Manure Storages

Developed by the Engineering Practices Subcommittee of the ASAE Agricultural Sanitation and Waste Management Committee; approved by ASAE Structures and Environment Division Standards Committee; adopted by ASAE March 1978; reconfirmed December 1982, December 1983; removed reference to ASAE S288 and reconfirmed December 1984; reconfirmed December 1985, December 1986; revised March 1988; revised editorially February 1989; revised October 1991; reaffirmed December 1996, December 1997; revised December 1998; reaffirmed February 2004.

1 Purpose and scope

1.1 This Engineering Practice provides recommendations for siting, design, and construction of manure storage units. Its recommendations are for both earthen and fabricated structures.

1.2 This Engineering Practice does not include recommendations for anaerobic treatment of livestock waste. See ASAE EP403 for this purpose.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Engineering Practice. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Engineering Practice are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Standards organizations maintain registers of current valid standards.

ACI S318-95, *Building Code Requirements for Reinforced Concrete*
AISC S326, *Specifications for the Design of Cold Formed Steel Structural Buildings*
AISIS SG-971 (1997), *Specifications for the Design of Cold Formed Steel Structural Members*
ASAE EP250.2 DEC98, *Specifications for Farm Fence Construction*
ASAE EP288.5 DEC98, *Agricultural Building Snow and Wind Loads*
ASAE S292.5 OCT94, *Uniform Terminology for Rural Waste Management*
ASAE EP378 DEC98, *Floor and Suspended Loads on Agricultural Structures Due to Use*
ASAE EP379.2 NOV97, *Control of Manure Odors*
ASAE D384.1 DEC98, *Manure Production and Characteristics*
ASAE S466.1 DEC98, *Nomenclature/Terminology for Livestock Manure Handling Equipment*
ASAE EP470 DEC97, *Manure Storage Safety*

3 Definitions

3.1 Manure storages are for the accumulation of manure, wastewater, and runoff for the period of time required to allow for the accumulation's environmentally safe disposition.

3.2 Distinction between types of manure storages is usually by the consistency of the manure stored and/or the type of construction. For the purpose of this Engineering Practice, manure storages made by constructing an excavated pit, dam, embankment, dike, levee, or a combination of these procedures will be referred to as *holding ponds*. Fabricated structures for storage of liquids and slurries will be referred to as *tanks*, and those for storage of solid manure will be referred to as *dry stacking facilities*. Refer to ASAE S292 and ASAE S466 for terminology.

4 Laws and regulations

4.1 All federal, state, and local laws, rules, and regulations governing the use of manure storages shall be followed. Included are those pertaining to local zoning, flood plain management, shoreland protection, and buildings. Necessary approvals and permits for location, design, construction, and operation shall be secured.

5 Design criteria

5.1 General criteria

5.1.1 The need for manure storage should be based on the level of management, labor availability, nutrient conservation, timeliness of application to crop needs, and environmental considerations.

5.1.2 Required storage volume. The general equation for the required storage volume (see figure 1) is as follows:

$$S = \frac{N \times MW \times D}{MD} + WWV + BV + ROV + P$$

where:

S	is	volume of storage required, m^3 (ft^3)
N	is	number of animal units (AU)
MW	is	mass of manure produced per AU per day, kg/day·AU (lb/day·AU) (see ASAE D384)
AU	is	1000 kg (1000 lb) live animal mass
D	is	number of days of storage, days (see 5.1.2.1)
WWV	is	wastewater volume, m^3 (ft^3) (see 5.1.2.2)
ROV	is	runoff volume, m^3 (ft^3) (see 5.1.2.3)
P	is	precipitation volume, m^3 (ft^3) (see 5.1.2.4)
MD	is	manure density, kg/m^3 (lb/ft^3) (see ASAE D384)
BV	is	bedding volume
	=	VR (N×B×D)/BD, m^3 (ft^3) (see 5.1.2.5)

where:

VR	is	volume reduction factor (range, 0.3 to 0.5)
B	is	mass of bedding use per day per animal (kg/day·animal unit) (lb/day·animal unit)
BD	is	loose bedding density, kg/m^3 (lb/ft^3).

5.1.2.1 Days of storage (D). The required days of storage should provide for:

–periods of weather that prevent spreading;
–periods of melting snow and frozen ground;
–periods of soil saturation; and
–periods when fields are not available for spreading or until crops require application of waste.

The storage unit shall provide the minimum storage time required by local or state regulatory agencies.

5.1.2.2 Wastewater volume (WWV). The wastewater volume includes contaminated water such as milking center wastewater, wash water, spillage, and leakage for the days of storage. Wastewater is generally excluded from dry stacking facilities.

5.1.2.3 Runoff volume (ROV). The runoff volume is the normal runoff volume during the days of storage plus the runoff volume from the 25y/24h storm event from the storage unit's drainage area. To minimize

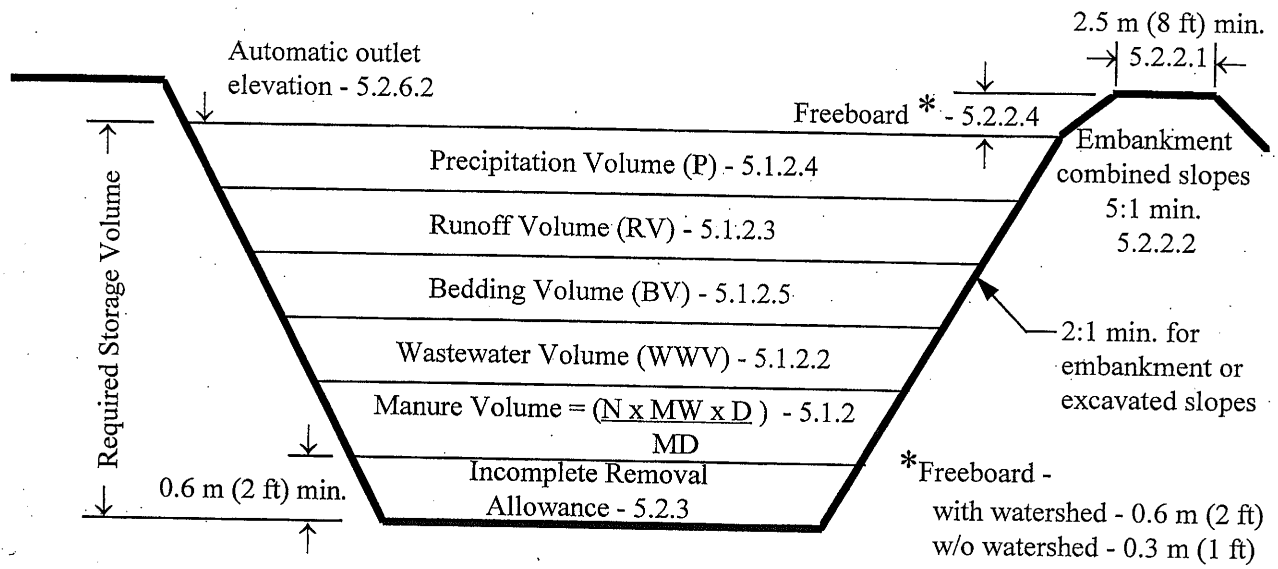

Figure 1 – Holding pond detail

the storage requirement for holding ponds and tanks, uncontaminated water should be excluded to the extent practicable unless needed for a purpose such as dilution.

5.1.2.4 Precipitation volume (P). A precipitation volume is the volume of precipitation less evaporation for the days of storage on the surface of the storage unit plus the volume of precipitation for the 25y/24h storm event on the surface of the storage unit. If the storage unit is covered, this allowance for the normal precipitation less evaporation and the 25y/24h storm on the surface of the storage unit is not required.

5.1.2.5 Bedding volume (BV). The bedding volume depends on the quantity of bedding and its characteristics, such as type, void space, initial moisture content, and water absorption capacity.

5.1.3 Siting. Siting of manure storage units shall give consideration to minimizing the potential for producing undesirable odors and contamination of surface and ground water.

5.1.3.1 Manure storage units should be located to minimize the pollution potential to ground water and surface waters such as lakes and streams.

5.1.3.2 Wind direction probability data should be considered in siting the storage unit to minimize the frequency of odor transport to housing developments or neighboring residences (also see ASAE EP379).

5.1.3.3 Locate manure storage away from wells or other ground water supply sources as described in clauses 5.2, 5.3, and 5.4.

5.1.3.4 Locate the manure storage unit at least 15 m (50 ft) away from a milk house or as required by state code or milk marketing regulations.

5.1.3.5 Manure storage units should be located to provide accessibility to equipment throughout the year, to provide convenient filling and emptying, and to minimize visual impact.

5.1.3.6 Manure storage units should not be sited in a floodplain unless protective measures are taken to prevent the removal of stored manure by floodwaters.

5.1.3.7 Storage units should be in a location that will allow enlargement if future expansion of the operation is anticipated.

5.1.4 Safety. Storage units shall include appropriate safety features. See ASAE EP470 for safety criteria.

5.1.5 Visual appearance. Consideration should be given to using vegetation or natural or constructed barriers to improve the appearance of storage units and/or to screen them from view.

5.1.6 Effluent utilization. Effluent from storage units may not be discharged to streams, lakes, or other waterways, or be allowed to run off the owner's property. Storage unit effluent is usually land applied. The rate of application should not cause runoff. The amount applied should result in annual nutrient applications that approximate crop need and do not cause undesirable levels of nutrients or toxic material to accumulate in soil, plants, soil water, ground water, or runoff. The method and timing of application should be such that odors will be minimized. Biweekly or weekly dosing using surface irrigation systems should be preferred to a continuous dosing. Application frequency should consider labor availability, cropping schedules, rainfall, and soil conditions.

5.2 Holding pond criteria

5.2.1 Ground water protection. A holding pond's proximity to wells and other ground water supplies, and the soils and foundation in which it is constructed shall be such that the potential for ground water contamination is abated.

5.2.1.1 Proximity to water supplies. Separation distances specified by applicable state or local regulations shall be followed. The nearest liquid edge of holding ponds should be a minimum of 90 m (300 ft) from wells and other ground water supplies.

5.2.1.2 Soils and foundation. A thorough site investigation shall be made to determine the physical characteristics and suitability of the soil and foundation for a holding pond. Holding ponds should be located in soils of low permeability. More permeable soil types may require an impermeable membrane such as a synthetic liner, impermeable soil liner, concrete lining, incorporation of bentonite with in-situ soil, or another acceptable method or material that will provide a suitable seal. Treatments should be determined from geologic data available for the area, the performance of similar installations, geologic investigations when appropriate, and applicable local codes and state regulations.

NOTE - It would be desirable to state a design infiltration rate for the movement of liquids through the bottom and sidewalls of holding ponds. However, state-of-the-art has not developed to the point that there is a universally accepted rate. The USDA-Natural Resources Conservation Service has published in-situ soil properties for which a liner should be considered in its Agricultural Waste Management Field Handbook available from the USDA Consolidated Forms and Publications Distribution Center, Landover, Maryland.

5.2.2 Earth embankment and excavation

5.2.2.1 Embankment top width. The minimum embankment top width should be 2.5 m (8 ft).

5.2.2.2 Side slopes. The combined wet and dry side slopes of settled embankments should be not less than 5:1 (5 horizontal to 1 vertical), and neither slope should be steeper than 2:1. Excavated cut slope should not be steeper than 2:1. Soil stability and the method to be used in maintaining embankment vegetation should be considered in determining the appropriate side slopes.

5.2.2.3 Embankment settlement. The embankment top elevation should be increased by at least 5% during construction to allow for settling.

5.2.2.4 Freeboard. For holding ponds with a watershed, the top of the settled embankment should be at least 0.6 m (2 ft) above the required storage. When inflow to the holding pond is always controlled, such as with a pump system, this freeboard can be reduced to 0.3 m (1 ft).

5.2.3 Incomplete removal allowance. Unless facilities are provided to remove the materials completely, an allowance of at least 0.6 m (2 ft) should be provided in the bottom of the holding pond in addition to the required storage volume (see clause 5.1.2) to accommodate materials not removed during emptying. Consideration should be given to treating the holding pond influent with solid/liquid separation to minimize problems associated with solids.

5.2.4 Bottom elevation. The holding pond bottom elevation should be above the high water table or as modified by subsurface drainage. In addition, it should be at least 0.9 m (3 ft) above fractured bedrock. For perched water tables, a curtain drain with a positive outlet may be installed around the structure to permanently lower the water table. A positive outlet for the drain shall be provided. The bottom elevation shall comply with any state or local codes regarding separation distance from water tables.

5.2.5 Provision for agitation and emptying. Provide a pumping platform, wall, or sloping ramp access to agitate and empty the holding pond. Concrete ramps or agitation pads should be provided to prevent damage to earthen-lined holding ponds.

5.2.6 Inlet and outlet

5.2.6.1 Inlet. Inlet devices should discharge the waste into the holding pond beyond the toe of the embankment or cut slope. Pipes or open channels may be used. The minimum diameter or least dimension of the inlet should be 150 mm (6 in.) for non-dairy waste and at least 200 mm (8 in.) for dairy waste. If the inlet discharges below the holding pond's water surface and originates within a building, it should be vented to prevent gases from being released within the building. The discharge end should include erosion prevention measures.

5.2.6.2 Outlet. An automatic overflow device, such as an earthen spillway or pipeline, should be installed that will begin discharging when the level of the holding pond reaches or exceeds the required storage volume elevation. This outlet should be designed for events above the 25y/24h storm event. No outlet, however, should be installed to automatically discharge when the holding pond level is below the required storage volume elevation unless the discharge is to another storage facility. Outlets for this purpose should have a minimum capacity of 1.5 times the peak daily inflow rate. The discharge end of the outlet should include erosion prevention measures. Outlets should discharge to an area that minimizes potential for contamination of, or entrance to, a receiving water.

5.2.7 Safety. A fence that has the capability to reduce the opportunity for entrance of livestock, children, pets, and others should enclose the holding pond. Fences should be constructed to protect the embankment and to permit access for holding pond maintenance (see ASAE EP250). Signs should also be posted to warn of the holding pond's dangers. For a complete reference on safety, see ASAE EP470.

5.2.8 Protection. Embankments and disturbed areas surrounding the holding pond should be treated to control erosion. Some means, such as vegetation or rock armor, should be considered for protecting the embankment from erosion. If vegetative means are used, suitable top soil should be placed on the top and dry slope of embankments to a depth of 15 cm (6 in.) to 30 cm (12 in.) to promote vegetation establishment. Species selection should favor low-growing, sod-forming grasses and avoid use of vegetation having long tap roots. For holding ponds having a surface area greater than 2 ha (5 acres), consideration should be given to providing embankment protection from wave action.

5.2.9 Visual appearance. Consideration should be given to using vegetation and natural or constructed barriers to improve the appearance of the holding pond and/or to screen it from view.

5.3 Storage tank general criteria

5.3.1 Soils and foundation. A thorough site investigation shall be made to determine the physical characteristics and suitability of the soil and foundation for the fabricated storage structure. Avoid construction of below-ground storage tanks below the water table unless curtain drains or interception drains are installed around the perimeter of the storage unit. The drain shall be at an elevation of 0.3 m (1 ft) below the bottom to permanently lower the water table. A positive outlet for the drain shall be provided. Minimum distances between the bottom of the storage and the high water table shall comply with state and local regulations. The minimum separation distance for essentially watertight tanks from wells and other ground water supplies shall be 30 m (100 ft).

5.3.2 Provision for agitation and emptying. Provision for agitation and emptying the storage unit should be provided.

5.3.3 Incomplete removal allowance. An allowance of at least 0.2 m (8 in.) should be provided in the bottom of the storage unit to accommodate materials that are not removed during emptying. If a sump is provided, no allowance is needed.

5.3.4 Depth allowance for agitation and ventilation. An allowance of 0.3 m (1 ft) should be provided at the top of the manure storage unit for agitation and/or ventilation requirements.

5.3.5 Depth requirements. Below ground storages, to be agitated with commercially available agitation pumps, should be at least 1.8 m (6 ft) deep and no greater than 3.6 m (12 ft) deep. The storage depth is measured from the floor to the top of the storage unit opening or cover.

5.4 Stacking facility general criteria

5.4.1 Management of liquid seepage from dry stack facilities. Liquid (precipitation and urine) from solid or semisolid stacking facilities should be drained to an appropriate liquid storage unit or held in the storage unit. If liquid is retained in the storage unit, the floor should be sloped 0.5% to one side or end with stacking started at the shallow side or end. Solids should be retained in the stacking facility by use of a floor drain or vertically slatted wall constructed with pressure-treated lumber. The wall should be designed according to loading with the spacing between the slats approximately 12.7 mm (0.5 in.) apart. For floor drains, a 150-mm (6-in.) layer of corncobs, shredded bark, or shredded corn stalks is necessary on the floor. Provide floor drains with removable grills and easy clean-out capability. Slope floors slightly toward floor drain or vertically slatted wall. Install 150 mm (6 in.) or larger diameter corrosive-resistant pipe in the bottom of the drain to carry liquid to an appropriate liquid storage unit.

5.4.2 Proximity to water supplies. The separation distance from wells and other ground water sources shall be as specified by applicable state or local regulations. As a minimum, the separation distance between the nearest edge of waste stacking facilities and wells and other ground water supplies should be 90 m (300 ft).

6 Materials and structural design

6.1 Structural design

6.1.1 Structural design methods and criteria. Methods used for structural design of manure storage units should be consistent with the code and/or standards for the respective material.

6.1.1.1 Vertical walls. See clause 6.1.2 for wall design loadings.

6.1.1.2 Sloping walls. Wall design loading should be as indicated in clause 6.1.2, modified for the effects of the wall slope.

6.1.1.3 Floors and ramps. A concrete floor is recommended for convenient emptying of wastes and possible control of ground water pollution. Earth or crushed rock can be used if a water pollution hazard does not exist. The saturated soil will support the manure handling equipment, and a structural floor is not needed.

Table 1 – Lateral earth pressure values[1)]

Soil		Equivalent fluid pressure kPa/m (lbf/ft²·ft) of depth			
		Above seasonal high water table[2)]		Below seasonal high water table[3)]	
Description[4)]	Unified classification[4)]	Flexible wall	Rigid wall	Flexible wall	Rigid wall
Clean gravel, sand, or sand-gravel mixtures (maximum 5% fines)[5)]	GP, GW, SP SW	4.7 (30)	7.9 (50)	12.6 (80)	14.1 (90)
Gravel, sand, silt, and clay mixtures (less than 50% fines); coarse sands with silt and/or clay (less than 50% fines)	All gravel/sand dual symbol classifications and GM, GC, SC, SM, SC-SM	5.7 (35)	9.4 (60)	12.6 (80)	15.7 (100)
Low-plasticity silts and clays with *some* sand and/or gravel (50% or more fines); fine sands with silt and/or clay (less than 50% fines)	CL, ML, CL-ML, SC, SM, SC-SM	7.1 (45)	11.8 (75)	14.1 (90)	16.5 (105)
Low to medium plasticity silts and clays with *little* sand and/or gravel (50% or more fines)	CL, ML, CL-ML	10.2 (65)	13.4 (85)	14.9 (95)	17.3 (110)
High plasticity silts and clays (liquid limit more than 50%)[6)]	CH, MH	—	—	—	—

[1]For lightly compacted soils (85% to 90% maximum standard density). Includes compaction by use of typical farm equipment.
[2]Also below seasonal high water table if adequate drainage is provided.
[3]Includes hydrostatic pressure.
[4]All definitions and procedures in accordance with ASTM D2488 and D653.
[5]Generally, only washed materials are in this category.
[6]Not recommended. Requires special design if used.

6.1.1.3.1 On soils where water pollution or equipment support may be a problem, concrete floors and ramps are recommended. Design for anticipated equipment loads. For wheel loads up to approximately 2300 kg (5000 lb), 130-mm (5-in.) thick floors and 150-mm (6-in.) thick ramps over 150 mm (6 in.) granular fill are typically adequate. With no wheel loads, 100-mm (4-in.) thick floors are adequate.

6.1.1.3.2 On soils where water pollution will not be a problem but equipment support may be, an 89-mm (3-in.) layer of wetted and compacted stone chips over 130 mm (5 in.) of crushed 40-mm (1.5-in.) diameter stone is typically adequate.

6.1.2 Design loads for walls

6.1.2.1 Interior design load. Interior hydrostatic pressure is 10.2 kPa/m (65 lbf/ft²·ft) of depth where stored waste is not protected from precipitation. A value of 9.4 kPa/m (60 lbf/ft²·ft) may be used where the stored waste is protected from precipitation and will not become saturated. For that portion of the walls below ground or backfill level, the exterior earth pressure may be assumed to resist 50% of the interior hydrostatic pressure from the ground surface to a depth of 1.2 m (4 ft) and 100% of the interior hydrostatic pressure below the 1.2 m (4 ft) depth. Design partition walls for the full 10.2 kPa/m (65 lbf/ft²·ft) hydrostatic pressure on either side unless openings in the wall assure equal loads on each side of the wall.

6.1.2.2 Exterior wall design load. External loads consist primarily of lateral earth pressures, hydrostatic pressures, wind loads, surcharge pressures, and floor or cover, building, and equipment loads (see table 1).

6.1.2.2.1 Lateral earth pressures depend on the type and density of the soil or backfill material, wall flexibility, structural shape, and water table level. Wall supported at both the top and bottom, cantilever walls having a base thickness-to-height ratio >0.085, and walls of circular structures should be considered rigid walls. Walls designed as a cantilever and having a base thickness-to-height ratio <0.085 may be considered flexible walls. Table 1 provides lateral earth pressure values to be used.

6.1.2.2.2 Where installation or operation permits the movement of heavy equipment within 1.5 m (5 ft) of the wall, an additional 0.6 m (2 ft) of soil surcharge shall be considered in the wall analysis. Additionally, concrete pads may be advisable to better distribute loads.

6.1.2.2.3 Walls projecting above the ground surface level or walls supporting a building should be designed for the appropriate wind loads. Refer to ASAE EP288.

6.1.2.2.4 Walls and columns subjected to loads from structure covers, buildings, and building floors should be designed for the effect of such loads.

6.1.2.3 Design loads for footings

6.1.2.3.1 Footing loads include all dead and live loads above the footing level. Design soil bearing pressures should be determined from data on soil strength, performance of nearby structures, or soil testing and analysis when appropriate. Footing designs for circular structures should include the lateral pressure resulting from the foundation materials within the circular ring footing with a surcharge load from the storage material.

6.1.2.3.2 All footings are to be located at or below the maximum frost depth. A compacted foundation of frost-free material such as drained granular material, extending to below frost depth, may be used as an alternate to extending the structural footing.

6.1.2.4 Design loads for storage unit covers in addition to dead loads

6.1.2.4.1 If an outdoor storage tank cover is constructed at least 460 mm (18 in.) above ground level and not accessible to livestock or vehicle traffic, use a distributed load of 1.92 kPa (40 lbf/ft^2) plus an appropriate snow load.

6.1.2.4.2 If the storage unit cover is to support floor loads, use loads from ASAE EP378.

6.1.2.5 Design loads for floors. Use loads from ASAE EP378.

6.2 Materials

6.2.1 Reinforced concrete. Refer to ACI 318.

6.2.2 Pressure treated round poles, posts, and square timbers or plank. Refer to ASAE EP388.

6.2.3 Steel. Refer to AISC S326 and AISIS SG-971.

6.3 Plans and specifications. In the drawings and specifications, identify all materials utilized in a storage structure as steel, wood, concrete, and indicate where they are used. Also identify coatings, linings, sealants, etc, with reference to appropriate standards or specifications governing their quality.