plans required to be prepared and stamped by a registered professional engineer?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Is a Construction Quality Assurance plan required of the contractor and/or designer?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Storage Features		
Are safety requirements such as signage or fencing required for manure storage facilities?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are there secondary containment requirements for unplanned discharges?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know

Table 23A-2. Regulatory compliance assessment: Liner considerations for manure storage systems.

Regulatory Issue	Is this issue addressed by regulations? If "Yes," summarize those regulations.	Is my livestock/poultry operation in compliance?
Liner Information Requirements		
Are there specific requirements for liner construction?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are there permeability or seepage limits?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are there pre-construction requirements for permeability testing of soils to be used in liner construction?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
Are there post-construction requirements for permeability or seepage testing of completed liner?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know
For an existing non-permitted facility, are their requirements for documenting permeability or seepage rate?	___ Yes ___ No If Yes, summarize:	___ Yes ___ No ___ Not applicable ___ Don't Know

Liner Testing Requirements

Test or Analysis	Description	Required by my State	Regulatory Limit
Liquid Limit (LL)	Minimum moisture content of soil/water mixture at which mixture behaves like a liquid (can be stirred).	Pre-construction? __Yes __No Post-construction? __Yes __No	
Plastic Limit (PL)	Minimum moisture content of soil/water mixture at which mixture behaves like a plastic solid (can be rolled into ball or thread).	Pre-construction? __Yes __No Post-construction? __Yes __No	
Plasticity Index (PI)	Liquid limit minus plastic limit. Indicates range of moisture contents that soil behaves as a plastic solid. A larger number is more ideal for constructing a liner.	Pre-construction? __Yes __No Post-construction? __Yes __No	
Standard Proctor density	Maximum density of soil when compacted at optimum moisture. Soils compacted to 90%-95% of Proctor density are least permeable.	Pre-construction? __Yes __No Post-construction? __Yes __No	
Coefficient of permeability	Soil characteristic that defines its resistance to the movement of liquid.	Pre-construction? __Yes __No Post-construction? __Yes __No	
Seepage rate	Combines soil permeability, liner thickness, and pond depth to calculate flow of liquid through soil per unit of pond area.	Pre-construction? __Yes __No Post-construction? __Yes __No	
Particle size or sieve analysis	Divides a soil sample into portions based on particle size. A larger fraction of smaller particles provides better material for a liner.	Pre-construction? __Yes __No Post-construction? __Yes __No	

APPENDIX B
Sample Geological Report Forms

ID# _____

WASTE WATER TREATMENT SITE GEOLOGICAL EVALUATION
MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
BOX 250, ROLLA, MISSOURI 65401 314-368-2160

1. Project _____ County _____

2. Location ¼, _____ ¼, _____ ¼, Sec. _____, T. _____, R._____, Quad. _____

3. Latitude:_____ Deg, _____ Min,_____ Sec. Longitude:_____ Deg,_____ Min, _____ Sec._____

4. Owner _____ Address _____

5. Requested by: _____
_____

6. Previous Reports: Not Applicable: _____
ID# _____ ID# _____ ID# _____ ID# _____ ID# _____
Date: _____ Date: _____ Date: _____ Date: _____ Date: _____

7. (A) Were plans submitted? _____ (B) Was site investigated by NRCS? _____

8. Facility Type: mechanical plant ❑, earthen lagoon with discharge ❑, earthen holding basin ❑, land application ❑, marsh system ❑, other ❑

9. Waste Type: animal ❑, human ❑, process/industrial ❑, leachate ❑, other ❑

General Geology

10. Date of: a. field visit _____, b. soils investigation _____

11. Overall geologic limitations: slight ❑, moderate ❑, severe ❑

12. Topography: 0%-4% ❑, 4%-8% ❑, greater than 15% ❑
On: broad upland ❑, ridgetop ❑, hill slope ❑, narrow ravine ❑, flood plain ❑, alluvial plain ❑, terrace ❑, sinkhole ❑

13. Bedrock: _____
_____
_____

14. Overburden (soil): _____

_____

_____

15. Receiving stream classification: gaining ❑, losing ❑, not applicable (no discharge) ❑

16. Collapse potential: slight ❑, moderate ❑, severe ❑

17. Recommended construction procedures: installation of clay pad ❑, compaction ❑, artificial sealing ❑, diversion of subsurface flow ❑, rock excavation ❑, limit excavation depth ❑

18. Determine overburden (soil) properties: particle size analysis ❑, Atterberg limits ❑, standard proctor density ❑, overburden thickness ❑, permeability coefficient: undisturbed ❑, remolded ❑

19. Determine hydrologic conditions: groundwater elevation _____, direction of groundwater movement _____, 100-year flood level _____

20. Notify geologist: before exploration ❑, during construction ❑, after construction ❑, not necessary ❑

21. Remarks:

*THIS DOCUMENT IS A PRELIMINARY GEOLOGIC REPORT. IT IS NOT A PERMIT. ADDITIONAL DATA MAY BE REQUIRED BY THE DEPARTMENT OF NATURAL RESOURCES PRIOR TO ISSUANCE OF A PERMIT. THIS REPORT IS VALID ONLY AT THE ABOVE LOCATION AND BECOMES INVALID ONE YEAR AFTER THE DATE BELOW.

22. Report by _____ Date _____

23. CC: _____

24. Upper _____, Lower _____

ID# _____

LOSING/GAINING STREAM CLASSIFICATION SYSTEM
MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
BOX 250, ROLLA, MISSOURI 65401 314-368-2160

A. Project _____
County _____
Stream: _____

FROM Location _____ Sec. _____, T. _____, R._____, Quad. _____

_____

Latitude:_____ Deg, _____ Min,_____Sec._____ Longitude:_____ Deg, _____ Min,_____Sec._____

Previous Classification:

ID# _____ ID# _____ ID# _____ ID# _____

Date: _____ Date: _____ Date: _____ Date: _____

1. Valley Development:

A. Cross Section	
V shaped	0
U shaped	1
B. Longitudinal Section	
Consistent gradient	0
Erratic or variable gradient	1
C. Channel	
One flow path well defined	0
Braided, flat-bottomed, rectangular	1
None or sinkholes	4
D. Vegetation in channel	
Limited or willows	0
Dense brush, trees, or weeds	1
E. Sorting/stratification of alluvium	
Well-sorted persistent stratification	0
Poorly developed or none	1

2. Bedrock:

A. Low permeability	0
B. Low permeability below thin weathered zone	1
C. Persistent open fractures and/or moderate to high permeability	2
D. Karst	4

3. Flow Characteristics:

A. Continuous flow, constant, or increasing	0
B. No flow, intermittent flow, or pools	1
C. Continuous flow but is obviously decreasing	2
D. Obvious flow loss	4
E. No flow when adjoining streams have flow	4

4. Depths of Potentiometric Surface:

A. Less than 20 ft	0
B. Greater than or equal to 20 ft	4

5. Structural Deformation (Faults or Folds):

A. Unknown or none within one mile	0
B. Known to occur between ½ mile and one mile	1
C. Known to occur less than ½ mile	2

6. Water Tracing Results:

A. Water remains in channel	0
B. Water loss resurges in alluvial spring(s) or seep(s) downstream in some valley	3
C. Water loss resurges in bedrock spring(s) downstream in some valley or in another watershed	6

7. Stream Gaging (Flow should be at least 0.2 CFS):

A. Gaining during low flow conditions	0
B. Flow decreases less than 30%	0
C. Flow decreases more than 30%	6

TOTAL _____

GAINING: 0-5 _____

LOSING: 6-34 _____

B. Remarks: _____

_____

_____

_____

Investigator:_____ Date:_____ Field Investigations:_____ Dye Trace_____

Upper _____ Lower _____

ID# _____

ASSESSMENT OF EARTHEN LAGOON COLLAPSE POTENTIAL
MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
BOX 250, ROLLA, MISSOURI 65401 314-368-2160

Project _____ County _____

Location _____ Sec. _____, T. _____, R._____, Quad. _____

_____

Latitude:_____ Deg, _____ Min,_____Sec._____ Longitude:_____ Deg, _____ Min,_____Sec._____

1. Stream Classification:

❑ Gaining	0
❑ Losing	4

2. Depth to Water Table:

❑ ≤ 50 ft	0
❑ > 50 ft	4

3. Residuum Thickness:

❑ < 10 ft	0
❑ ≥ 10 and < 40 ft	1
❑ ≥ 40 and < 100 ft	2
❑ ≥ 100 ft	4

4. Predominant Characteristics of the Upper 20 ft of Bedrock and/or Superficial Material:

❑ Solution-free bedrock, glacial drift, or alluvium with gaining conditions.	0
❑ Bedrock with permeable weathered zone 10 ft thick, or minor solution features and/or associated residuum	2
❑ Bedrock with significant solution voids > 10 ft below bedrock surface, and/or residuum with relict bedrock structure, or alluvium with losing conditions	4

5. Proximity of Nearest Sinkhole to the Lagoon:

❑ ≥ 1 mile distant	0
❑ ≥ 1/2 mile but < 1 mile distant	1
❑ ≥ 1/4 mile but < 1/2 mile distant	4
❑ ≥ 500 ft but < 1/4 mile distant	6
❑ Within 500 ft	8

6. Proximity of Nearest Underground Opening to the Lagoon:

❑ No evidence ≥ 1/2 mile distant	0
❑ ≥ 1/4 but < 1/2 mile distant	2
❑ ≥ 500 ft but < 1/4 mile distant	4
❑ < 500 ft but not beneath site	8
❑ Beneath the site	16

7. Surface Area of the Lagoon:

❑ ≤ 1 acre	1
❑ > 1 acre and ≤ 2 acres	2
❑ > 2 acres and ≤ 3 acres	3
❑ > 3 acres and ≤ 4 acres	4
❑ > 4 acres	5

8. Maximum Operating Depth of Liquids:

❑ ≤ 5 ft	1
❑ > 5 ft and ≤ 10 ft	2
❑ > 10 ft and ≤ 15 ft	3
❑ > 15 ft and ≤ 20 ft	4
❑ > 20 ft	5

TOTAL _____

Slight Potential: Total 2 to 9

Moderate 9-22

Severe > 22

Remarks:_____

_____

_____

_____

_____

Investigator: _____ Date:_____

About the Author

This lesson was prepared by Charles Fulhage, Extension Agricultural Engineer, and John Hoehne, Extension Agricultural Engineer–Commercial Agriculture Program, both at the University of Missouri, Columbia, when this lesson was developed. The first author can be reached at the following e-mail address:

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References

Nielson, Robert D., M. DeWayne Mays, Don W. Goss, and Frank Geter, 1996. NRCS Agricultural Waste Management Field Handbook, Chapter 10, p. 10D-10.

Glossary

Darcy's law. Mathematical expression relating the rate of seepage to permeability, liquid depth, and liner thickness.

Earthen impoundments. Basins constructed of soil materials for the purpose of storing and/or treating manure and wastewater.

Flocculated. Particles that clump together rather than remaining dispersed.

Lifts. Layers of soil placed successively to form a liner or embankment.

Permeability. Movement of water through a soil profile.

Permeability rate. Rate at which water moves through a soil profile.

Plasticity Index. Range of moisture contents over which a soil behaves as a plastic solid.

Proctor density. Maximum density of a soil compacted at its optimum moisture content.

Soil amendments. Additives that, when mixed with soil and compacted, reduce the permeability rate.

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Click on road map to return to Contents.

Reviewers

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Livestock and Poultry Environmental Stewardship Curriculum: Lesson Organization

This curriculum consists of 27 lessons arranged into six modules. Please note that the current lesson is highlighted.

Module A. Introduction

1. Principles of Environmental Stewardship
2. Whole Farm Nutrient Planning

Module B. Animal Dietary Strategies

10. Reducing the Nutrient Excretion and Odor of Pigs Through Nutritional Means
11. Using Dietary and Management Strategies to Reduce the Nutrient Excretion of Poultry
12. Feeding Dairy Cows to Reduce Nutrient Excretion
13. Using Dietary Strategies to Reduce the Nutrient Excretion of Feedlot Cattle

Module C. Manure Storage and Treatment

20. Planning and Evaluation of Manure Storage
21. Sizing Manure Storage, Typical Nutrient Characteristics
22. Open Lot Runoff Management Options
23. **Manure Storage Construction and Safety, New Facility Considerations**
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Module D. Land Application and Nutrient Management

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