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DAIRY MANURE MANAGEMENT FROM BARN TO STORAGE

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FARM BUILDINGS & EQUIPMENT TASK FORCE

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History of This Guideline

This guideline is a revision of *Guidelines for Dairy Manure Management*, DPC 27, first published in 1977 through the combined efforts of the Building and Utilities Task Force of the Northeast Dairy Practices Council (now the Dairy Practices Council, DPC) and the Northeast Regional Agricultural Engineering Service (NRAES). Last revised in November 1984, the original guideline replaced NDPC 2, Handling Manure as a Liquid and NDPC 5, Handling Manure as a Solid. The original Guideline was prepared by the Buildings and Utilities Task Force with a. R. Grout serving as subcommittee chair.

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Special appreciation is extended to Stanley Weeks, subcommittee chair of the Farm Buildings and Equipment Task Force, and to the many other individuals who assisted with this revision.

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Guideline for

Dairy Manure Management from Barn to Storage

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SECTION 1: PLANNING, GETTING HELP, AND MEETING REGULATIONS

Planning

It is important to plan ahead for small and large improvements in dairy manure systems to predict the costs, risks, savings, and operating changes that will occur. There are many options; thus careful and objective planning is a key to success.

Planning hints for dairy manure management include

1. Look objectively at your dairy, its future, the sources of manure and wastes, investment in labor versus automation.
2. Decide where and when to spread manure, as affected by soil types, slope, crops, available land, weather, and labor schedule.
3. Consider the options for housing animals and the alternatives for handling equipment, separating solids, creating a soil-amendment material, generating methane, and utilizing manure.
4. Have alternative plans for the unexpected, such as breakdown, inclement weather, vacations, and sickness; avoid special equipment with limited uses.
5. Choose a system that will work for you, recognizing that

- High bedding use fits with solid manure handling.
- Low bedding use is necessary for liquid manure handling.
- Long straw, hay, baling twine, and scrap metal interfere with liquid systems, particularly pumping.
- Sand abrades equipment, and steel scrapers polish concrete.
- Liquid and slurry manure flow faster than solid manure.
- Gravity flow is simpler than mechanical scrapers, but may require more management.
- Moving and lifting liquids with bucket loaders should be avoided.
- Labor and equipment demands for unloading storages are high and concentrated at certain times of the year.
- Unloading and field spreading must be scheduled around tillage, planting, and harvesting priorities.
- You can make any system work, but if you plan a good system in advance, it will work even better.

Guides for planning a manure handling system include

1. Learn about various systems, legal constraints, and favorable and unfavorable experiences of others.
2. Evaluate seriously your present manure handling and predict your future needs.
3. Decide when and where to spread manure, the period and size for storage, and the types and amounts of manure to be collected, transferred, stored, unloaded, transported, and spread.
4. Compare specific alternatives and conflicts, and judge performance.
5. Select your best combination and assemble the components.
6. Operate, manage, maintain, and improve your manure handling for your own and your neighbors' benefit.
7. Assess the cost and return factors carefully and be realistic (do not forget energy requirements).

You can independently collect information and make decisions about manure handling, or your working team can cooperate to make joint decisions that assemble a complete, balanced, and smooth operating system.

Getting Help

Begin with your milk inspector, *milk plant field inspector,* certified milk inspector, or representative of a quality milk program who knows the sanitary and public health regulations. He or she should know about *outstanding dairymen* with recent improvements and about environmental and zoning constraints at your location.

Check with your *Cooperative Extension agent or specialist* for research reports, technical information, successful farmers, and sources of assistance for planning, designing, constructing and managing dairy manure systems. One or more of the county agents may deal with environmental protection and/or water quality programs for your area.

Contact the *Natural Resources Conservation Service, USDA*, for technical assistance and advice. They evaluate soils and site, and design runoff control and manure storage facilities. They also approve plans for cost-sharing projects.

Contact *your county or regional Soil and Water Conservation District;* they are good resources and familiar with state, county, and local regulations.

Determine if an *agricultural consultant* can meet your needs in a timely and cost-effective way.

Survey information from *agricultural periodicals*, farm magazines, and *equipment manufacturers* and distributors.

Meeting Regulations

Check which state and local *government agencies* have jurisdiction or control at your location. Agricultural buildings and facilities may be exempt from state and local building codes but not from local zoning and setback regulations. Regulations to protect the environment also vary among localities and are more restrictive if public water supplies can be polluted. County and state health departments have a legal responsibility for preventing epidemics and improving public health. Environmental resource or conservation agencies try to prevent air and water pollution. *Approval* from an environmental agency and a local building permit, as well as approval *from your milk inspector,* may be *needed before construction.*

Seven simple rules that help meet legal regulations are
1. Keep control of manure and keep it on your own property.
2. Keep manure out of milk, drinking water, and streams.
3. Keep manure and mud off public roads.
4. Conserve manure nutrients and utilize for growing plants.
5. Use manure to increase organic matter and improve water absorption in soils.
6. Minimize the odor nuisance to your family and neighbors.
7. Protect animals and people from potential accidents and health hazards.

Safety

Everyone has an obligation to design, supply, buy, operate, and maintain manure storage and handling systems that are safe for workers and visitors.

! Manure systems present hazards from asphyxiation, poisoning, drowning, and machinery entanglement and entrapment. Pumps, pits, and tanks can easily contain poisonous gases or a lack of oxygen that will not be apparent until someone enters the tank and is overcome. Multiple deaths have occurred as a result of failure to follow appropriate procedures for working in these confined spaces.

SECTION 2: MANURE CHARACTERISTICS AND PRODUCTION

Manure Characteristics

Manure includes the feces and urine from farm livestock. It contains waste products from digestion and other bodily processes and is described as

- sticky (viscous)
- smelly (odorous)
- soupy, normal, stiff, or dry.

These characteristics depend largely on the diet, development, and health of animals. Manure has different characteristics depending on whether it was produced from
• young dairy calves fed mostly milk
• lactating cows with high-energy, high-protein rations
• dry cows and bred heifers eating more dry hay.

Characteristics of manure change with
• time (because of bacterial action)
• temperature (because of drying, bacterial action, freezing)
• added bedding materials and other waste products
• added water and other liquids.

In the case of manure from dairy animals
• The weight ratio of feces to urine is 2.25:1.
• Manure weighs 62 pounds per cubic foot, or 8.3 pounds per gallon (water = 62.4 pounds per cubic foot [PCF]).
• The dry matter content as produced is 13.5%± 0.5% from lactating cows.
• The volatile solids are 83%, and BOD_5 (biochemical oxygen demand—five-day test method) is 13% of the total solids.
• Typical sand-laden manure weighs 10 pounds per gallon, or 75 pounds per cubic foot.

Also see "Common Conversion Factors".

These values are helpful in designing biological degradation systems, manure separators, or methane generators, and also in determining field application rates. Manure is a good source of plant nutrients and organic solids. As produced, manure contains approximately 8.5 pounds Nitrogen, 3.5 pounds $P_2 0_5$, and 5.2 pounds K_2O per ton. Most of this is available for plant usage, except for some of the N that is part of the NH_3 (ammonia), of which some escapes as a gas, depending on how soon it is incorporated into the soil. A program of regular manure sampling and analysis is required in order to get precise nutrient numbers for your situation.

Manure Production

The amount of raw manure produced daily is 8 to 10% of an animal's weight.* Within this range, the amount
• increases with higher feed intake rates
• increases with higher water intake and higher temperatures
• decreases with high-fiber and restricted diets
• decreases with lower water intake and colder temperatures.

The daily production of manure differs among different groups of animals. Table 1 is a guide to the number of animals in a typical dairy herd, average weight, and a production factor for selected groups in a dairy with 100 cows. Please use specific weights, numbers, or adjusted production factors where more accurate information is available. Refer also to "Common Conversion Factors".

In this example, heifers and young stock produce one third as much manure as mature cows and the milking herd produces 62% of the total. The total approaches 8 tons or 250 cubic feet each day without any added bedding, water, or other waste. This slightly exceeds the rule of thumb for a herd with dry cows and replacements, which is

3 cubic feet x number of milking cows = total daily volume in cubic feet

*Classic studies (pre-1975) show 8.2%, but recent measurements from high milk producing groups (20,000+ rolling milk production average) approach 10% of the body weight daily. Other studies indicate litter removed less bedding added in pens of calves was 9.8 to 12.7%.

Effects of Adding Bedding and Water

Bedding is added in stalls and pens to keep animals clean, dry, and comfortable when resting. With an initial moisture content of 10%, common bedding materials (such as shavings, sawdust, or chopped hay and straw) absorb two to three times their initial weight with water. Notable exceptions are inorganic materials (sand, ground limestone, calcite etc.), which may hold only 1/10 to 1/5 of their weight, depending on texture and moisture content.

Adding dry matter or organic bedding materials to manure

- absorbs free liquids and reduces flowability of manure
- increases the dry matter
- improves stackability and bulk handling if enough is used
- can create floating mats and stratified layers in storage ponds
- can cause plugs in manure pipes or channels.

Adding water or liquid wastes to manure

- reduces the solids content and increases flowability
- increases quantity of manure handled
- tends to wash particles when agitated and increase separation in storage
- can create more severe odors in long-term storage
- allows pumping and irrigation if sufficient water is added.

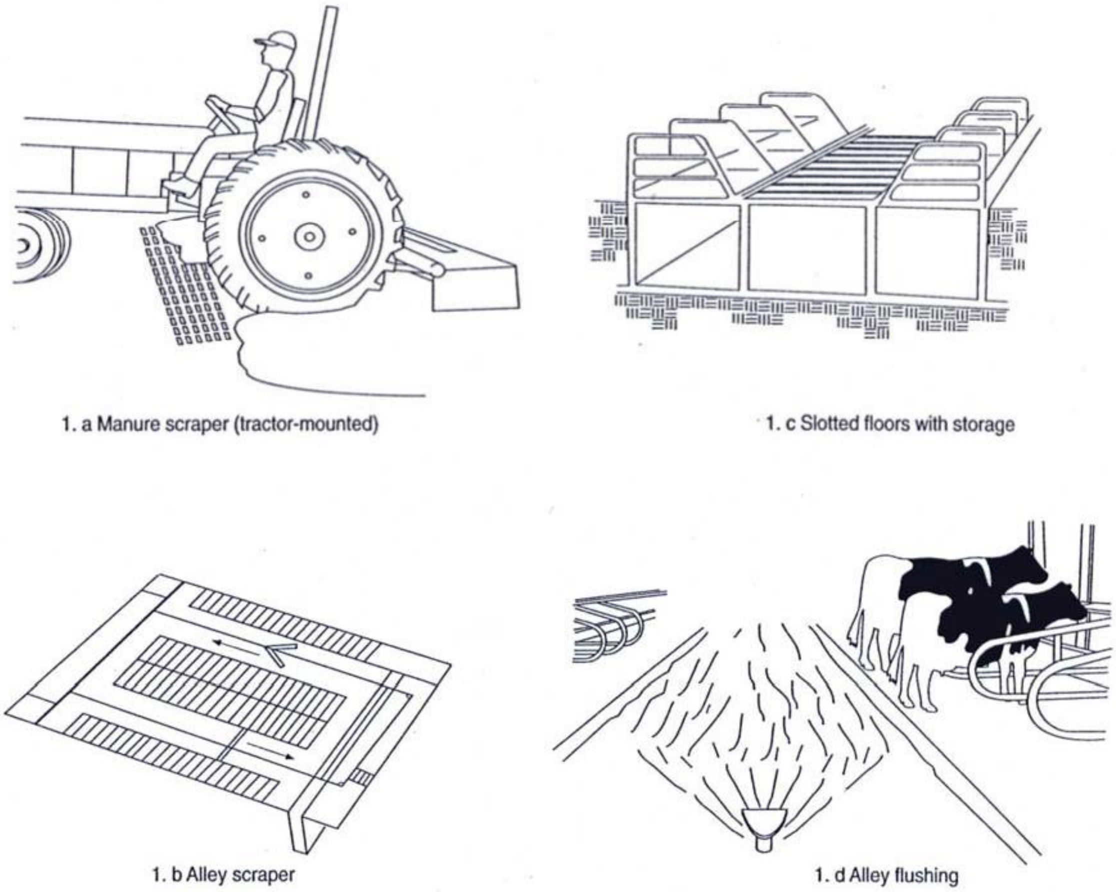
Using sand or inorganic bedding materials

- can keep cows relatively clean and comfortable
- improves traction on manure-covered concrete
- increases wear on manure handling equipment and voids warranties
- increases settling in manure pipes and holding ponds
- results in a lava flow-type material that does not stack
- adds significantly to the tonnage hauled and spread
- may require the use of both a liquid and a solid handling system.

Table 1 Manure production from all animals in a typical dairy herd with 80 milking cows plus dry cows and replacements

Dairy Group	Number	Average Weight	Manure Factor (%)	Daily (Ib)	Production (ft^3)
High milking cows	20	1,350	10.0	2,700	43.6
Mid milk production	40	1,350	8.5	4,590	74.0
Low milking cows	20	1,400	8.2	2,240	36.1
Dry cows	20	1,450	8.0	2,260	36.5
Bred heifers	25	1,000	7.8	1.950	31.5
Young stock	45	500	7.5	1,690	27.3
Total	170	____		15,430	249.0

Figure 1 Manure collection systems



Solids Separation

Many of the problems associated with the handling and the storage of manure slurry containing a high proportion of solid material can be overcome by mechanical separation. The products of separation are an easily handled solid and a readily pumped liquid. The output of liquid and fiber, together with the dry matter content of both fractions, depends on the dry matter content of the raw slurry delivered to the separator and on the separator design. The liquid and fiber contain similar quantities of N, P_2O_5, and K_2O on a per unit weight basis as the unseparated slurry; however, since separation yields two to four times as much liquid as fiber, most of the plant nutrients are in the liquid. Solid separation can be used as a first stage in a biological treatment system.

Separating solids and liquids in dairy manure
- is difficult
- with some separator designs, requires an equal volume of added water to wash the larger fiber particles and dissolve gelatin like materials, doubling the amount of material handled.

Various methods to separate the liquid and solid fractions include
- sloping or vibrating screens
- porous channels or screens with scrapers
- roller, belt, or screw presses
- centrifuges or similar equipment
- draining liquid from settling areas.

After the fibrous or solid portion has been pressed, it
- contains 65 to 80% water

• is similar to finely chopped silage and can be handled as a solid
• after heating (short-term composting) can be used for bedding freestalls
• can be sold as a soil-amendment product.

The liquid fraction
• contains dissolved solids and nutrients in suspension
• contains about 6%settleable solids and dissolve solids
• can be recycled for flushing manure alleys or channels, but not milking barns or holding areas
• is readily pumped and can be irrigated for final land distribution
• will not crust over in storage.

Other Characteristics-Drying and Freezing

Rapid moisture evaporation from manure wetted surfaces
• occurs with any combination of higher temperatures, lower humidity, and rapid air movement
• allows manure to stick to drier surfaces
• influences the performance of gravity flow channels, scrapers, and other handling equipment (see "Manure Collection Systems").

Frozen manure
• freezes at lower temperatures than urine and free water
• remains crystalline at temperatures as low as 14°F (-10°C)
• negatively affects the operation, performance and maintenance of various types of handling equipment.

SECTION 3: MANURE MANAGEMENT ALTERNATIVES

Each manure system has advantages and disadvantages, and no one system is best for all farms. Considerations in choosing a system include investment, labor, convenience, aesthetics, regulations, and personal preference. Developing the best system for a given dairy farm also requires considering the size of the operation, its sources of manure and waste water, its cropping practices, soil types, topography, proximity to neighbors, and other factors.

The manure system should do the following:
1. keep the cows and milking area clean and attractive for sanitary production of wholesome milk
2. prevent contamination of water in lakes, streams, springs, and wells
3. produce minimal odor and fly problems during storage and application to fields
4. allow maximum use of the manure as fertilizer for crop growth
5. minimize hazards to humans and animals
6. save labor and energy during manure handling and field application.

Any plan for, or modification of, a dairy operation should consider all the alternatives for manure management and allow for equipment breakdown, weather and field conditions, vacations, sickness, and future changes in technology or farm management. Alternatives for farm management, housing, and manure handling and disposal should be considered, along with the possibilities of leasing equipment, custom hiring, or sharing equipment with a neighbor. One or several tours or visits should be part of the planning process to see what works for other farmers. Manure handling equipment sales representatives. Natural Resources Conservation Service personnel, county agents, university specialists, and private consultants can also offer ideas. Before any manure handling system is installed in or near a barn where milking takes place, the milk regulatory agency should be notified

Moisture Content and Management Options

The moisture content of manure partially determines how it can be handled and stored. The manure produced in dairy calf, heifer, and cow barns varies in moisture content, depending on the feed ration and the amount and type of bedding used. Cows in freestall, tie-stall, and bedded-pack barns require about 4, 8, and 14 pounds of bedding per cow per day, respectively. The manure can be classified according to three consistencies: solid (16% or more solids), semisolid (12% to 16% solids), and liquid (12% or less solids). Figure 1 illustrates some of the collection systems commonly used to handle dairy manure; see "Evaluating Manure Storage Options" for a discussion of which storage systems can be used with each type of manure.

Solid manure contains considerable fibrous bedding and is easily handled with a front-end loader and conventional manure spreader. In most cases it can be stacked. Excess water (e.g., from leaking self-waterers or runoff from roofs) must be kept out of the manure.

Semisolid manure generally contains some bedding and can be handled with a front-end loader and a conventional or flail spreader. It will flow to some extent, but is too thick to agitate and pump from storage with liquid manure handling equipment. Increased amounts of bedding make semisolid manure more solid. Precipitation and groundwater should be continuously drained away from storage; otherwise, semisolid manure becomes the consistency of liquid manure.

Liquid manure usually contains little or no bedding, and water may be added so that the manure can be agitated into a *liquid* consistency and handled with a liquid manure pump and a *liquid* manure spreader. If liquid manure is handled with irrigation equipment, considerable quantities of water must be added. Special high-pressure chopper pumps and large-orifice irrigation nozzles are also necessary.

Manure Collection Systems

Collection systems include gutter cleaners and gravity-flow channels in tie-stall dairy barns and tractor scrapers, automatic alley scrapers, flushing, and slotted floors in freestall dairy barns (figure 1). Outside yards, lots, and feeding areas can be cleaned with scrapers or in some instances flushing. Bedding pack and pen areas should be designed to allow cleaning with tractor loaders. New and major renovated pack areas should have sufficient access and clearance to allow use of large front-end loaders for pack removal.

Scrapers with rubber edges or made from sections of large rubber tires tend to squeegee the floor and provide less wear and polishing of concrete (figure l.a). Metal blades or buckets with considerable downward pressure are more effective under freezing conditions. Manure may be pushed off an elevated lip directly into a spreader or pushed into a storage or collection gutter. In some cases it is pushed to an area with a buck wall for loading with a bucket loader.

Automatic freestall alley scrapers are often cost and labor savers on large farms, and frequent operation provides cleaner alleys and cows (figure l.b). The cost and time required for maintenance of alley scrapers is often less than the total cost (including labor, machinery, maintenance, and injured animals) of daily tractor scraping. Unattended operation of alley scrapers is not recommended where very small or newborn calves could be dragged away by the slow-moving blade. Alley scrapers must discharge through a hole, over a collection channel, or off the edge of a storage. The drop-off point for the manure must be located and protected to ensure that people, animals, and equipment will not inadvertently fall in.

Slotted floors provide a method for immediate removal of manure from the animal area (figure l.c). Once beneath the floor, manure may be stored in an under-floor tank or removed by an automatic scraper, flushing, or a gravity flow channel. In enclosed barns, manure stored under slats can result in gas, odor, and moisture problems and should be avoided. Keep animals and people out of enclosed barns and provide maximum ventilation during agitation and cleanout if a manure tank is located under the slats. Floors may be configured with long parallel slats and slots or oblong holes in a so-called waffle pattern. Field observations indicate that animals seem to walk more surely on waffle slats, but no research is available concerning either configuration. Slatted floors allow urine to drain quickly away and manure is pushed through the slots by animal traffic. The result is a drier environment for the cows' hoofs. If slotted floors are used in extremely cold situations, manure will eventually freeze and not go through the slots. Provide access for a tractor scraper to remove manure during periods of extremely cold weather.

Flush cleaning is a low-labor method that allows for frequent cleaning and results in drier alleys and cleaner cows (figure l.d). Important components of flush systems are adequate water supply, water disposal system, elevations, slopes, pumps, and pipes. Systems can successfully operate much of the year, even in cold climates, if adequate facilities are available to take care of storage of extra water. The most common problems with flushing systems are the quantity of water required and the need to separate solids for reusing water. Farmers are often over-whelmed by the amount of water that must be handled and the need for more dilution water in recirculating systems than expected. Criteria for satisfactory flushing include water volume per flush, flow rate, duration of flush, velocity of water, and depth of water. Water for flushing systems can be supplied from tip-tanks or from reservoirs with large gates that open. These are dump-flush system. Water delivered through large pipes from high-volume pumps supplies pump-flush systems. Water from elevated holding tanks or ponds can be used with either system, depending on the head, size of pipes, and size of valves.

In general, a 3-inch depth of water and 5 feet per second velocity are recommended for both dump-flush and pump-flush systems. A 3% alley slope is often considered ideal for dump-flush systems in order to maintain a flushing wall of water. Higher initial flow rates will require steeper slopes in order to contain the flush of water within the alley. Shallower slopes of ¾ to 1½ % are used in pump-flush systems to provide longer-duration flow of water to transport material in the alley.

SECTION 4: TRANSFERRING MANURE FROM BARN TO STORAGE

Gravity Pipes for Transferring Manure

Most fresh animal manure will flow by gravity from a high to a low point. This concept of gravity flow can be used to transfer dairy manure from the barn to storage. In general, 4 to 6 feet of elevation drop or head between the barn floor and the full storage level is adequate for manure to flow 100 feet. The pipe slope is not as important as the total head difference.

Several factors determine how well the manure will flow, including
• amount and consistency of manure
• type and amount of bedding
• water added (if any)
• temperature and uniformity of the mix
• pipe size, type, and length

Terrain that slopes about 10% away from the barn gives enough head for both filling and emptying the storage. For more detail, see "Section 5: Manure Storage".

Manure Type

Manure with as little bedding as possible flows best. Dairy manure with up to 3 pounds of bedding per cow per day flows satisfactorily. Manure with excess bedding or with long hay or straw may not flow well unless extra water, such as milking center waste, is added. Extra bedding wasted on days when stalls are bedded should be well mixed with the manure. Calf-pack manure should be well mixed with more liquid manure before it enters the collection hopper.

Gravity systems do not handle frozen manure very well. Low temperatures make manure more viscous, as does drying during hot weather. Adding water helps both situations, but it is important not to use too much water. This may cause more rapid separation of solids and add to the volume of manure that must be handled later. An alternate handling method should be planned for those days when manure is frozen, is too dry, or is not mixed sufficiently to ensure gravity flow.

Collecting Hopper

When manure is scraped or collected from the barn, a collecting hopper guides it into the transfer pipe. Manure may be scraped into the hopper by a front-end loader (figure 2) or fed into it by a gutter cleaner (figure 3). Manure may also be loaded directly into a spreader or the hopper using an automated alley scraper (figure 4). Hoppers are often covered with a grate and made narrow enough for a tractor and spreader to straddle.

More than one collection hopper may be built on a pipe. Figure 5 shows hoppers installed in a four-row freestall barn. Any combination of two or more hoppers or a continuous gutter can be used to collect manure from several scraped alleys.

Any durable construction material may be used for the hopper. It should be built so that the top of the transfer pipe is at least 4 to 6 feet below the floor and is protected from freezing. The top opening should be 3 by 5 feet or greater. To keep the hopper from over flowing or backing up into a gutter, it should be sized to hold the daily volume of manure produced (e.g., 100 cows x 1.8 cu ft per cow per day = 180 cu ft). Figure 6 shows a typical hopper. A smooth transition from hopper to pipe is imperative in order to eliminate material catching and plugging at edges and comers.

Milking center waste or other additional water should enter the first hopper about 3 to 4 feet below the barn floor. A removable grid with an opening 8 feet or wider should be installed. A removable cover should be included to keep animals, people, and large objects from falling into the hopper, unless it is located apart from animal traffic or is protected by a permanent railing.

Figure 2 Gravity-flow manure storage system.

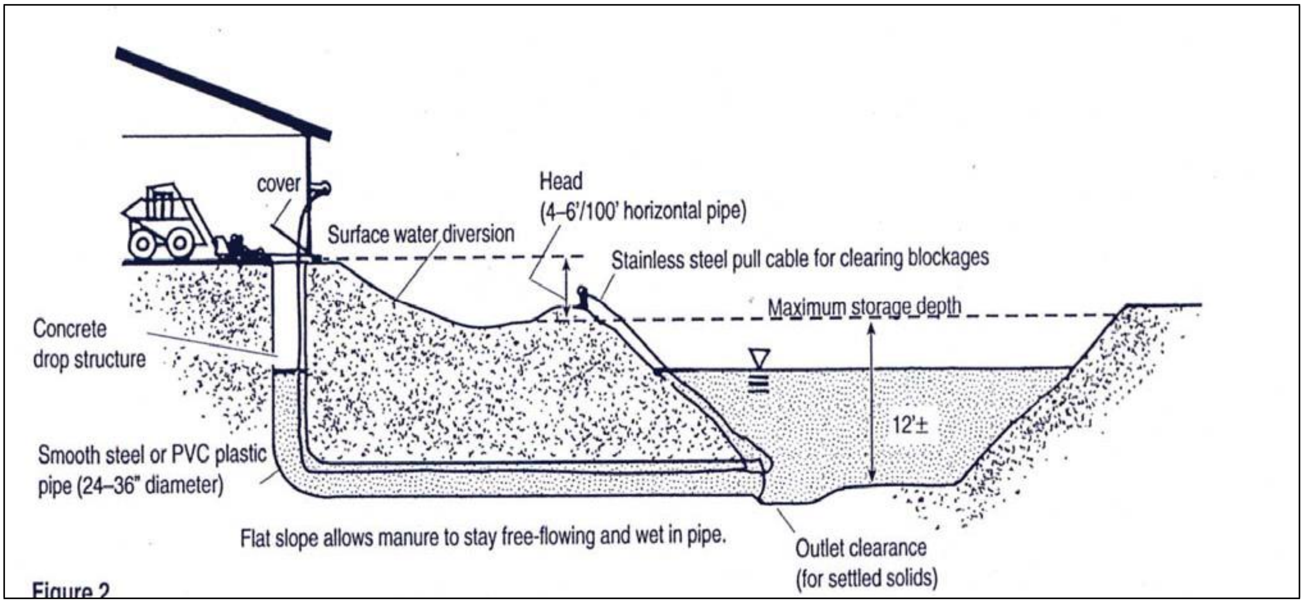
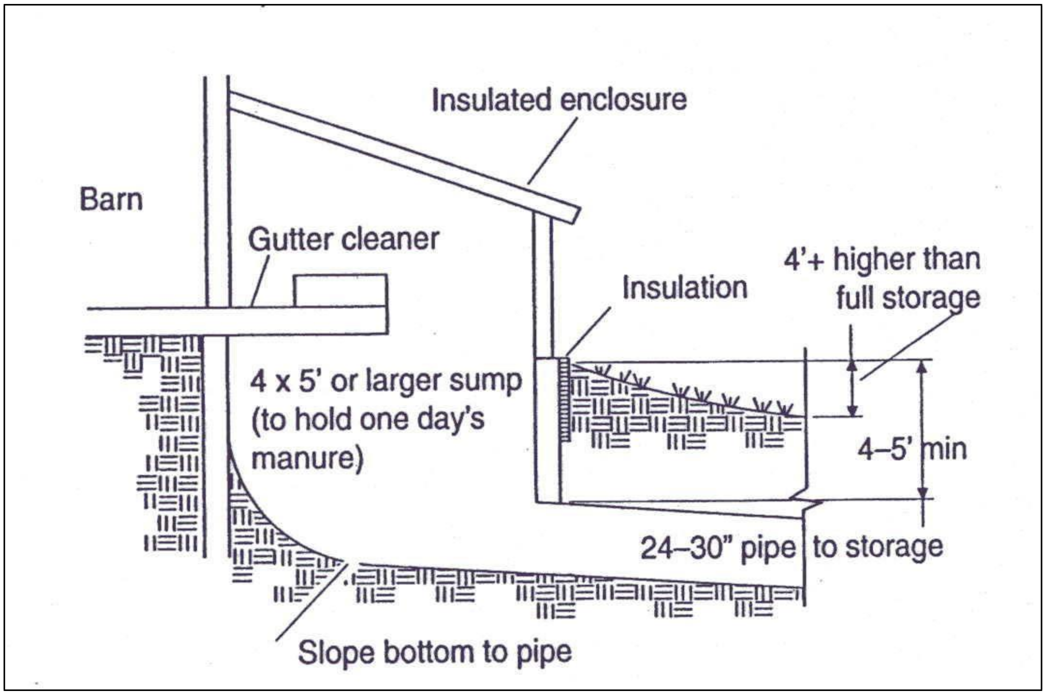
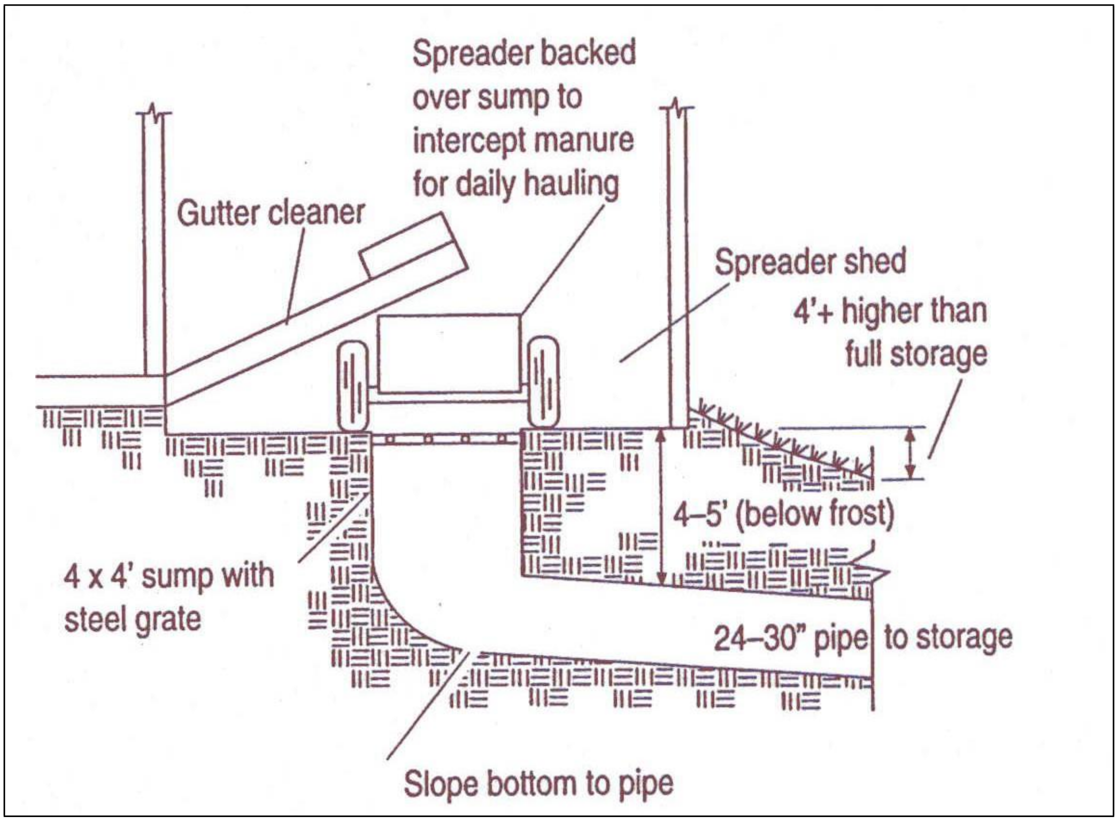


Figure 3 Reception pit and gravity pipe



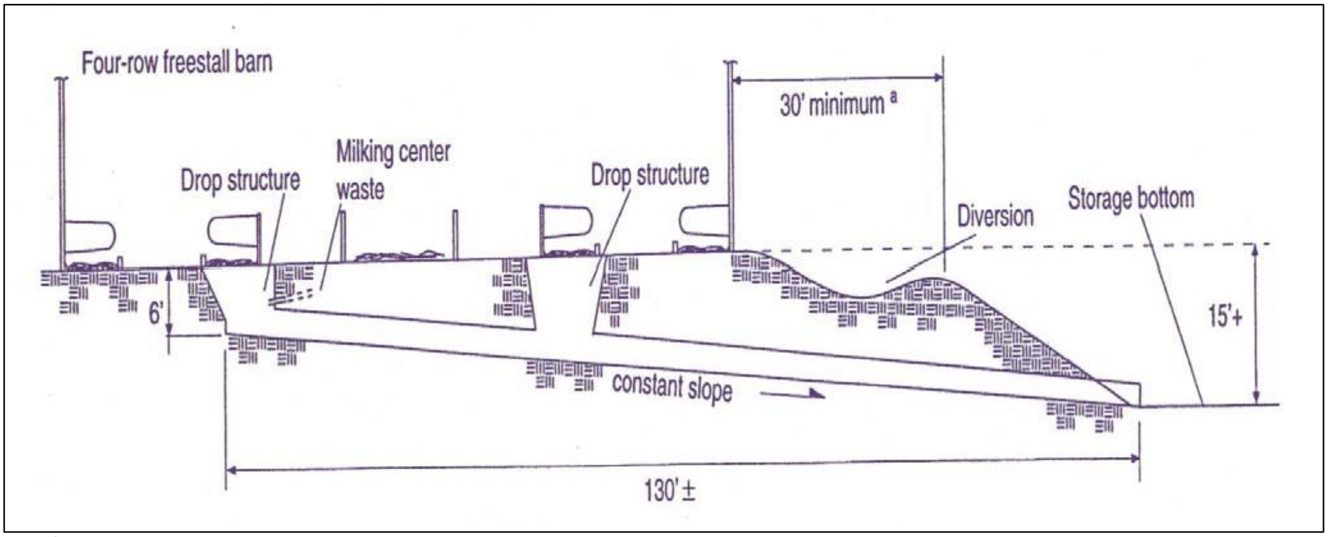
Source: *Dairy Manure Management,* Pennsylvania Department of Environmental Resources. 1986

Figure 4 Manure spreader or reception pit and gravity pipe



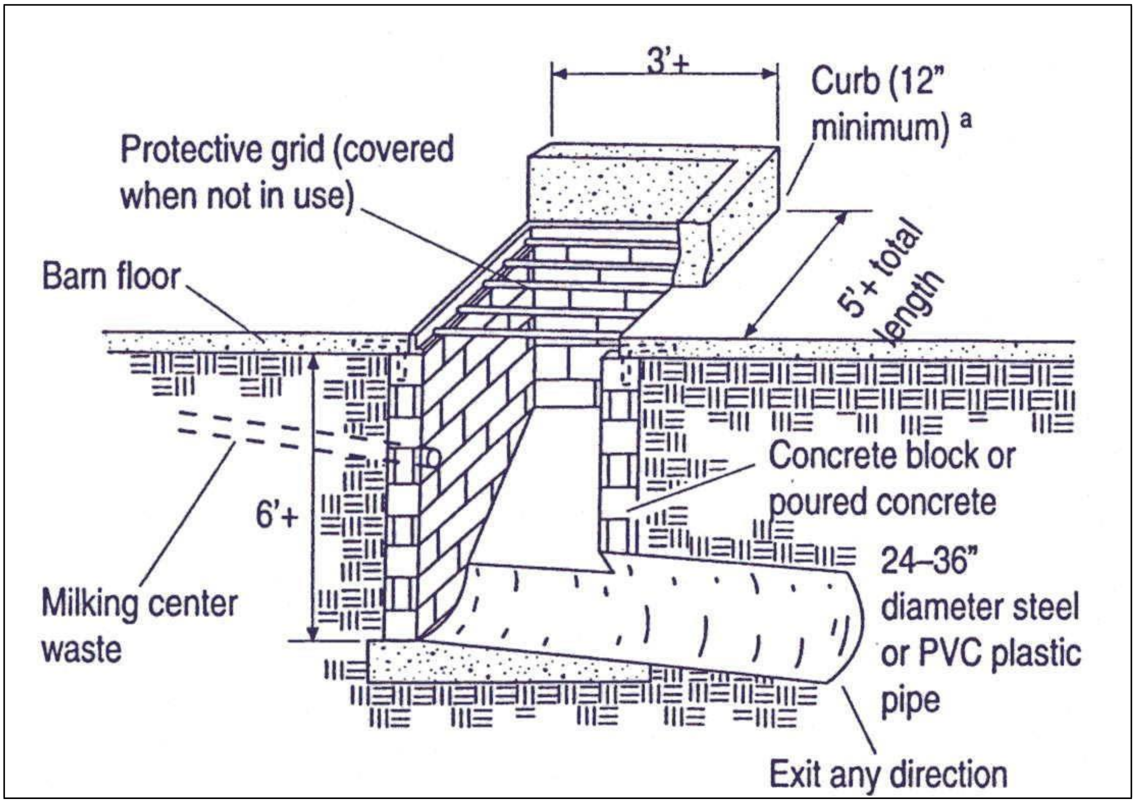
Source: *Dairy Manure Management*, Pennsylvania Department of Environmental Resources. 1986

Figure 5 Collecting hoppers in freestall alleys



[a] Only applies where water diversion is necessary. If rain gutters are used on the roof, storage could start at the barn wall.

Figure 6 Cross section of a typical collecting hopper



[a] Install removable cover in animal traffic areas.

Transfer Pipe

A large pipe, buried below the frost line, transfers the manure from the bottom of the drop structure to the storage. Smooth 24- to 36-inch-diameter plastic or steel pipe is suggested. Smaller pipe may be satisfactory if no bedding is used. Steel pipe should be coated on the outside with asphalt or wrapped to resist corrosion. The pipe should be installed so that it enters the bottom of the storage. The pipe should be as straight as possible. If a turn or bend is needed, it should be located at the collection hopper.

The pipe should be kept level or on a uniform slope over its entire length.

Gravity Channels

To accommodate sand bedding in a gravity manure system, some producers have used a wide gravity channel placed across the end of the barn and extending out into the base of the storage pit. This eliminates any pipe connections and allows free flow to the storage. The storage pit usually has an access ramp and concrete bottom that allows a skid-steer to be driven into the barn channel at clean-out time to remove sand accumulation. A large tarp or carpet is mounted over the outside opening of the channel pit to prevent the cold from penetrating into the barn.

Equipment Options for Moving Manure to and from Storage

A variety of equipment is available to move manure from the barn, milking center, or feedlot to the storage unit, and from the storage to the field. The equipment is classified according to the three manure types: solid, semisolid, and liquid. The various equipment options for each type of manure are listed in tables 2 and 3. Some equipment can handle all three types of manure, while other equipment can handle only one type. Special equipment with limited use should be avoided.

If labor is in short supply, automated equipment such as alley scrapers and electric manure pumps should be considered, especially for work done daily or weekly.

Not all equipment can handle the bedding materials in a freestall bam. Chopper pumps, piston pumps, and augers do not work well with sand bedding. It is important to check with the manufacturer to see if their equipment will work with the planned manure handling and storage system.

For more uniform field application of nutrients, liquid manure should be agitated before it is taken from the storage. Rectangular storage units that are not over 100 feet wide by 250 feet long can be agitated with pump agitators. Circular storages with side-mounted pumps should not be over 80 feet in diameter unless they are agitated from the center.

Agitation of liquid manure in an earthen storage usually requires a pump on a trailer or three-point rear tractor hitch. Earthen storage systems can also be agitated with a propeller agitator on a trailer or three-point rear tractor hitch. Propeller agitators generally are half the cost of basin pumps. Propeller agitators can also be used where elevators and augers are used to unload storages. The agitators help mix the solids and liquids so that they flow to the elevator, auger, or gravity unload pipe. Depending on manure consistency, these propeller agitators can stir manure up to 100 feet away.

Pumping Manure to Storage

An alternative to gravity-flow transfer of liquid manure to storage is pumping. Manure can be collected in a small concrete pit or sump, then transferred to storage using low- or high-head systems (table 4). Low-head pump systems include trash pumps, positive displacement pumps, and pneumatic pumps.

High-head pump systems can develop heads of over 200 feet (86 pounds per square inch [psi]). Closed impeller centrifugal pumps are used for transfer of liquid manures to storage a long distance away. They are also commonly used for irrigation of manure. Because of impeller "slippage," flow rates in a centrifugal pump can be controlled by opening or closing the discharge valve.

All pump systems should be protected from backflow at the pump, especially if the storage level is above the level of the top of the pit hopper. Use of both flapper or check valves at the end of the pipe and manual knife valves in-line provide a double safeguard against unwanted backflow. Another way to prevent storage backflow when pumping from a lower elevation is to use an elevated sump design (figure 7).

Table 2 Equipment options for moving manure into the storage area

Solid Manure Handling Equipment	Semisolid Manure Handling Equipment	Liquid Manure Handling Equipment
Front-end loader	Front-end loader	Front-end loader
Skid-steer loader	Skid-steer loader	Skid-steer loader
Gutter cleaner	Gutter cleaner	Gutter cleaner (flat)
Stacker	Stacker	____
Piston pump	Piston pump	Piston pump
____	Air pump	Air pump
____	Gravity-flow pipe	Gravity-flow pipe
____	Manure ramp	Manure ramp
____	Alley scraper	Alley scraper
____	____	Vertical-shaft chopper pump
____	____	Gravity-flow channel
____	____	Flushing

Table 3 Equipment options for removing manure from the storage area

Solid Manure Handling Equipment	Semisolid Manure Handling Equipment	Liquid Manure Handling Equipment
Front-end	Front-end	
Skid-steer	Skid-steer	
Auger with flail-type	Auger with flail-type	12-inch auger with flail-type feeder
	Auger	12-inch auger
	Elevator	Elevator
	Gravity-flow pipe	Gravity-flow pipe
____	____	Vertical-shaft chopper pump
____	____	Inclined-shaft pump with trailer
____	____	Irrigation pump

Trash Pumps

Many open and semi-open impeller pumps do not develop the head needed for high pressure irrigation, but are well suited for liquid manure transfer to storage (figure 8). Open and semi-open impeller pumps are sometimes called trash pumps because of their ability to move high solid liquids. Chopper-agitator or eater blades are often added to an open impeller pump to break up manure solids prior to pumping.

Vertically mounted chopper-agitator pumps can be used in storage tanks (figure 9). They will not work on the sloped sides of an earthen storage unless used in conjunction with a vertical dock. Open pit, trailer mounted, chopper-agitator pumps capable of operating in a slanted position are especially useful for earthen storage basins with sloping banks. The high agitation ability and high pumping rates of vertical and inclined shaft choppers make them ideal for agitation of manure slurries prior to basin emptying.

Positive Displacement Pumps

Another type of pump commonly used for transfer of liquid manure to storage is the positive displacement pump. Positive displacement refers to the pump's ability to push (by displacement) a fixed volume of material through the pump at a constant rate. Positive displacement pumps are of two main types: screw pumps and piston pumps. Screw pumps can pump manure with relatively high solids content, but they should never be operated dry. The material being pumped must be free of hard or abrasive solids (sand). The helical screw is the most common screw pump used in livestock manures.

Note: Helical screw pumps have operating characteristics similar to closed impeller pumps, with available pumping pressures over 200 feet of head. Because of their high discharge pressures, helical screw pumps may be used for direct irrigation out of liquid manure pits. However, as with all positive displacement systems, line pressures must be carefully monitored. Pressure buildup from plugged irrigation nozzles can burst pipes. High pressure helical screws can be used as storage transfer pumps when lifting liquid manure to higher elevation storages.

Figure 7 Sump design to prevent storage backflow when pumping from a lower elevation

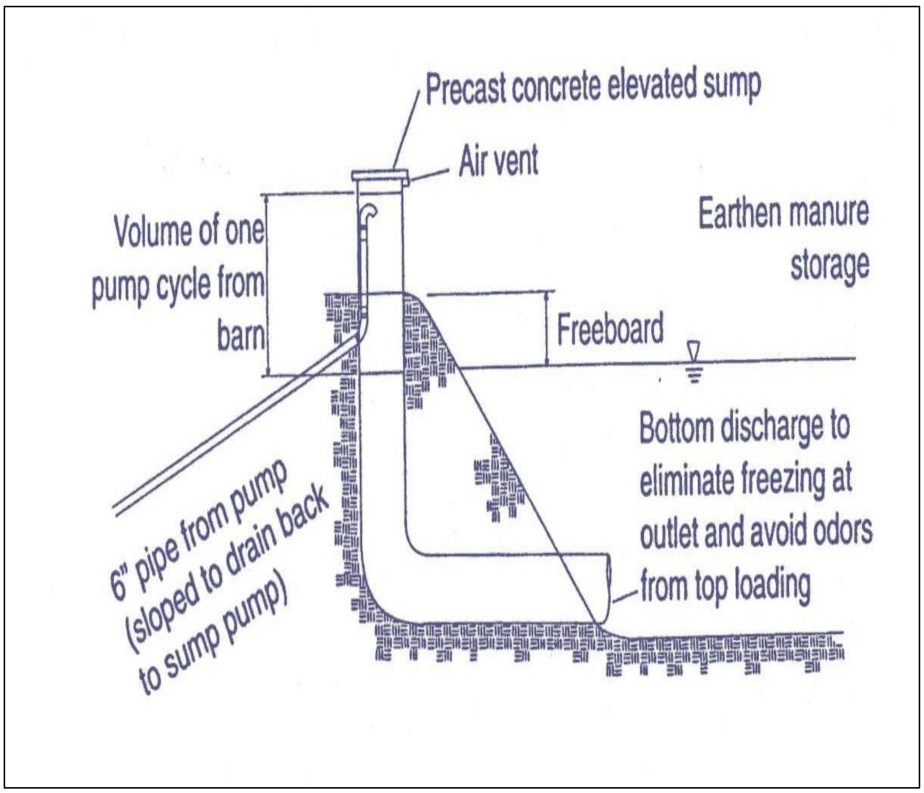
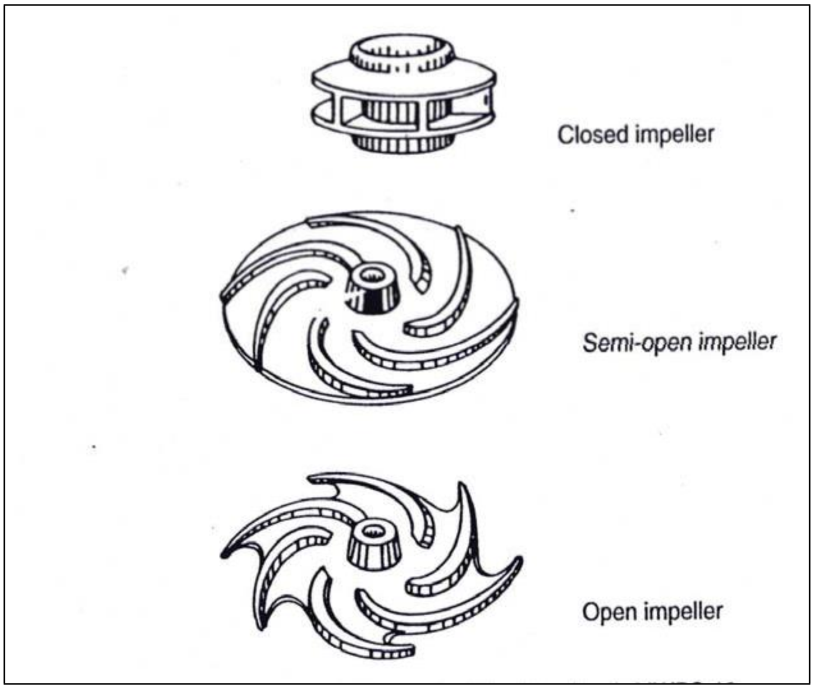
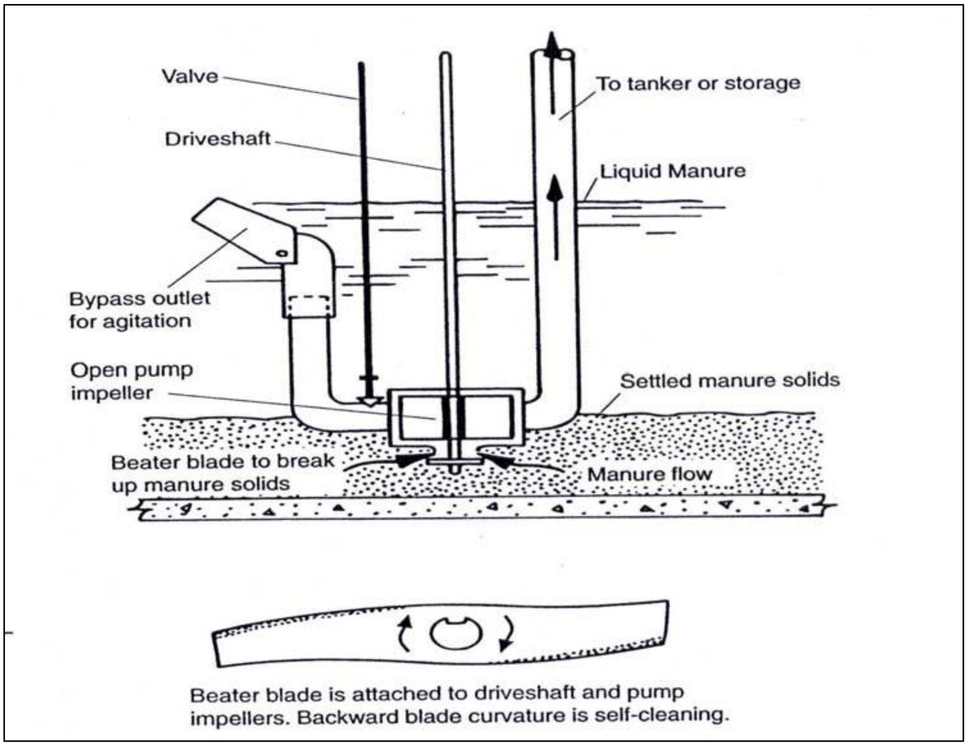


Figure 8 Centrifugal pump impellers



Source: Adapted from *Livestock Waste Facilities Handbook*, MWPS-18.

Figure 9 Open impeller chopper agitator pump



Source: Adapted from Livestock Waste Facilities Handbook, MWPS-18.

Table 4 Liquid manure handling pumps

Pump type	Maximum solids content (%)	Agitation ability	Agitation range (ft)	Available pumping rate (gpm)	Available pumping head (ft of water)	Power requirements (hp)	Applications
Centrifugal Open & semi-open impeller: Vertical shaft chopper	10-12	excellent	50-75	1,000-3,000	25-75	65+	gravity irrigation, tanker filling, pit agitation, transfer to storage
Centrifugal Inclined shaft chopper	10-12	excellent	75-100	3,000-5,000	30-35	60+	earthen storage agitation, gravity irrigation, tanker filling
Centrifugal Submersible transfer pump	10-12	fair	25-50	200-1,000	10-30	3-10	agitation, transfer to storage
Centrifugal Closed impeller	4-6+	fair	50-75	500+	200+	50+	recirculation, sprinkler irrigation, transfer to distant storage"
Elevator	6-8	none	0	500-1,000	10-15	5+	transfer to storage
Helical screw	4-6	fair	30-40	200-300	200+	40+	agitation, sprinkler irrigation, transfer to storage, holding pond and lagoon pumping, tanker filling, no foreign objects
Piston Hollow piston	16-18	none	0	100-150	30-40	5-10	transfer cattle manure without long fibrous bedding
Piston Solid piston	16-18	none	0	100-150	30-40	5-10	transfer cattle manure with unchopped bedding
Air-driven Self-loading vacuum tanker	8-10	poor	20-25	200-300+	N/A	50+	tanker loading
Air-driven Pneumatic	12-15	none	0	100-150	30-40	___	transfer to storage

[a] To convert head in ft of water to psi, divide by 2.31.
[b] Chopper needed prior to pumping dairy manure.

Source: Adapted from *Livestock Waste Facilities Handbook,* MWPS-18.

The second type of positive displacement pump is the piston pump. Piston pumps are designed to transfer liquid as well as high-solids content materials (16- 18% total solids [TS]). They are commonly used to transfer lot scrapings or tie-stall and freestall barn manure to storage. Large diameter (10- to 24- inch) PVC plastic or smooth steel pipe prevents most plugging. SDR 35 pipe or heavier pipe is recommended for piston pump systems (SDR 35 means the pipe diameter is 35 times the thickness of the pipe wall).

A piston pump is usually installed in the barn. Manure storage may be up to 300 feet away, but systems with pipelines of 100 feet or less have consistently better performance. Piston pumps can be either hollow piston or solid piston types.

Dry or frozen manure may require alternate methods of handling. If heavily bedded material from a calf pen or other solids must be pumped, it should be left in the gutter overnight (to accumulate additional liquid from manure). Before pumping, water or wastewater should be added so the material will not pack. Keep pipelines as straight as possible to avoid plugging and/or being pushed apart from the internal pressure developed. Where bends are necessary, use large-radius fittings.

Pipes should be installed on a uniform grade. Do not create low spots in the pipeline that could become settling points for sand, gravel, and lime. If sand is used with a piston pump, the pipeline must be kept short. The piston pump can pump manure with sand in it, but cannot flush out its own line. Once sand and gravel settle in a pipe, a solid plug may be required to push material out of the line. It has been reported that water at over 700 gallons per minute (gpm) for a 12-inch line will be required for flushing settled solids. Piston pumps will wear out quickly with abrasive sand. The best advice is not to use piston pumps (or screw pumps) in barns or systems using sand.

In all slurry pumping applications, pipe should be at least 6 inches in diameter. When pumping uphill with a piston pump, shorten the recommended distance by the percentage equivalent to the total rise in line in feet. For example, when pumping uphill 10 feet, reduce total pipe length at least 10% from manufacturer's recommendations for level or downhill pumping.

Unless the pump is worn from years of use, or is limited by dryer manures and heavy bedding, a piston pump will move a consistent volume. A 10 hp motor driving a piston pump that transfers manures from 12 to 15% solids should be able to achieve a 100 gpm pumping rate. At this rate, a hopper can be emptied in 3 to 4 minutes. This volume of flow will usually keep up with a gutter cleaner moving at 24 feet per minute from a typical tie-stall dairy barn with once-per-day cleaning.

Pneumatic Pumps

Pneumatic (air-driven) pumps are another form of low- head transfer used for livestock manures. Air-driven pumps are of two types: vacuum tank wagons and pneumatic pumps. Vacuum tank wagons use suction developed by a vacuum pump (driven by tractor PTO) for filling or, in reverse, for pressurized unloading. Common tank wagon capacities range from 800 to 4,500 gallons, and larger. Vacuum pumps on tank wagons generally cannot lift liquid manure higher than 12 feet, nor can they handle solids contents above 8 to 10%.

Pneumatic pumps are a type of air-driven pump that are in use on farms. Pneumatic pumps have been used in sludge applications and with various corrosive fluids in industry. The pump is constructed of a large (1,500 gallon) underground steel tank, supplied with compressed air. Collected manure is placed in the tank until ready for transfer. To empty the tank, the loading hatch is closed. Pressurized air is pumped into the top of the tank, which forces manure out the bottom through underground PVC piping to storage. A one-way flapper or check valve is fitted to the tank outlet at the bottom to prevent backflow. The potential for serious injury exists if the air-operated hatch fails. The American Society of Testing Materials (ASTM) has strict design requirements for pressure vessels due to the extreme hazard of air under pressure.

High-Head Pumps

Liquid manures with less than approximately 4% total solids can be pumped from earthen basins or lagoons using pumps designed for conventional water irrigation. Semi-open impellers can be used in place of closed impellers to reduce the possibility of clogging at the pump. Even in well-managed systems, large solids always seem to get in the manure (e.g., twine, afterbirths, 2 x 4s, tools, plastic gloves, soda cans and bottles, hoof trimmings, tails, rocks, pipes, etc.). For large solids, cutter attachments or chopper blades can be added internally to standard centrifugal pump sections. Be aware that pump attachments increase horsepower requirements. Many cutter attachments or chopper blades do not perform satisfactorily.

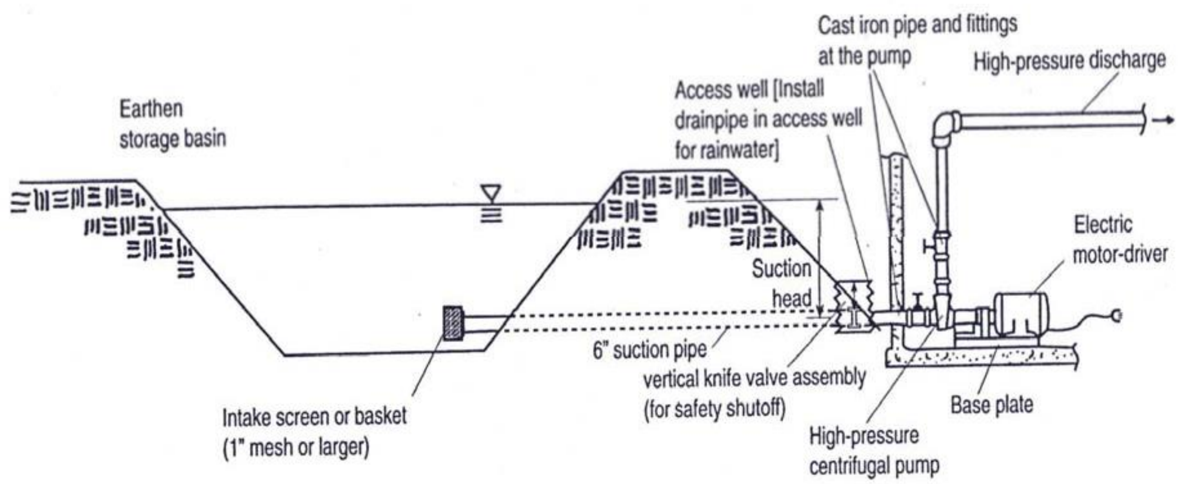
In heavier manure slurries, centrifugal pumps may not have sufficient suction to pull or "lift" manure more than 10 to 14 feet above the storage level (practical suction lift for clean water is about 20 feet). To assure adequate delivery of liquid manure to the pump intake, a flooded suction arrangement can be used (figure 10). Flooded suction avoids having to prime the pump each time, but increases the risk of accidental spillage and drainage between uses. Two valves are always recommended on the suction pipe when using a flooded suction arrangement. An emergency bermed area is also recommended. If flooded suction is not practical, the discharge from the PTO driven chopper- agitator pump can be attached to the intake of a centrifugal irrigation pump for force-feeding of slurry into the pump intake. Force-feeding of this type is often used by farmers to empty their storages, especially where agitation is required.

Liquid manure should be well mixed and free of large foreign material prior to being pumped. Large solids should be screened out at the pump inlet, or better yet, before entering the storage. In order to prevent impeller clogging, pumping of liquids with large amounts of long-stemmed vegetation or large debris should be avoided.

Liquid slurries from 7 to 10% TS can be pumped and irrigated, but will require vigorous agitation to break up solids and keep them in suspension during pumping. Semi-open impeller centrifugal pumps are often used for pumping and irrigation of liquid manure slurries with solids contents up to 10%. Long distance pumping of slurries above 10% TS is impractical because of very high pipe friction losses. For larger operations (and small operations pumping long distances), manure separators can be a cost-effective alternative to pump driven choppers.

Each pump has specific pump characteristics relating the head and volume produced to the horsepower required. Pumps vary in their efficiency and effectiveness in solid handling. Be sure to get the manufacturer's recommendation for the specific site and range of manure conditions that the pump will be used for.

Figure 10 Flooded suction arrangement



Special Friction Considerations

Pipe friction losses for liquid manure at solids contents above 4% should be increased from 10 to 50% above friction loss values for water. Because manure is variable, some judgment is required when using this rule. The designer may consider a 10% increase too conservative (too high) for some liquid manures. Where thicker manures are pumped longer distances, 50% may not be considered high enough.

Pipe friction losses begin to increase exponentially above 4% TS. However, exact pipe friction losses for liquid manures are not available. The above rule assumes proper pipeline design and takes into account the increased pressure required to pump liquid manures above 4% TS.

Proper matching of pumps with the piping is necessary to assure adequate flow. Several factors determine the total amount of head added by pipeline friction, including pipe size (inside diameter), pipe material (internal roughness), valves and fittings that are used, and total pipe length. Friction loss per 100 foot of pipe increases in smaller pipe diameters and with rougher inside surfaces. To obtain a given flow rate, more fluid must be pushed through a smaller pipe, increasing the head requirement (and horsepower) of the pump.

Pipe materials must be matched with the liquid manure pumping system. Pipes, seals, and joints must be able to withstand the pressure and abrasion of the liquid manure being pumped. PVC plastic pipe is usually less expensive than aluminum pipe, and is used for permanent underground installations.

Design of pipelines for liquid manure should include the following considerations:

- The capacity of the pipeline must be sufficient to provide adequate flow of manure.
- Large elevation changes between the barn and the storage create uneven pressures.
- All fittings should be made of material that is recommended for use with the pipe.
- To avoid corrosion, nonmetallic pipe valves and fittings should be used whenever possible.
- Plastic risers must have at least the same strength as the pipe.
- Piping systems not in continuous use should be planned for draining between pumping events by placing drainage outlets at all low places in the line (to prevent solids settling or possible freezing).
- Where provision is needed to flush the line free of manure (as in cases where draining can not be provided by gravity) a suitable valve should be installed at the far end of the pipeline.
- Air release and vacuum relief valves or combination air-vacuum release valves should be installed at all summits, ends, and at the entrance of pipe lines (to provide for air escape and air entrance).
- Avoid the use of fast-closing check valves or flapper valves (due to the increased risk of water hammer or (surge pressures).

Pipelines must be installed according to manufacturer's recommendations. Pipe installation includes pipe joints, trench construction, pipe placement, thrust blocking, backfilling, and in-place testing and inspection.

SECTION 5: MANURE STORAGE

Earthen storages are used most often, but other types are satisfactory. The bottom should slope 2 to 3% from inlet to outlet if it the storage is to be unloaded by gravity flow. A storage that is to be unloaded by a pump should slope 1 to 2% toward the pump-out location. A sump at the pump-out location is highly recommended. The inlet should be as low as possible and the inlet pipe should be covered with manure before freezing occurs.

The bottom, or at least part of it, should have a hard surface if the storage is to be cleaned with wheeled equipment. Total cleanout prevents weed growth, which occurs on some manure surfaces during the second year. Sand or other inorganics used for bedding settles at or near the inlet and must be removed occasionally. A heavy crust forms under some weather and management conditions, and agitation may not break it up effectively. In these cases, a hard-surface ramp and solid-surface bottom permit removal with a front-end loader.

Evaluating Manure Storage Options

When evaluating manure storage options, it is desirable to consider both their advantages and disadvantages. The following review is not all-inclusive; it is intended as a guide. Only some of the points listed below will be of concern with some installations; in other cases, additional factors might enter into the decision.

The storage option chosen must work with other management practices. The cow-management system should be selected first, and then an appropriate housing and manure system chosen. The manure system should be safe, expandable, compatible with pollution regulations, and capable of handling all sources of manure on the farm (figure 11). Runoff from feedlots may need to be handled separately to keep storage costs down.

Cropland that is located long distances from the farmstead is sometimes easier to fertilize if the manure is hauled directly to the field and stored, then spread at planting time. These satellite manure storage sites can be flat spots in the field away from surface water with no direct drainage to water, or they can be permanent storage pits constructed along the side of the field.

Cost savings on manure storages come from savings on commercial fertilizer, labor, improved management control, and longer equipment life. Manure analysis, measured application rates, crop-yield checks, and soil tests help to optimize returns from the manure storage. Table 5 summarizes the suitability of different types of storage systems for handling solid, semisolid, and liquid manure.

Daily Haul

Advantages: Only manure is hauled, not precipitation. The investment in equipment is low, and the workload is distributed throughout the year.

Disadvantages: A separate management system is required for yard runoff and wastewater from the milking center. Equipment life is shortened by corrosion, wetting and drying, and daily trips through the mud and the snow. Extra time for equipment maintenance and startup is required. More time is required on a daily basis, even during the rush of planting and harvesting. Priority must be given to hauling. Manure must be hauled regardless of weather conditions, and land may be unavailable for spreading during the crop production season. Hauling on wet ground may increase soil compaction and rutting. Nutrients are lost during long-term exposure of applied manure. The potential is great for pollution and loss of manure nutrients due to runoff, especially on sloping fields.

Figure 11 Airy manure storage and handling systems

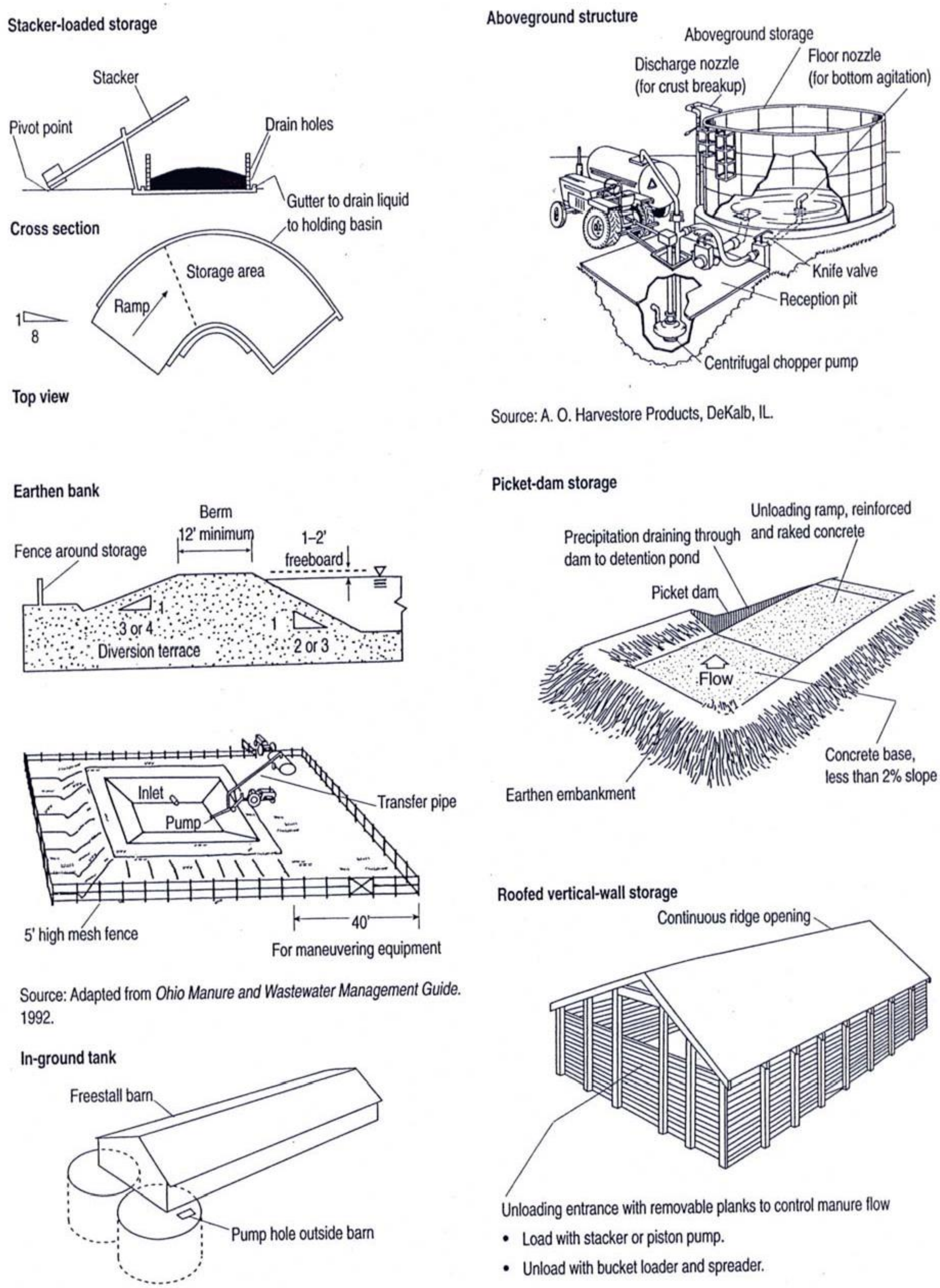


Table 5 Suitability of storage systems for three types of manure

Solid	Semisolid Manure	Liquid Manure
Daily haul	Daily haul	Daily haul
Stacks	Stacks	___
Earthen bank-concrete floor	Earthen bank-concrete floor	Earthen bank-concrete floor
__	__	Earthen bank-earthen floor
__	Aboveground silo or rectangular tank[a]	Aboveground silo or rectangular tank beneath slotted floor
Picket dam	Picket dam	___
Roofed vertical-wall	Roofed vertical-wall	___
Bedded pack	___	___
___	___	Anaerobic lagoon
___	___	In-ground tank

[a] If precipitation water is drained out, the manure can be hauled away as a semisolid.

Uncovered Storages

Advantages: All discharges—such as manure, milking center wastewater, and feedlot runoff—can be handled in one system. Since no roof is needed, open storages cost less than covered ones. Dangerous gases do not accumulate.

Disadvantages: With open storages, manure generally needs to be handled as a slurry or liquid. To produce semisolid manure, precipitation must be drained from the storage area via a picket dam or the equivalent. This separated liquid must be stored and land applied in an appropriate manner. If slurry handling is chosen, the bedding must contain minimal amounts of fine textured material. The workload is concentrated during planting and harvesting. Obnoxious odors are released at the time of agitation and spreading of liquid manure. An open storage must be fenced to keep out children and livestock.

Stacks

Advantages: Stack systems can accommodate large quantities of long, fibrous bedding and can be used in areas of shallow depth of soil to bedrock or ground-water. No agitation is required, and much of the manure is always in a ready-to-haul condition.

Disadvantages: A separate management system is required for runoff from the yard and stack and for wastewater from the milking center. Separate equipment is needed for handling manure liquids and solids. Large quantities of concrete also may be required. Freezing temperatures present problems unless the stacker is movable. Bedding may need to be added to get the manure to stack. Fly and insect control must be included, especially in southern climates.

Earthen Bank with Concrete Floor

Advantages: Both the milking center wastewater and the bam manure can be stored together in liquid systems. Earthen bank storages with concrete floors can handle semisolid as well as liquid manure if an entrance ramp is constructed and provisions are made for separating precipitation from the manure (picket dam). Concrete floors are used in limestone, fractured shale, or fractured bedrock areas.

Disadvantages: A semisolid manure system may require precipitation and milking center wastewater to be handled separately from manure. Considerable land area is disturbed during construction. Fencing is required to keep people and livestock out. If manure is handled as a semisolid, a concrete floor and picket dam increase installation cost.

Earthen Bank with Earthen Floor

Advantages: Both the milking center wastewater and the bam manure can be stored together in liquid systems. Earthwork results in low-cost construction, and such a storage can be filled in easily and a new one constructed if expansion occurs. The storage can thus be located adjacent to the bam.

Disadvantages: Considerable land area is disturbed during construction. Requires maximum site investigation, testing, and construction supervision. Strong odor occurs during agitation and spreading. Load-out equipment cannot be operated on the earth floor. Relatively impermeable soil is required. Groundwater may be polluted in areas of limestone or fractured rock strata. Concrete or other linings may be necessary. Fencing is required to keep people and livestock out of storage.

Earthen Bank with Polyethylene Liner

Advantages: Both the milking center wastewater and the barn manure can be stored together in liquid systems. Earthwork and linings made of high-density polyethylenes can be a cost-effective storage in locations where seepage from earthen structures may be a concern. This practice applies where liquid loss from a pond through leakage is or will be of such proportion as to prevent the pond from fulfilling its planned purposes, or where leakage will contaminate groundwater, damage land or crops, or cause other environmental problems.

Disadvantages: Considerable land area is disturbed during construction. Location selected should allow a bottom groundwater drain/leak detection pipe under the liner to exit to daylight. Load-out and agitation equipment cannot be operated on the liner (a concrete pump-out/agitation section at one end is an option). Fencing is required to keep people and livestock out of storage.

Anaerobic Lagoon

Advantages: Irrigation can be used to dispose of treatment-basin wastewater. Odor problems are minimal during the short irrigation period.

Disadvantages: Treatment basins require a much larger volume than do storage basins to provide for decomposition of solids by bacteria, but treatment basins also need to be narrow enough to clean out with a drag line, if necessary. Because of bacterial action, nearly all of the ammonia nitrogen (a potential nutrient) is lost to the air. Fencing is required to keep people and livestock out of the basin.

In-Ground Tank

Advantages: Generally, no pumps are needed to fill the storage, and a minimal during the short irrigation period. A roof can be added to keep out precipitation.

Disadvantages: The manure must be handled as a slurry or liquid and must be pumped out of the storage. Bedding must be short material and limited in quantity. The floor is usually poured concrete construction with steel reinforcement. The walls may be poured-in-place reinforced concrete or precast reinforced concrete. Because the tanks must be watertight, construction and operation of these storages in areas with high water tables can cause problems. Strong odor occurs during agitation and spreading. Drowning is a possible hazard, and toxic and explosive gas can build up if the storage has a cover.

Aboveground Silo or Rectangular Tank

Advantages: Aboveground storage tanks can be constructed in areas with shallow bedrock or where the depth to groundwater is shallow. A minimal amount of land area is required. When ladders are removed, it is difficult for unauthorized persons to gain access to such a storage unit.

Disadvantages: The manure must be handled as a slurry or liquid, and only a minimum amount of fine bedding can be used. The manure needs to be pumped in and out of storage unless elevation is sufficient for gravity flow. These storages cost much more than earthen storages. They offer no flexibility in expanding storage capacity. Agitation and removal of solids from large-diameter storages may pose a problem, and strong odor occurs during agitation and spreading. Valve failure or tampering with gravity-unloaded systems can result in manure spills which create environmental, aesthetic, or legal problems.

Picket Dam

Advantages: There is a wide choice of suitable bedding materials, and the use of readily available equipment, such as a front-end loader and box spreader, can help keep costs low. Since no agitation is necessary, manure is always ready to haul, and since there is little precipitation or dilution water to haul, fewer trips are necessary.

Disadvantages: When large amounts of bedding are used, manure may pile up at the loading point. Multiple loading points, a movable elevator, or chopped or fine bedding can eliminate this problem. For liquid runoff from the storage, a separate storage or grass infiltration area (if the site permits) is required. Separate handling equipment also may be required, but it may be borrowed or rented. If a separate liquid storage is used, greater land area is tied up. Liquid separation depends on the type of bedding and size of the storage and is not always fully effective. For best results, precipitation should drain continuously from the storage. The longer precipitation is retained with the manure, the more mixing will occur. This increases cleanout and handling difficulties. The workload is concentrated during planting and harvesting. To reduce load-out time, a loader with a large bucket for loading of spreaders is required.

Covered Storages

Advantages: No extra water from precipitation needs to be hauled to the field.
Disadvantages: A higher initial cost is incurred because of the roof or tank top, and the toxic and explosive gas hazard is increased by the cover. The workload is concentrated during planting and harvesting.

Underground Tank beneath Slotted Floor

Advantages: Milking center wastewater can be introduced into the same system. No extra equipment is required to place the manure in the storage. Because the storage is located under the barn, there is minimal loss of tillable acreage.

Disadvantages: Manure must be handled as a slurry or liquid; the bedding must be minimal amounts of fine material; and extra water might be required for dilution (in addition to milking center effluent). The tank is expensive to construct because it must withstand soil and groundwater pressures and must support the barn floor. Agitation is required prior to pumping out the storage. Strong odor occurs during agitation and spreading, and dangerous gases may build up during and directly after agitation. A pit ventilation system is required if the building is enclosed. Extreme care must be taken at agitation and pump-out time to keep people and animals outside the building and protect them from released gases.

Roofed Vertical-Wall Storage

Advantages: A wide choice of bedding materials can be used. The manure can be handled with a front-end loader and box spreader—readily available equipment, so costs can be kept low. Power requirements for loading and spreading are also lower than with liquid systems. The manure is available for hauling at any time.

Disadvantages: A separate system is required for disposal of milking center wastewater. The cost of building a roof and concrete or lumber walls increases initial expense. Generally, manure must be pumped into the storage with a large piston-type pump.

Bedded Pack

Advantages: A wide choice of bedding materials can be used, and no special manure storage needs to be constructed. To keep costs low, the manure can be handled with a front-end loader and box spreader. Power requirements for loading and spreading are also lower than with liquid systems. The manure is available for hauling at any time. Cattle are housed on the bedded pack, so no additional area is needed.

Disadvantages: Bedding must be added frequently and in large quantities to keep cattle clean. The building's walls must be high enough to allow for the buildup of the manure pack and strong enough to withstand the force of the pack and the unloading equipment.

Solid Manure Storage

Solid manure will stack either because sufficient fibrous bedding has been added or because the manure has dried. It is transported with an extended gutter cleaner, auger, stacker, tractor with front-end loader, or solid piston pump. Storages are unloaded with a front-end loader. A conventional manure spreader is used to haul and spread manure.

If manure is stacked as a solid
- Bedding must be used.
- It is easily adapted to tie-stall barns.
- Annual cost of stacking is little more or no more than daily haul.
- Less volume is stored than in liquid systems.
- Excess water (leaking self-waterers, runoff from roofs or surrounding area) must be kept out of the manure.
- A separate system for milking center wastewater and runoff from the pile is required.

Construction

Stack manure on a concrete slab at least 3 inches thick. Thicker concrete or reinforcing is optional but reduces cracking from the weight of machinery. A crushed limestone base is acceptable instead of concrete. Earthen floors are not recommended because they are difficult to scrape.

Walls and roofs are optional. One wall or more is good because it
- controls leachate flow more effectively
- can be used to buck manure against during unloading
- screens manure from view
- reduces size of floor area

Walls can be made with reinforced concrete, reinforced masonry, pressure-treated wood, or other corrosion-resistant, durable materials.

Roofs are used to
- keep precipitation out so manure is easier to unload as a solid
- screen manure from view

Fence area to keep out dairy cows.

Size

Table 6 summarizes typical floor areas needed for storage of solid manure for four months.

Table 6 Typical floor area (square feet) of solid manure storages for a four month storage[a]

Number of Cows	Without Sidewalls	4-foot Sidewalls	8-foot Sidewalls
50	2,000-3,000	1,300	900
100	3,000-3,200	2,400	1,800

[a] Production assumed to be 2 cu ft per cow-day and manure stacks at 45° angle of repose.

Runoff Control

Any drainage from the stack must either be contained for later field spreading or be made to flow to a grass disposal area. Slope the base slightly (2% of less) away from loading point to direct drainage from the stack.

Grade to divert surface runoff from the stack. *Do not allow direct entry of runoff to waterways.*

Table 7 gives estimated runoff volume for roofed and unroofed storages and lots for six months.

Table 7 Runoff-collecting pond size for a six-month storage

Storage Type	Runoff Volume Estimated
Roofed storage	50 cu ft/cow
Unroofed storage	100 cu ft/cow
Lot runoff	1,500 cu ft/1,000 sq. ft

Bedding

Absorption capacities of some bedding materials are listed in table 8. The density of selected bedding materials is summarized in table 9. Table 10 compares bedding requirements for selected housing systems.

Table 8 Bedding material water absorbing capacity (bedding at 10% moisture)

Material	Pounds Water Absorbed per Pound Bedding
Hardwood chips, shavings, or sawdust	1.5
Pine (softwood) shavings	1.7-2.6
Pine (softwood) sawdust, chips	2.5-3.0
Straw or hay	3.0-4.5

Table 9 Bedding material density

Form	Material	Density (pounds Per cubic foot)
	Hay	3.5-4.4
	Straw	3-7
	Shavings	9
	Sawdust	7-12
Baled	Hay	6-8
	Straw	4-5
	Shavings	20
Chopped	Hay	5-7
	Straw	6-8

Table 10 Bedding requirements [a]

Housing System	Long Straw (pounds per cow-day)	Chopped Straw (pounds per cow-day)	Shavings (pounds per cow-day)
Stanchion barn	7.6	8.0	—
Freestall barn	—	3.8	4.3
Loose housing bedded area	13.0	15.4	—

[a] Determined for a 1,400-pound dairy cow from research projects at the University of Wisconsin.

Semisolid Manure Storage

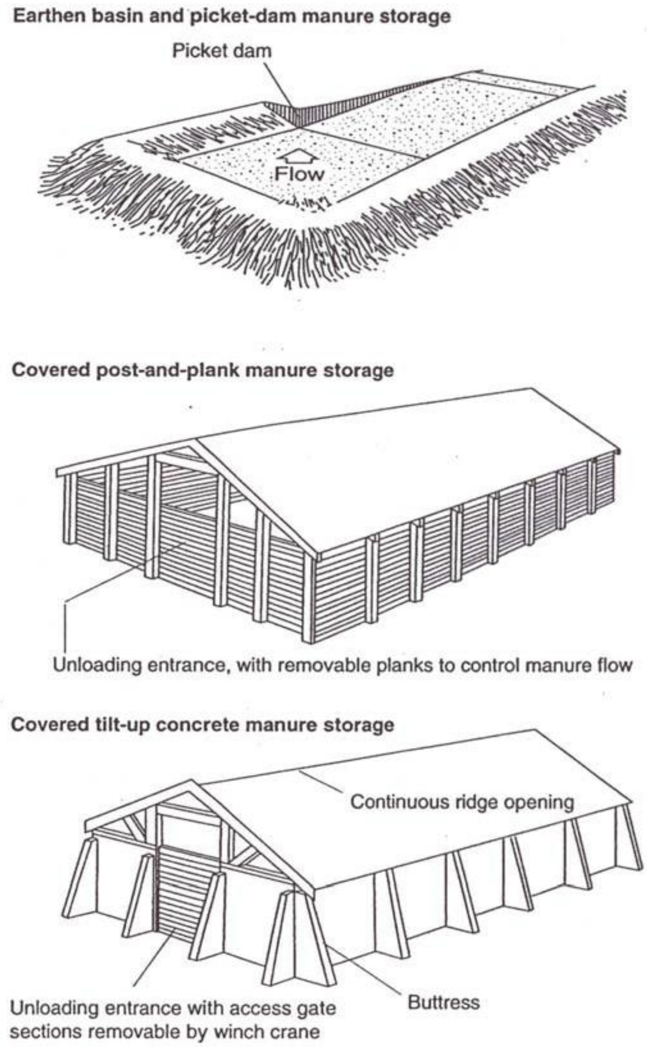
Manure can be stored and handled as a semisolid in covered storages or in uncovered storages with drainage devices (figure 12). An earthen basin or vertical wall storage above or partially above ground can be used. Successful handling as a semisolid requires that small to moderate amounts of bedding be used, water from direct precipitation be excluded or drained away, milking center or other effluent be kept from the storage, and all surface runoff and groundwater be kept out of the storage.

Storage as a semisolid allows the use of conventional manure handling equipment, including front-end loaders, box-type spreaders, and dump trucks. It results in less material to handle and haul to the field since extra water has been separated or soaked up by bedding. It adapts well to barns where some bedding is used.

A roof to exclude precipitation or a picket dam and drain to allow rainwater and snowmelt to be removed immediately are recommended. Storages must have an entry ramp and solid floor to allow operation of unloading tractors and spreaders in the storage area. Storages should be large enough to provide for at least six months' holding capacity to allow for flexibility in cleaning out the storage.

The storage should be located
- convenient to dairy barn
- at least 100 feet downslope from any water supply
- at least 300 feet from nearby downwind homes
- screened from houses and highways
- accessible for filling and emptying
- in an area that will allow future expansion
- above the water table and possible flood line
- in compliance with any local zoning restrictions

Figure 12 Semisolid manure storage



Covered Semisolid Manure Storages

A roof keeps water out and screens manure from view. There should be at least one foot of open space between the top of the walls and the roof to allow cross-ventilation and partial drying. In gable-roof storages ventilation openings at the very top minimize collection of foul air under the roof. The roof must be high enough to permit the operation of unloading equipment in the storage.

Roofs can be built over earthen basin or vertical sidewall storages. A vertical-sidewall storage provides more storage volume under the same size roof since there are no sloping sidewalls. In some designs the roof can provide partial support for the sidewalls, thus reducing the construction cost.

A drain in the unloading area is also recommended to remove any water that may collect and interfere with unloading operations, especially if the unloading ramp extends outside the roofed area. The area around the ramp should be graded to exclude runoff water.

Picket Dam Drains

Semisolid storages exposed to precipitation must have provisions to remove rain and melted snow from the manure as quickly as possible. Most rainfall and melted snow runs along the surface of a manure pile to the edge. If provisions are made to separate this water immediately, very little of it will mix with the manure. It will be dirty water and will need to be stored for spreading or treated in a grass filter area. A picket dam with appropriate water drainage works well for this job. A picket dam drains precipitation from the storage; it does not remove water added to the manure at the barn. For successful operation it is important that water draining through the dam be drained or pumped away immediately to prevent it from being absorbed back into the manure pile. The manure pile must slope toward the picket dam to encourage water to drain away.

Construction

A picket dam must be well constructed since the manure will pile up against it to the depth of the storage (figure 13). The dam is built with pressure-treated posts and horizontal stringers. Vertical 2-inch-thick planks separated by ¾ -inch slots are nailed to the stringers. As the storage fills with manure, the vertical slots remain continuously open, allowing free water to drain through. If horizontal slots are used for drainage, the openings will be sealed off periodically as the manure builds up in the storage, causing water to accumulate to the level of the next horizontal slot.

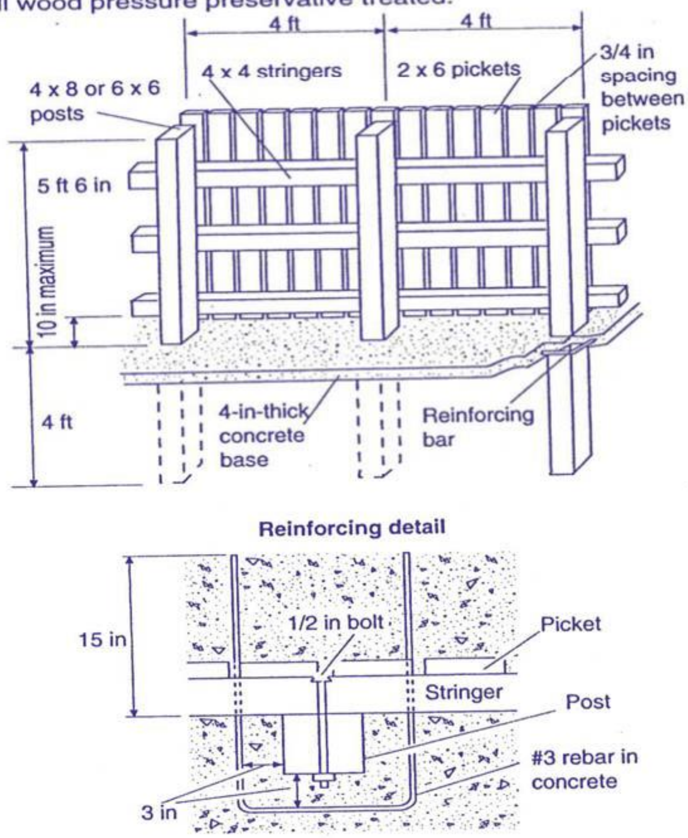
Figure 13 Guidelines for picket dam construction

Guidelines-timber size and spacing in picket dams

			Horizontal stringers		
Posts[a]	Size	Spacing	Depth	Size	Spacing
0-4 ft	4 x 6	5 ft	0-4 ft	4 x 4	3 ft
5 ft	6 x 6	4 ft	4-6 ft	4 x 4	2 ft
6 ft	6 x 8	4 ft	6-8 ft	4 x 4	1.5 ft
7 ft	8 x 8	4 ft			

[a] Aboveground length

Note: Use 2 x 6 vertical pickets spaced 3/4 in apart.
All wood pressure preservative treated.



Location

Dam location is critical. Water runs off accumulated manure to the sidewall and along the edge to the low point. The picket dam must be located and sized to intercept and drain away water that runs off the manure pile. This usually requires the dam to start along one side of the bottom of the storage and continue up the unloading ramp. A slotted box structure located away from the edge of the storage does not work as well as one at the sidewall.

Two or more picket dam drains may be needed where manure is loaded in the center of a large storage. Water should always have a drainage path from the face of the manure pile to the drain. The unloading ramp and the picket dam should be near each other and in the area where water accumulates last. This arrangement drains water from the ramp and from a partially unloaded storage. If drainage is not provided at the unloading area, water will accumulate and make unloading difficult and unpleasant. The floor should be level or should slope no more than 2 away from the loading point. If the point of unloading is separated from the picket dam by stored manure, water will collect and cause problems during unloading. Don't push manure into the picket dam when unloading. Use a solid buck wall instead.

Removal of Drained Liquid

Liquid draining through the dam should be removed immediately from behind the picket dam. Allowing the water to accumulate behind the dam will result in much of it being absorbed into the manure, resulting in a sloppy material at unloading. This defeats the purpose of the system and often results in having to unload the storage as a liquid.

Drained liquid should be directed to a runoff-control basin, a milking center waste handling basin, or a grass filter bed. *The leachate is a strong pollutant and must be controlled so that no discharge to waterways occurs.* A sump equipped with a heavy-duty, submersible, solids-handling sump pump with water-level on-off control should be used to elevate leachate from low points if a gravity drain is not possible.

Earthen Basin Storages

Earthen basins either covered or with picket dam drains, are relatively inexpensive semisolid storages. A covered earthen storage, however, will hold considerably less manure than a vertical-sided storage with the same size roof due to the side slope required.

Location

The storage must be located and constructed to minimize the chance of ground or surface-water pollution. Traffic patterns; distance to neighbors, farm houses, and wells; access for loading and unloading; and future expansion should be all considered when locating a semisolid storage.

Construction

The milk regulatory agency should be notified before construction begins. Check with your local, county, state, and zoning authorities for water quality-related regulations. The Natural Resources Conservation Service or another competent source of engineering expertise should be consulted regarding the suitability of soil type, location, and design. The base for a semisolid manure storage should be constructed of at least 4-inch-thick concrete. It should be level or have no more than a 2% slope. A gravel subbase and reinforcing steel are optional, but soil under concrete should be well compacted.

Side banks with a 2:1 or 3:1 (run: rise) slope are normally recommended. Slope depends on soil type and recommendations from the Natural Resources Conservation Service or other professional design service. Steeper slopes are possible with some soils, but construction may be more difficult. A steep inside slope helps to keep the water collection area to a minimum. All surface water from outside the basin should be diverted so that it does not enter the storage.

Unloading ramps should be reinforced concrete, at least 4 inches thick, with a rough (raked) surface. Maximum slope is 8:1. Concrete should be placed on compacted fill and a 6-inch gravel subbase with 6-inch x 6-inch, 10-gauge, welded-wire fabric reinforcing mesh.

Consider using a high-density polyethylene geomembrane liner with geotextile underliner pad in order to prevent seepage losses. Standards and specifications for liners are available from the Natural Resource Conservation Service.

Earthen basins should be fenced to keep out people and cattle and appropriate signs should be posted.

Vertical-Wall Storages

Vertical-wall storages are usually a more attractive, but a more expensive, alternative to earth basins. They provide for maximum storage volume under a roofed area. They may be preferred where a high water table is present, where space is limited, the soil is not suitable for holding manure in an unlined storage or the soil is shallow to bedrock, or where a manure basin would endanger people or animals.

Aboveground semisolid manure storages should be professionally designed to withstand pressure equal to water. The unloading entrance must also be designed to control the flow of manure during unloading. Aboveground structures can be built with reinforced concrete, tilt-up concrete, reinforced concrete block, or pressure preservative-treated wood posts and planks. Install drain tile around the storage foundation to intercept and divert groundwater. Sidewall construction may be cheaper if the storage can be built partially in-ground or if the earth is backfilled against it. Partially in-ground storages should not extend into high water tables.

Sizing Manure Storage Units

The required capacity of the manure storage unit for a given dairy farm depends on four main factors:
1. the volume of manure going into the storage
2. the volume of bedding, milking center wastewater, and rainfall runoff going into the storage
3. the extra storage depth required for precipitation, dead space, and freeboard
4. the length of time manure is to be stored.

Once the required storage capacity is known, the dimensions of a storage unit can be calculated. This section describes how to calculate the required storage capacity, presents tables and figures indicating storage dimensions, and shows how to calculate storage sizes.

Manure Volume

Ideally, the manure from all animals—cows, heifers, and calves—should be stored. Table 1describes the average age distribution in various size herds and the average weight of animals of various ages. From table 1, total manure production for a herd with 100 cows is 15,430 pounds, or 249 cubic feet per day. Also see "Common Conversion Factors".

Note: Farmers should use actual herd numbers and weights for sizing storage facilities if these numbers are known.

Volume of Bedding, Wastewater, and Runoff

When bedding, milking center wastewater, or manure-laden runoff from bamyards is to be put into a storage unit, the extra storage capacity must be determined and the storage unit size increased accordingly. The amount of bedding per cow per day varies, depending on whether the cows are housed in tie-stalls or freestalls, or are in loose housing arrangements. Table 11 gives typical bedding volumes after bedding is compacted in the storage to half its original volume. The volumes range from 0.2 to 1.5 cubic feet per cow per day. When possible, the actual amounts of bedding used should be measured. Likewise, the volume of milking center wastewater per cow per day varies from 2 to 8 gallons, and decreases as the number of cows increases (see table 12). Actual water usage should also be measured.

Precipitation less evaporation on barnyard lots in the humid Northeast amounts to about 18 inches of runoff every 6 months, producing about 1.5 cubic feet of runoff for each square foot of barnyard. If the barnyard area is large, draining runoff into the manure storage can add a large amount of dilution water and can change solid or semisolid manure into liquid manure. Two options are to use a solids settling tank and either a grass infiltration area or a separate earthen storage.

A detailed method of rainfall/runoff/evaporation computation that also may be used is described in the *Natural Resources Conservation Service Agricultural Waste Management Field Handbook* (see the "References" section).

Extra Depth for Precipitation, Dead Space, and Freeboard

No matter what the volume of manure, wastewater, and runoff going into a storage, extra depth must be provided to allow for precipitation, dead space, and freeboard. Storages may or may not have drainage areas.

Table 11 Volume of bedding in storage per cow per day

Type of Bedding

Type of Housing	Shavings Straw cu ft)	Chopped Straw (cu ft)	Shavings Straw (cu ft)
Tie-stall	0.8	0.6	—
Freestall	—	0.3	0.2
Loose	1.5	1.1	—

Note: Use these values if accurate volumes of bedding usage are not known. Based on University of Wisconsin research on bedding volumes,

Table 12 Estimated volume of wastewater from milking centers

Number of Cows Milked	Wastewater Generated
0-50 cows	5-8 gal/cow-day
50-150 cows	4-6 gal/cow-day
150+ cows	4-6 gal/cow-day

Note: Use these values if accurate volume of wastewater is not known. 7.5 gallons equals 1 cubic foot. Consult *Guideline for Milking Center Wastewater*, DPC 15, NRAES-115, for additional information.

The following storage-capacity design criteria are recommended:
a. For storages with drainage areas, consider the normal runoff for the storage period; the normal precipitation, less evaporation, for the storage period; the 25-year frequency, 24-hour rainfall on the storage surface and drainage area; and the solids accumulation in the storage due to runoff.

b. For storages without drainage areas, consider the normal precipitation, less evaporation, for the storage period; the 25-year frequency, 24-hour rainfall runoff on the storage surface; and the solids accumulation in the storage due to runoff. State or local regulations may specify freeboard requirements.

At the bottom of most liquid storage units is a space 8 to 12 inches deep that cannot be pumped. To minimize the dead space, the bottom of some storages is sloped 1 to 2% towards the pump-out location. A recess or sump in the bottom at the pump-out location further reduces the dead space and is highly recommended.

"Freeboard" is extra depth that serves as a safety factor. For a covered storage, 6 inches of freeboard is adequate; for an open storage with earth walls, 12 inches or more is necessary. Open storages with concrete, wood, or coated metal walls require at least 6 inches of freeboard.

Generally, the sum of the extra precipitation, dead space, and freeboard is rounded off to 2 feet for earthen storages, since the dead space is in the smallest part of the storage. Manure levels are easier to observe in open storages with tops at, or just above, ground level. A marker to indicate the design full level, not including rainfall, runoff, and safety factors, should be present. The vertical distance between the design full level and the top of the storage should be a minimum of 2 feet, which satisfies requirements for freeboard.

Tables 13 and 14 give dimensions to store a given volume and thus can account for the total volume of manure, bedding, wastewater, and runoff going into a storage. Table 13 gives possible dimensions for circular tanks; table 14 gives possible depths and top dimensions for rectangular earthen basins with inner side slopes of 2 to 1. For other shapes or designs, contact a private consultant or your county Natural Resources Conservation Service.

Figures 14.a and 14.b also give possible bottom dimensions for rectangular earthen storages of a given volume with inner side slopes of 2 to 1. The figures differ from table 14 by showing bottom, rather than top, dimensions; and by being graphs, rather than tables. The figures give more information than table 14, including the number of cubic yards of concrete needed for the bottom of storage of a given volume. Figure 14.a is for storage units with 6 feet of working depth; figure 14.b is for units with 8 feet of working depth. One method of using the figures involves selecting the necessary volume from the left-hand scale and one dimension from the bottom scale. The other dimension is indicated by the solid diagonal lines extending from lower left to upper right. To calculate volume of concrete for a "square" storage, the necessary volume can be selected from the left-hand scale and the point of intersection located horizontally with the line marked "square bottom." The volume of concrete for a 5-inch-thick floor is indicated on the dashed lines.

Table 13 Circular storage dimensions to hold a given volume

	Depth of Storage (ft)			
	8	12	16	20
Volume (cu ft)	**Diameter of Storage (ft)**			
10,000	40			
20,000	56	46	40	
30,000	69	56	49	
40,000	80	65	56	50
50,000	89	72	63	56
75,000	109	89	77	69
100,000	126	103	89	80
125,000	140	114	100	88
150,000		126	109	97
175,000		136	118	105
200,000			126	113
250,000			141	126

Note: For depths and volumes not listed, use the following equation:
Volume = $\pi r^2 D$

where
π =3.14
r =radius of tank (½ of diameter)
D =depth of tank

Table 14 Rectangular storage with side slopes 2:1, top dimensions to hold a given volume

	Width of Storage (ft)								
	60	60	60	80	80	80	100	100	100
	Depth of Storage (ft)								
	8	10	12	8	10	12	8	10	12
Volume (cu ft)	**Length of Storage (ft)**								
20,000	70	67	65	___	___	___	___	___	___
30,000	99	92	88	___	___	___	___	___	___
40,000	128	117	111	___	___	___	___	___	___
50,000	156	142	134	112	101	95	___	___	___
75,000	___	___	___	161	143	132	127	112	104
100,000	___	___	___	210	184	169	164	143	131
125,000	___	___	___	259	226	207	201	175	159
150,000	___	___	___	308	268	244	238	206	186
175,000	___	___	___	___	309	281	275	237	213
200,000	___	___	___	___	___	318	313	268	241
225,000	___	___	___	___	___	___	___	300	268
250,000	___	___	___	___	___	___	___	331	296

Note: For depths and volumes not listed, use the following equation:
$\text{Volume} = WLD - SLD^2 - SWD^2 + 1.33\ S^2D^3$

where

L and W = top length and top width
S = 2 for 2:1 inside side slope
D = depth

Figure 14.a

Rectangular storage, 6 feet working depth, sides sloped 2:1, bottom dimensions to hold a given volume. Example is given in situation 2.

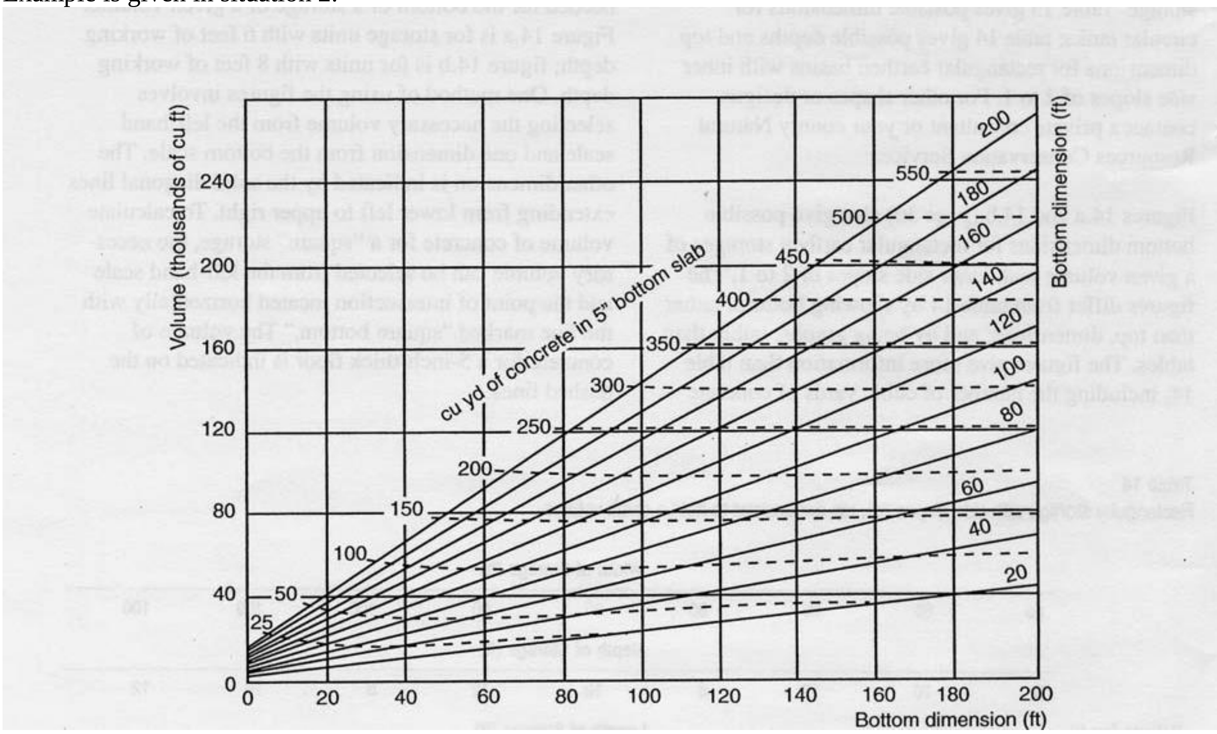
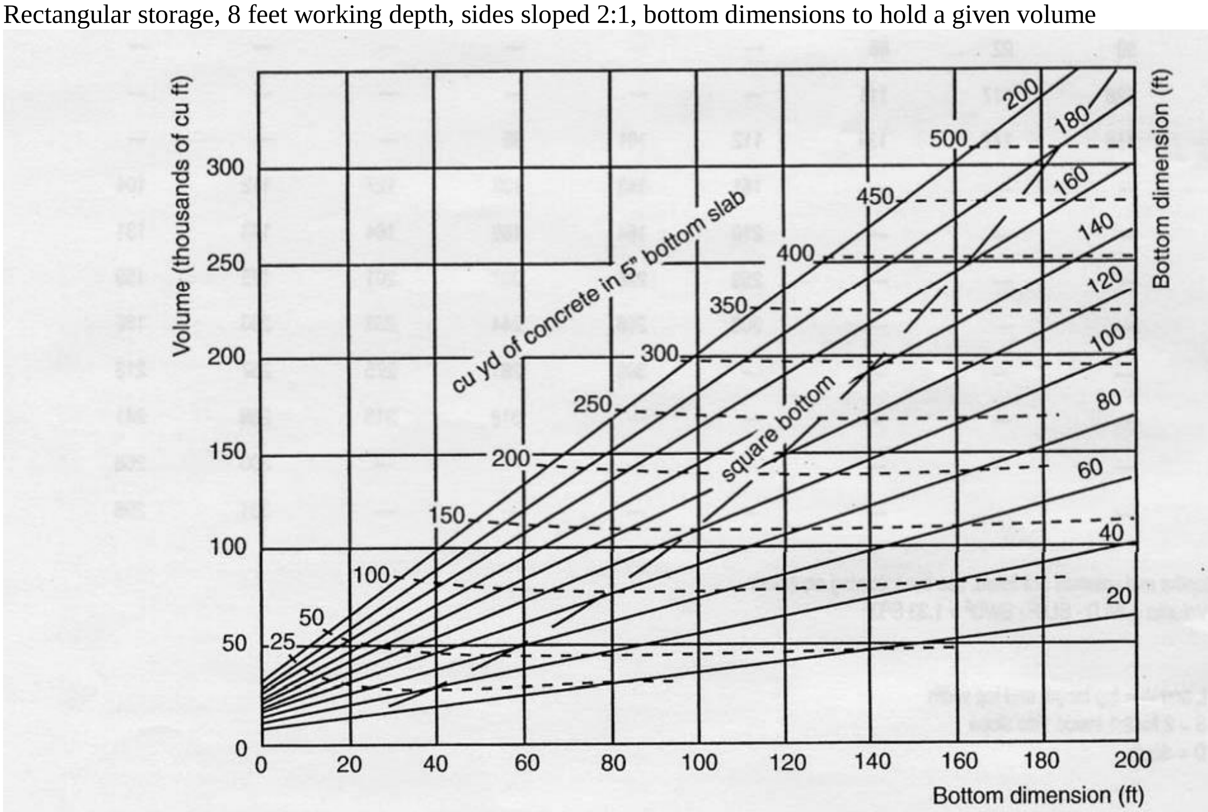


Figure 14.b

Rectangular storage, 8 feet working depth, sides sloped 2:1, bottom dimensions to hold a given volume



Sample Situations and Solutions for Sizing Storages

Situation 1

What are the dimensions of a roofed vertical-wall storage that will hold six months of manure from 50 cows in a tie-stall barn if chopped straw bedding is used and the cows weigh 1,400 pounds each?

Storage volume:
From table 11 assume a bedding volume of
0.6 cu ft/cow-day x 50 cows x 180 days = 5,400 cu ft

Assume a manure volume of
1.4 cu ft/1,000 lb. x 1,400 lb./cow x 50 cows x 180 days =17,640 cu ft

Total storage volume (sum of bedding and manure volumes)
5,400 cu ft+17,640 cu ft = 23,040 cu ft

Storage dimensions:
Assume a depth of 6 ft or 8 ft and a width of 40 ft.

Calculate length using the formula length = volume ÷ (depth x width)

For a 6-ft storage depth, the length is 23,040 cu ft ÷ (6 ft x 40 ft) =96ft

Allowing 6 inches extra for freeboard, the dimensions are 6.5 ft deep by 40 ft by 96 ft.

For an 8-foot storage depth, the length is 23,040 cu ft ÷ (8 ft x 40 ft) =72ft

Allowing 6 inches extra for freeboard, the dimensions are 8.5 ft deep by 40 ft by 72 ft.

Situation 2

What are the dimensions of an open storage to hold six months' manure and milking center wastewater from an operation that milks 100 cows housed in a freestall bam? Include dry cows, shavings for bedding, and milking center wastewater, but do not include manure from heifers or calves. The cows weigh an average of 1,400 pounds each. No runoff will go into storage because all is diverted.

Storage volume:
From table 1 assume a manure volume of
1.4 cu ft/1,000 lb. x 1400 lb./cow x 121 cows x 180 days = 42,689 cu ft

From table 11 assume a bedding volume of
0.2 cu ft/cow-day x 121 cows x 180 days = 4,356 cu ft

From table 12 assume a milking center wastewater volume of
5.0 gal/cow-day x 1 cu ft/7.5 gal x 100 cows x 180 days =12,000 cu ft

Total storage volume (sum of manure, bedding, and wastewater volumes) is
42,689 cu ft + 4356 cu ft + 12,000 cu ft = 59,045 cu ft

Dimensions for circular storage:
Assume a working depth (D) of 10 feet. Determine the diameter by using table 13 or calculate the radius (r) by using the formula
volume $= \pi r^2 D$

59,045 cu ft = 3.14 x r^2 10 ft
59,045 cu ft ÷ (3.14x10 ft) =r^2
43.3 ft = r, or 87 ft diameter

Assuming 2 feet extra depth for rainfall, freeboard, and dead space, the dimensions are 12 ft deep by 87 ft diameter.

Dimensions for rectangular earthen bank storage:
To calculate the top dimensions of a rectangular storage with sloping sides, use table 14 or the formula

$$\text{Volume} = WLD - SLD^2 - SWD^2 + 4/3\ S^2 D^3$$

or the formula

$$\text{Length} = (V + SWD^2 - 4/3\ S^2 D^3) \div (WD - SD^2)$$

Assume a top width (W) of 100 feet, an inside slope (S) of 2:1, and a working depth (D) of 10 feet.

To calculate length (L)

$$59{,}045 = 100\ (L)\ (10) - 2\ (L)\ (10^2) - 2\ (100)\ (10^2)$$
$$+ 4/3\ (2^2)\ (10^3)$$
$$59{,}045 = 800\ L - 14{,}680$$
$$800L = 73{,}725$$
$$L = 92.1$$

Again, assuming 2 feet of freeboard, the top dimensions of the basin must be increased to account for side slope.

Length is

92 ft + (2 [sides] x 2 [ft additional freeboard depth] x 2 slope) =100 ft.

Width is

100ft+8ft = 108ft

The top dimensions for a 12-ft-deep storage are 108ft by 100ft.

If the working depth is 6 ft and one bottom dimension is 70 ft, the other bottom dimension is 110 ft (figure 14.a).

If the working depth is 8 ft and one bottom dimension is 70 ft, the other bottom dimension is 65 ft (figure 14.b).

To calculate top dimensions for the above two options, add to the lengths and widths the product

slope x total depth (working depth + 2 ft freeboard) x 2 sides

This accounts for the sloping sides.

For the first option

70ft+ (2x8ftx2) 102ftand110ft + (2x8ftx2) =142 ft

Top dimensions for an 8-ft-deep storage are 102 ft by 142 ft.

For the second option

70ft+ (2x10ftx2) =110ftand65ft+ (2x10ftx2) =105 ft

Top dimensions for a 10-ft-deep storage are 110 ft by 105 ft.

Situation 3

What are the dimensions needed for a picket-dam storage to hold six months of manure from an operation milking 67 cows? Allow for dry cows + heifers + calves. The housing is a stall bam with chopped straw bedding for the cows and no bedding for the heifers and calves. The manure from all the animals is pumped into the storage. Because liquid drains through the picket dam to a grass infiltration area or holding basin, no allowance for volume in the manure storage needs to be made for runoff and precipitation.

Storage Volume:
From table1 multiply the ratio of 67 cows /80 cows x 249 ft^3/day x 180 days to yield a manure volume of 37,540 cu ft.

Bedding volume is

0.6 cu ft/cow-day (table 11) x 83 total cows (67 milking & 16 dry) x 180 days = 8,960 cu ft

The total storage volume needed is

37,540 cu ft + 8,960 cu ft = 46,500 cu ft

Storage dimensions:
None of the tables or figures accommodate the single vertical wall of the picket-dam system. To calculate the top dimensions, modify the formula for table 14 to read

$$V = WLD - 3/2\ \ SLD^2 - SWD^2 + 4/3\ (S^2D^3)$$

The maximum height for a picket dam is 7 feet. Assume the storage to have a top width (W) of 80 feet, a slope (S) of 2, and a working depth (D) of 7 feet. To the working depth, add an extra foot for freeboard. At 2 to 1 side slopes, the additional depth will increase the top dimensions by 2 feet (1 foot on each side). To calculate the length

$46{,}500 = 80\ (L)\ (7) - 3/2\ (2)\ (L)\ (7^2) - 2\ (80)\ (7^2)$
$+4/3\ (2^2)\ (7^3)$
$46{,}500 = 560\ (L) - 147\ (L) - 7{,}840 + 1.829$
$46{,}500 = 413\ (L) - 6011$
$52{,}511 = 413\ (L)$
$L = 127.1$ ft

Working dimensions for a 7-ft-deep storage are 80 ft by 127 ft. Actual top dimensions to allow for a total depth of 7.5 ft, with additional depth for freeboard, are 82 ft by 129 ft.

What size storage unit is necessary for the liquid from the system described in Situation 3, and what size settling basin for the lot runoff? The liquid includes milking center wastewater, runoff from the manure storage unit, and runoff from an outdoor concrete lot 100 ft wide by 160 ft long. The wastewater and manure storage runoff are piped directly into the liquid storage unit; the lot runoff must first pass through the settling tank in order to separate out the solid manure.

The volume of milking center wastewater is

5.0 gal/cow-day (table 12) x 1 cu ft/7.5 gal x 60 cows x 180 days = 7,200 cu ft

The volume of runoff from manure storage (18 inches deep on each square foot of storage area) is

18in x1ft/12in x 82ft x 129ft=15,876 cu ft

The volume of runoff from the outdoor lot (18 inches deep on each square foot of lot area) is

18in x 1ft/12in. x 100ft x 160ft = 24,000 cu ft

Runoff from a 25-year frequency, 24-hour rainfall event also needs to be added (assume 6 Inches for this example; check with NRCS for design number for your area). Volume for the 25-year event will be

6in x1ft/12in x 100ft x 160ft = 8,000 cu ft

Total volume of liquid into storage is
7,200 cu ft + 15,876 cu ft + 24,000 cu ft+ 8,000 cu ft = 55,076 cu ft

To calculate the dimensions for a rectangular storage with 2 to 1 side slopes, assume a storage unit with bottom dimensions of 80 ft by 122 ft by 8 ft deep (table 14).

Adding 2 feet of extra depth and slope distances, the top dimensions for a 10-ft-deep storage are 88 ft by 130 ft.

From figure 14.a, a storage unit with a 6-foot working depth will have bottom dimensions of 60 x 100 ft.

Adding 2 feet of extra depth increases the top length and width by 32 ft
(8 ft depth x 2 ft slope/ft x 2 sides = 32 ft)

The top dimensions for an 8-ft-deep storage are 92 ft by 122ft.

From figure 14.b, a storage unit with an 8-ft working depth will have bottom dimensions of 50 ft by 70 ft

Adding 2 feet of extra depth increases the top length and width by 40 ft.
(10 ft depth x 2 ft slope/ft x 2 sides = 40 ft)

The top dimensions for a 10-ft-deep storage are 90 ft by 110ft.

Calculations for a settling tank for lot runoff are explained in detail in "Dairy Manure Runoff Control," in *Dairy Manure Management: A Supplement to Manure Management for Environmental Protection* (see the "References" section). An alternative to storing runoff is a grass infiltration area, also described in "Dairy Manure Runoff Control." Alternatives for handling milking center effluents are described in "Milking Center Wastewater Disposal" in *Dairy Manure Management*. Infiltration can normally be used if more than *300 feet* separate the open lot from a stream or drainage ditch.

Management of Storages

Safety Concerns

! Do not enter manure sumps, pits, or storage tanks without appropriate safety apparatus and procedures. No tool, pump part, or farm chore is equivalent in value to the cost of a human life! Another common hazard is failure to provide adequate guarding at manure tank openings and push-off ramps to prevent entry by people, tractor scrapers, or cows. All open storages must have adequate fencing to prevent visitors, including small children, from gaining entry.

Filling

Various methods are used to fill storages. Some add the manure from the top while others add from beneath the surface. Adding manure from the bottom can reduce freezing, fly, and odor problems and can increase nutrient retention, since the fresh manure is not exposed to the air. Adding manure from the top often results in a pile or backup around the loading point, especially in freezing weather.

The following methods are used for filling storages:

Barn cleaner extension: has limited flexibility because the storage unit must be adjacent to the barn and requires top loading. Freezing of machinery and manure may be a problem.

Tractor scraper and loader has limited flexibility because storage unit must be adjacent to the barn and requires top loading.

Large piston manure pumps or pneumatic transfer systems move manure through 9- to 15-inch PVC or steel pipe to the bottom of a storage basin. Manufacturers' recommendations for maximum pumping distance vary from 150 to 250 feet.

Centrifugal manure pumps move manure through 4- to 6-inch PVC or steel pipes to storage. Check manufacturer's recommendations for pumping distance.

Unloading

Unloading should be done on a schedule. The best time to spread is just prior to spring planting. A second alternative is to spread and incorporate the manure in the fall. Extra help can be hired and additional equipment rented to reduce the number of days to unload. Some dairy operators try to unload in stages whenever they have time. This system can work if it is scheduled, but without a schedule it is too easy to get behind. In many areas, custom haulers are a good alternative.

Fly Control

Flies normally cannot complete their life cycle in liquid or semisolid manure. Fly breeding and control may be a concern near edges of stored manure or where large amounts of bedding are used.

Odor Control

Odor is intensified by storage and can become a concern to neighbors when the storage is unloaded. Spreading on days that disperse odor makes it less objectionable. Immediate incorporation reduces odor and conserves nitrogen.

COMMON CONVERSION FACTORS

In planning and operating a manure management system, it may be necessary to express certain values in units different from those used in this guideline. Below are some common conversions or equivalent factors.

62 pounds of fresh manure	per cubic foot (does not include bedding)
32 cubic feet of manure	per ton (typical)
26 cubic feet of sand-laden manure	per ton (typical)
8 pounds of liquid manure	per gallon (typical)
10 pounds of sand-laden manure	per gallon (typical)
250 gallons of liquid or slurry manure	per ton
2,000 pounds of manure	per ton
27,154 gallons of manure	per acre-inch
3 tons of manure	per 100 cubic feet of spreader capacity
1.25 cubic feet of manure	per bushel
78 pounds of water	per bushel
3.75 tons of manure	per 100 bushels of spreader capacity
4 tons of liquid or slurry manure	per 1,000 gallons of spreader capacity
0.8 bushel of manure	per cubic foot
7.5 gallons of manure	per cubic foot

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