SKIM & HAUL SYSTEMS FOR SAND-LADEN DAIRY MANURE

Operation & Management

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Introduction

Manageable systems for handling, storing and applying sand-laden dairy manure are needed to accommodate dairy producers' interest in using sand as a bedding material for dairy cattle. This guide addresses systems that are often categorized as 'skim & haul' approaches. Alternative systems include storage of only sand-laden manure within a covered storage and removal of sand from the manure using designed facilities with heavy dilution.

In skim & haul systems, most if not all of a farm's manures and wastewater streams are delivered directly to an outdoor storage facility. There may be two or more similar storage facilities on a farm that has several cow barns or barns that are separated by a significant distance or barrier. The premise behind these systems is that given some dilution and time, gradations of material will develop in the storage facility that allow a portion of the contents to be readily removed as a liquid. The remaining material is removed using equipment designed to handle solid manure.

Many producers opt for this type of system because, compared to the alternative systems, a skim & haul system usually:

- provides the most storage capacity for a given level of initial investment; and
- appears to be the least complicated (just put all of the materials into the storage).

Management of these systems at clean-out time is usually more demanding than for alternative systems, however. Successful operation and management of a skim & haul system requires consideration of the entire manure-management system, including application. Key requirements and considerations for successful management of a skim & haul system are discussed in the following sections.

Basic Concepts

<u>Structural components:</u>

The storage facility in a skim & haul system must be designed to allow equipment access for removal of settled solids and material that is not easily pumped. Standard recommendations are to include a concrete floor, ramp and buckwall. Most systems also require a concrete push-off area since these storages are typically loaded using tractors or skidsteers. Push-off areas should provide at least 30 feet of paved perimeter access and a vertical wall to reduce the likelihood that a build-up of sand will block the loading area. The remaining perimeter walls (beyond that used for the buckwall and ramp) can be of earthen construction, assuming that appropriate liner material is utilized. Layout of these components is addressed later in this guide.

The storage costs and design needs are obviously greater for such facilities than for conventional earthen storage facilities used with liquid manures. Although most producers want storage capacity for a year or more, they will frequently balk at constructing a long-term storage facility for sand-laden manure due to the perceived high cost of the concrete floor. The construction cost per unit area of a concrete floor is less than that for constructing concrete walls or the access ramp (generally fixed costs), however, and a larger floor area increases maneuverability within the facility when handling solids. So, storage capacity should not be sacrificed easily. This guide uses the following terminology for describing storage capacity:

Storage facility	**Holds material for**
Temporary	2 weeks or less
Short-term	2 weeks to 2 months
Intermediate-term	2 to 6 months
Long-term	6 months or longer

<u>Effects of dilution:</u>

Addition of dilution water to the storage facility increases the amount of storage volume required as well as the gradation of materials within the storage facility. A typical new installation will be designed to hold manure and milking center wastewater. Silage leachate and runoff from outdoor cattle lots can also be directed into the system. In some cases, other cattle manures or wastewater streams may be added as well. The storage volume required for a desired storage duration, t, can be projected as:

$$V(t) = V_{SLDM}(t) + V_{MCW}(t) + V_{SL}(t) + {}_{VLR}(t) + V_{Other}(t) + V_{Precip}(t)$$, where:

$V(t)$ = storage volume required for the desired storage duration;

$V_{SLDM}(t)$ = volume of sand-laden dairy manure added during the period [A good estimate of daily input is 2.0 cubic feet per 1000 lb. of animal weight];

$V_{MCW}(t)$ = volume of milking center wastewater added during the period;

$V_{SL}(t)$ = volume of silage leachate added during the period;

$V_{LR}(t)$ = volume of lot runoff added during the period;

$V_{Other}(t)$ = volume of other wastes or wastewater streams added; and

$V_{Precip}(t)$ = volume of precipitation added directly to the storage facility.

Additional volume must be constructed to provide appropriate freeboard. Obviously, as the desired storage duration increases, the storage volume required increases proportionately.

Sand particles, because of their comparatively high density, will tend to settle out of aqueous suspensions fairly rapidly due to gravitational forces. Mucous and other viscous fluids present within dairy manure, on the other hand, restrict movement of particles within the manure. As a result, sand particles in undiluted sand-laden dairy manure settle out very slowly. If sand-laden manure is diluted and mixed/handled, these viscous forces can be overcome, and settling will take place at a faster rate. In many practical applications, manure is scraped (not flushed) and the level of dilution is low (less than 1 part added water to part sand-laden manure, mass basis). In these situations, the manure retains most of its viscosity and the following seemingly contradictory statements hold true:

a) Some sand particles will always settle out of suspension in the storage facility; and
b) Most of the manure will still contain sand.

<u>Stratification:</u>

The amount of settling and the degree of gradation or stratification that occur within a storage facility is affected by the level of dilution, the degree of activity (shear), and the amount of time manure is in the facility. Figure 1 illustrates the degrees of stratification that would be expected within storage facilities of different capacities on a typical farm that scrapes manure from barn alleys and stores sand-laden manure and milking center wastewater in the facility. The gradation will be continuous, but generalized layers include:

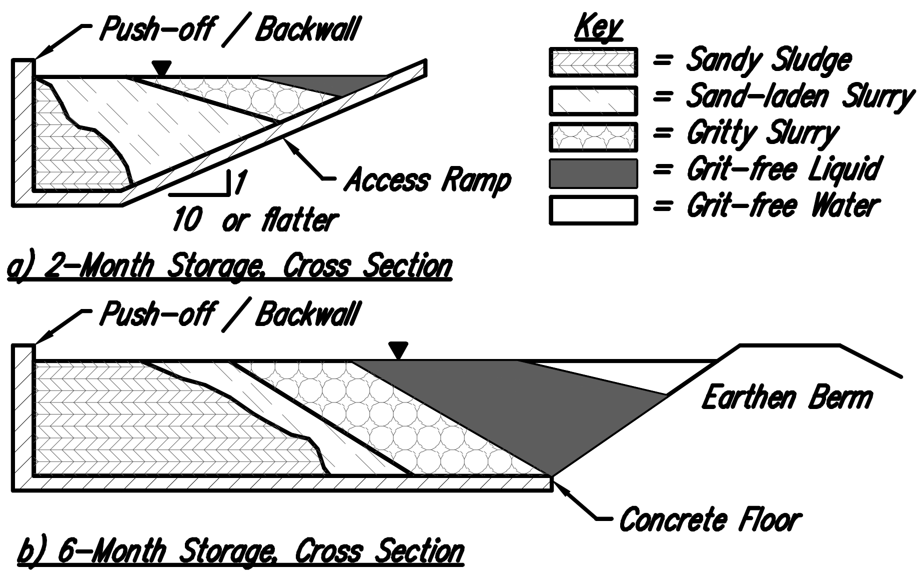

Figure 1. Stratification of material within storage facilities for sand-laden dairy manure.

Sandy sludge:	Readily handled as a solid, not pumpable
Sand-laden slurry:	Can be handled as a solid, very difficult to pump
Gritty slurry:	Not readily handled as a solid or liquid (significant wear on pump)
Gritty liquid:	Cannot be handled as a solid, pumpable (with some added wear)
Grit-free water:	Cannot be handled as a solid, very pumpable (without added wear)

Addition of dilution water increases stratification. Water that is applied to the surface of manure does not naturally mix in with the manure, so it will either run off the surface or pool on the surface. If sand-laden manure is deposited onto pooled liquid, as often occurs early in the storage period, the resulting dilution and mixing action (splash) is effective in causing the larger sand particles to settle out. This commonly leads to a buildup of sandy sludge near the push-off area. Meanwhile pooled water is displaced every time new manure is added to the storage facility. Eventually, the material near the push-off area will rise above the liquid level causing any water that is added to this surface to run off and away from the push-off area. From this time on, the gradation just slowly develops further.

As an important aside, consider why these facilities, holding lightly diluted (on an overall mass basis) sand-laden manure, do not function as settling basins. The dilution water that is essential for causing the sand particles to settle out of the manure always migrates away from the area where fresh manure is added. At best, these facilities may function as crude retention basins, where the goal is simply to keep the sand within the facility. A later section discusses considerations associated with retention basins for sand-laden manure.

Material volumes and handling:

Estimation of the volumes and composition of differing material in such facilities is much more of an art than a science and this is not likely to change anytime soon. To visualize the process, think of the gradation of material as mushrooming out from the loading area over time.

For a short-term storage facility, the bulk of the material will be [sand-laden and gritty] slurry and, typically, little liquid material (<10% volume) should be expected. Equipment that is usable for daily hauling of sand-laden manure should work for handling most of this material.

With an intermediate-term storage facility, a greater proportion of the material will be in liquid form when the storage nears capacity, especially near the fringes of the facility away from the loading area. Two handling systems will be needed to empty the storage; one for handling liquids, and a second for solids. Management of the facility will approach that needed for a long-term storage facility.

In long-term storage facilities, the stratified regions will be well defined by the time the facility nears its capacity. When a long-term storage facility is filled after being empty, nearly a third of the volume should be readily pumpable (liquid) and nearly another third should be readily handled with a front-end loader (sandy sludge and much of the sand-laden slurry). The intermediate portion of the material, however, will not be readily pumped or handled with a front-end loader.

Management:

A key to suitably managing a skim & haul system is being prepared to handle that most troublesome portion of the manure that cannot be readily pumped or handled with a front-end loader. As the name 'skim & haul' implies, if little or no agitation is used, the

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liquid fraction along the outer fringes of a facility can be removed quickly leaving an underlying mass to be hauled out. In this case, the liquid fraction can be applied using equipment such as a dragline hose system. However, the operator must then be prepared to deal with the remaining sloppy material covering the easier-to-handle sludge and slurry. On the other hand, agitation can be used to remove more [slurry] material from the storage using a pump. This approach makes it easier to handle the remaining material with a front-end loader, but it also slows down the pumping process, usually limits the operator to the use of tank spreaders for applying liquids, and involves more pump wear. This layer of gritty slurry ("slop", "goo", etc.) will always naturally be present in skim & haul systems. Producers need to plan in advance how they will handle this material or they will quickly become disenchanted with the system.

Facility Layout

The layout of short-term storage facilities is dominated by the fixed components – the ramp and buckwall – and facilitating removal of material with a front-end loader. Consequently, the entire storage facility is frequently constructed of concrete. In the simplest scenario, the ramp serves as both the loading and unloading area. Alternatively, a push-off area can be constructed along any side.

Long-term storage facilities provide a much better opportunity to apply manure to land in a responsible manner. In terms of handling sand-laden manure, a substantial portion of a long-term storage facility's sidewall may be of earthen construction. If room allows, the ramp may be constructed within the main facility. Since the ramp needs a long run to maintain a safe slope, it may be more desirable to extend it out across the sidewall. The location and orientation of the ramp needs to allow loading implements ample maneuverability inside the structure. This means that there must be opportunity to access the concrete floor from the ramp and there must be sufficient room beyond the end of the ramp to accommodate safe operation during the cleanout process, especially early in the process when the full extent of solids buildup is present. If in doubt, move the ramp further away from the loading (push-off) area.

Variations in Design and Management

Producers and contractors frequently look to modify the basic design in order to cut costs or provide more flexibility during cleanout. A few of the more common ideas are discussed here to consider the reasoning behind the modification and identify potential pitfalls.

<u>Skipping solids removal:</u>

Frequently, producers will consider not cleaning out solids after they've decanted the facility (skimmed off the liquid). This is an acceptable practice, but with definite limitations. If this practice is part of the producer's manure management plan this option provides added flexibility. As an example, a producer may skim off liquids during the summer to apply onto wheat ground and then empty the entire storage in the fall when more acreage is available.

The main limitation to this management practice is that storage capacity is reduced significantly each time the solids are left in the facility. Producers who intend to utilize the skim & haul approach need to recognize that the removal of solids must occur within a fairly short time immediately following removal of liquids. The addition of fresh manure and wastewater plus rainfall can turn solid material left in the facility into unmanageable slop fairly quickly. The operator who is unlikely to get both jobs done in a reasonable timeframe needs to consider another storage and handling system.

Partial floor:

One common way to cut costs is to pour a concrete floor in only part of the structure and line the remainder using clay. The idea is to place concrete only where the bulk of the sandy material will end up. Sometimes a stubwall (18-36 inches) is placed along the edge of the concrete floor to retain more sandy material.

A full concrete floor is preferred. If a partial floor is strongly desired, it should cover no less than half the floor area and must provide maneuverability to the loading implements. Even with a stubwall along the edge of the concrete floor, some deposition of sand beyond this floor area is likely. While the partial floor provides some access (e.g. backhoe) to the remaining floor area great care must be taken not to damage the earthen liner when removing this material in this manner. Also, it is imperative that solids be removed as frequently as liquids in this design. Otherwise, unacceptably high levels of sand will end up beyond the concrete pad.

Two-stage system:

Another common design modification is to construct two storage structures in series with a total capacity equal to that of the desired storage duration. The main reason usually cited for using two cells is that costs can be saved by reducing the size the first structure, which has the concrete floor, and constructing an earthen facility for most of the required capacity. An additional reason is that having two cells offers more flexibility in handling manure – can pump from either facility as desired. Typically, the desire is to size the second cell much larger than the first and haul mainly from the second cell.

While the reasoning makes sense, there are some major limitations to the practice with sand-laden manure. The basic premise that applies to decanting methods (overflows, porous dams, pumping, etc.) is that one can at best remove the amount of water that is added to the manure (i.e. wastewater and precipitation) without removing sand with the liquid. The table below illustrates what happens with a first cell with 3-months' storage capacity and a second cell with 9-months' capacity under two pumping schemes with very generous premises:

1) A third of the initial first-cell volume can be pumped into the second cell and half of subsequently added material can be decanted without moving sand from the first cell into the second.
2) Two thirds of the initial volume can be pumped into the second cell and half of subsequently added material can be decanted with only minor amounts of fine sand being moved from the first cell to the second.

Table 1. Illustration of material flows in a two-stage manure system for lightly diluted manure.

	Premise #1 – No sand removed		Premise #2 – Some fines removed	
Transfer #	Share of cell #1 volume pumped	Interval between pumping (months)	Share of cell #1 volume pumped	Interval between pumping (months)
1	1/3	3	2/3	3
2	1/6	1	1/3	2
3	1/12	0.5	1/6	1
4	1/24	0.25	1/12	0.5
Total	15/24 or 5/8	<5	15/12 or 5/4	6.5

In both of these liberal scenarios, the resulting storage capacity of the system is nearer to 6 months than a year. In both scenarios, one must ask if there are really any benefits as compared to constructing a single cell with 6-months' storage capacity. With the second scenario, one must ask if the system is sustainable and acceptable based upon perceived benefits.

In practice, no decanting method will allow such a system to effectively operate as a retention basin without regular cleanout because needed dilution water is preferentially removed from the system and the volumes don't add up as desired.

Summary

The skim & haul approach to storing and handling sand-laden dairy manure can be effectively utilized in a compatible management system. Producers need to understand the requirements for making such a system function well, including physical storage needs, handling practices, and manure-application constraints. Several of these requirements are described. Producers who may not satisfy these requirements, or who are looking for long-term solutions to handling sand-laden manure, should consider an alternative handling system or reconsider using sand for bedding.