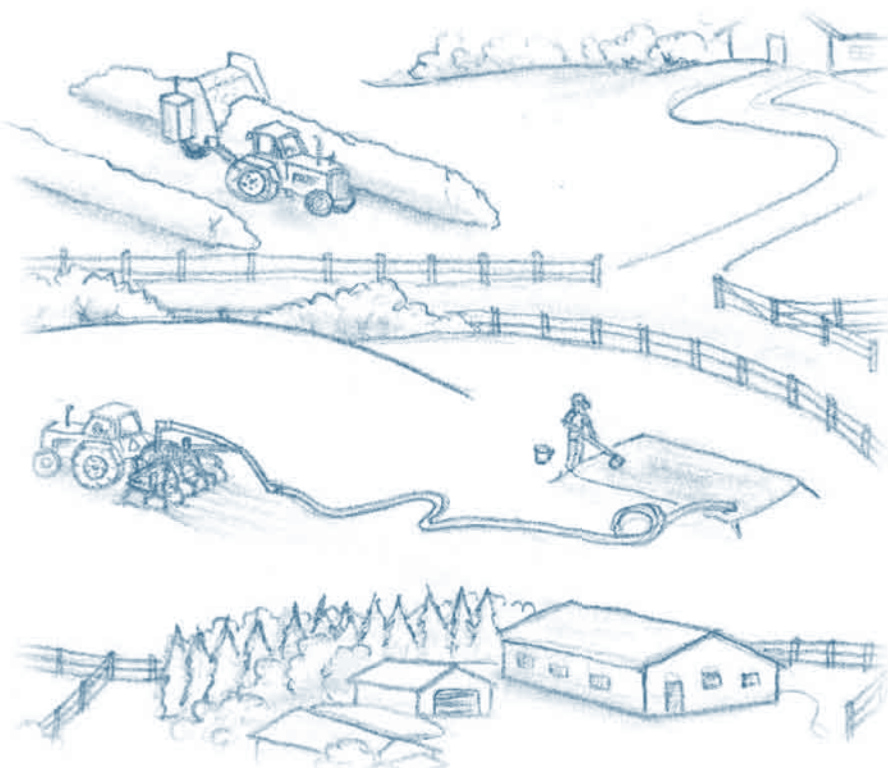
Chapter 4.1

Estimating Manure Inventory



learning objectives

- Briefly explain the importance of determining manure weight or volume.
- Estimate the weight of solid manure in a pile.
- Estimate the volume of liquid manure in storage facilities.
- Describe the optimal time to determine manure inventory.

Important Terms

Table 4.1.1 Key Terms and Definitions

Term	Definition
Agitation	The stirring up or mixing, in this context, liquid manure in a storage facility.
Circumference	The outer boundary of a circular area.
Cosine	The ratio of the length of the side adjacent to an acute angle of a right triangle to the length of the hypotenuse. Abbreviation: cos.
Diameter	A straight line passing through the center of a circle or sphere and meeting the circumference or surface at each end.
Freeboard	The distance from the top of the manure storage to the top of the manure.
Hypotenuse	The side of a right triangle opposite the right angle.
Perpendicular	Meeting a given line or surface at a right angle.
Pi (π)	The mathematical constant π is a transcendental real number, approximately equal to 3.14159, which is the ratio of a circle's circumference to its diameter.
Radius	A straight line extending from the center of a circle or sphere to the circumference or surface, respectively. The radius of a circle is half the diameter.
Right Angle	An angle that measures 90 degrees.
Windrow	A row or line of any material, but in this publication it refers to stored manure.

The weight or volume of available manure should be determined prior to land application. There are at least three reasons why getting an accurate estimate of manure volume or weight is important:

- The weight of available manure, together with nutrient content, can be used to estimate the required land base for manure utilization.
- To determine if a producer is subject to additional requirements under AOPA (e.g., if more than 500 tonnes of manure is handled).
- To estimate the time required to apply manure.

Weighing manure is the most accurate method for determining the quantity of manure applied. Physically weighing manure may not be practical or safe, in which case manure inventory must be estimated. There are three options for estimating manure inventory:

- Standard estimates or "book values" for average manure production for different livestock.
- Historical manure application records, or capacity indicators in storage facilities.
- Calculated estimates of pile weight or volume contained in a storage facility.

Standard estimates or "book values" are useful when estimating storage needs, but are of limited value for nutrient management planning. Standard values may not reflect the actual volume or weight of manure produced because of factors such as precipitation, feeding and bedding practices and water conservation practices.

Operations may have manure application records documenting the volume of manure applied in the past (e.g., number of loads hauled). Provided the operation has not changed in size, management or type of livestock this estimate can be reliable enough for nutrient management planning. In addition, existing manure storage facilities may be equipped with capacity markers that provide easy estimates of volume present.

The weight or volume of manure in a storage facility can be estimated using direct measurements and calculations. This method can be used in the absence of historical manure application records, and is more operation specific than using standard values. The rest of this chapter will focus on how to measure and calculate volume and weight of stored solid and liquid manure.

Estimating the Weight of Solid Manure

Nutrient content of solid manure is usually expressed as a percentage, or in weight of nutrient per unit weight of manure (e.g., kilograms per tonne). Weight can be estimated by multiplying the volume by the bulk density of the manure. To estimate the weight of solid manure:

1. Determine the shape of the manure pile.
2. Obtain dimensions of the pile.
3. Calculate volume.
4. Measure density of material in the pile.
5. Calculate weight.

Determine Shape of a Pile

Identifying the shape of a manure pile is necessary to determine the dimensions and calculations needed to estimate its volume. The volume of any shape is its area multiplied by its depth, although for some shapes these dimensions are not always easy to identify. Solid manure piles are often irregular in shape, but can be visualized as an assembly of several smaller, simple geometric shapes (Figure 4.1.1).

Calculating and adding the individual volumes of these smaller shapes will give the total volume of the pile. This process may require several calculations, but will yield a more accurate volume estimate for irregular piles. To calculate the volume of various shapes, refer to the shapes and associated equations provided in Figure 4.1.2.

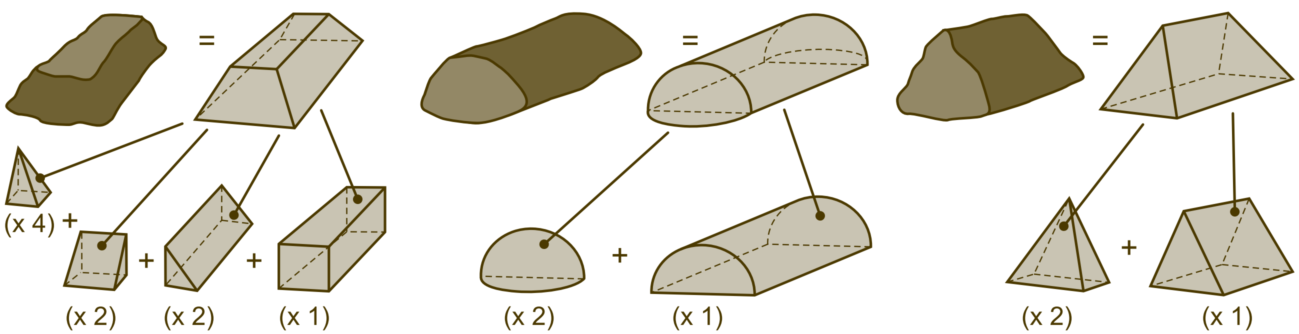
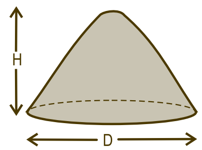
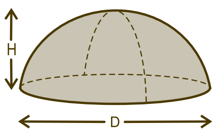
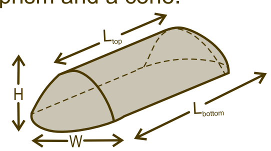
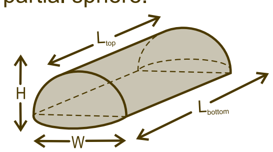


Figure 4.1.1 Complex Shapes Broken into Simple Shapes

Pile Type	Required Dimensions	Calculations to Estimate Volume (Approx.)
Peaked Pile: Closely resembles a cone. 	Diameter of pile (D_{pile}) Height of pile (H_{pile})	**Diameter of a pile:** D_{pile} = circumference ÷ π **Volume of a peaked pile:** $V_{pile} = 0.262 \times D_{pile} \times D_{pile} \times H_{pile}$
Rounded Pile: Closely resembles a partial sphere. 	Diameter of pile (D_{pile}) Height of pile (H_{pile})	**Diameter of a pile:** D_{pile} = circumference ÷ π **Volume of a rounded pile:** $V_{pile} = 0.131 \times H_{pile} \times [(4 \times H_{pile} \times H_{pile}) + (3 \times D_{pile} \times D_{pile})]$
Peaked Windrow: Can be visualized as a combination of a triangular prism and a cone. 	Length of windrow along the bottom (L_{bottom}) Estimated length of windrow along the top (L_{top}) Width of windrow ($W_{windrow}$) Height of windrow ($H_{windrow}$)	**Volume of a triangular prism:** $V_{prism} = H_{windrow} \times W_{windrow} \times L \div 2$ **Diameter of a cone:** $D_{cone} = (L_{bottom} - L_{top} + W_{windrow}) \div 2$ **Volume of a cone:** $V_{cone} = 0.262 \times D_{cone} \times D_{cone} \times H_{windrow}$ **Total windrow volume:** $V_{windrow} = V_{prism} + V_{cone}$
Rounded Windrow: Can be visualized as a combination of a partial cylindrical prism and a partial sphere. 	Length of windrow along the bottom (L_{bottom}) Estimated length of windrow along the top (L_{top}) Width of windrow ($W_{windrow}$) Height of windrow ($H_{windrow}$)	**Volume of a partial cylinder:** $V_{cylinder} = 0.7 \times H_{windrow} \times L_{bottom} \times W_{windrow}$ **Diameter of a sphere:** $D_{sphere} = (L_{bottom} - L_{top} + W_{windrow}) \div 2$ **Volume of a partial sphere:** V_{sphere} = $0.131 \times H_{windrow} \times [(4 \times H_{windrow} \times H_{windrow}) + (3 \times D_{sphere} \times D_{sphere})]$ **Total windrow volume:** $V_{windrow} = V_{cylinder} + V_{sphere}$

Adapted from Brodie, 1990

Figure 4.1.2 Equations for Calculating Volume of Various Shapes

Obtaining Dimensions of a Pile

Some pile dimensions can be measured directly using simple devices such as a tape measure. Direct measurement of other dimensions, such as height and diameter, may not be practical or safe. These must be estimated using indirect means.

» Estimating the Height of a Pile

Simple mathematical relationships between the lengths of the sides of a right triangle (i.e., triangle with a 90 degree angle) can be used to estimate the height of a pile. Lean a piece of wood (e.g., a 2 × 4) of known length against the pile, with one end on the crest of the pile and the other end on the ground (Figure 4.1.3).

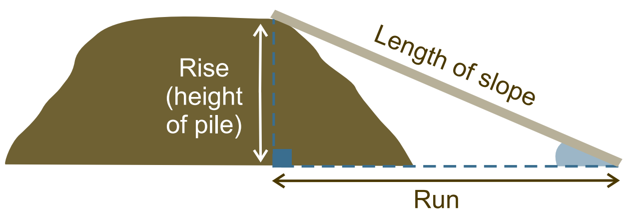


Figure 4.1.3 Using a Board to Estimate Height of a Pile (the "leaning 2x4" method)

Select an arbitrary point somewhere along the length of the board. Using a tape measure take the following measurements from this arbitrary point:

- The vertical distance from the point to the ground directly below.
- The distance from the point to the edge of the board resting on the ground.

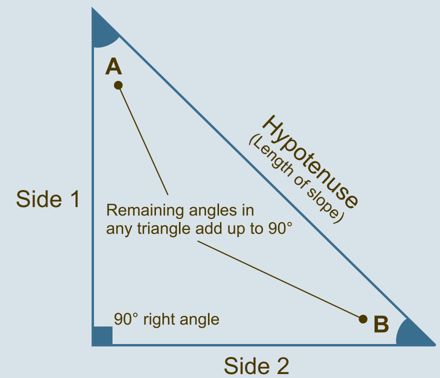
The ratio between these two measurements is identical to that between the height of the pile and the total length of the board. Multiplying the length of the board by this ratio will yield the height of the pile.

Key Mathematical Relationship of a Right Angle Triangle

$$\text{Tangent of angle} = \frac{\text{Length of opposite side}}{\text{Length of adjacent side}}$$

$$\text{Cosine of angle} = \frac{\text{Length of adjacent side}}{\text{Length of hypotenuse}}$$

$$\text{Sine of angle} = \frac{\text{Length of opposite side}}{\text{Length of hypotenuse}}$$



$$\left(\begin{matrix}\text{Length of}\\\text{Hypotenuse}\end{matrix}\right)^2 = \left(\begin{matrix}\text{Length of}\\\text{Side 1}\end{matrix}\right)^2 + \left(\begin{matrix}\text{Length of}\\\text{Side 2}\end{matrix}\right)^2$$

Figure 4.1.4 Labeled Right Angle Triangle

The graphic (Figure 4.1.4) represents a right angle triangle with the sides labeled in terms of angle 'A'. Any of the sides or angles of a right-angled triangle can be solved if the measurement for at least one angle (in addition to the 90 degree angle) and one side are known. This mathematical principle will be used to calculate the height of manure.

The Leaning 2 x 4 Method Used to Estimate Height of a Pile

A 4.9 m (16 ft) board is leaned against a solid pile of cattle manure. An arbitrary point is selected on the board that is 0.9 m above the surface of the ground and 2.0 m from the end of the board (Figure 4.1.5).

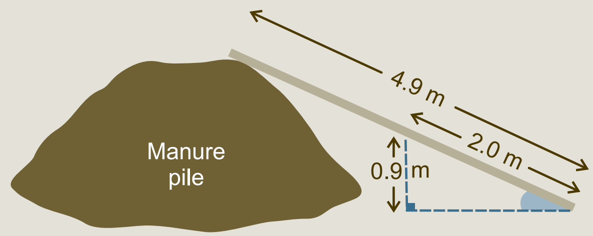


Figure 4.1.5 Solid Manure Pile

The ratio between these measurements is:

Rise: Slope Length Ratio = 0.9 m ÷ 2.0 m

= 0.449

Since it can be assumed that this ratio will be the same between the height of the pile and the total length of the board, the height of the pile is:

Height of the pile (m)= length of the board (m) x rise:slope length ratio

= 4.9 m x 0.449

= 2.2 m is the height of the pile

» Estimating Diameter of a Pile

For round piles, measure the circumference around the base of the pile. Circumference and diameter of a circle are directly proportional according to the following relationship:

Diameter = Circumference ÷ π

For windrows with rounded contours, measure the total length of the pile along the ground and then estimate the length along the top of the pile; this should be shorter. The difference between these two measurements is an acceptable estimate of the diameter of the partial sphere formed by the two rounded ends of the pile (Figure 4.1.2). In theory, the width of the pile is also an acceptable estimate of diameter. Since there can be considerable difference between these measurements, the diameter that is used for the volume calculation is the average of these two measurements:

Diameter = (Windrow Bottom Length – Windrow Top Length + Windrow Width) ÷ 2

Estimating the Diameter of a Pile

A rounded pile of manure has a measured circumference of approximately 22 m. π = 3.1416. The diameter of this pile is:

Diameter (m) = Circumference ÷ π

= 22 m ÷ 3.1416

= 7.0 m is the diameter of the pile

Calculate Volume of a Pile

Once all necessary dimensions have been measured (or calculated) (i.e., height, diameter), the next step is to calculate volume using the stepwise calculations in the rightmost column of Figure 4.1.2.

Calculating the Volume of a Rounded Windrow

A pile of manure resembles a rounded windrow (Figure 4.1.2). The rounded manure windrow has the following dimensions (top length = 24 m, bottom length 31 m, width 3.4 m and height 2.6 m (Figure 4.1.6).

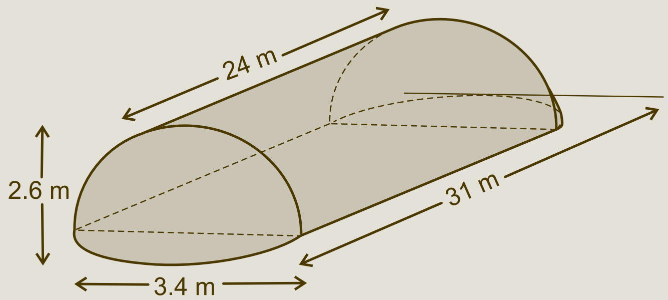


Figure 4.1.6 Windrow of Cattle Manure with Estimated Dimensions

The estimated volume of this pile is:

Volume of partial cylinder ($V_{cylinder}$) $= 0.785 \times H_{windrow} \times L_{top} \times W_{windrow}$

$= 0.785 \times 2.6\text{ m} \times 24\text{ m} \times 3.4\text{ m}$

$= 166.5\text{ m}^3$ is the volume of the partial cylinder

Diameter of the partial sphere (D_{sphere}) $= (L_{bottom} - L_{top} + W_{windrow}) \div 2$

$= (31\text{ m} - 24\text{ m} + 3.4\text{ m}) \div 2$

$= 5.2$ m is the diameter of the partial sphere

Volume of partial sphere (V_{sphere}) $= 0.131 \times H_{windrow} \times [(4 \times H_{windrow} \times H_{windrow}) + (3 \times D \text{ x } D)]$

$= 0.131 \times 2.6\text{ m} \times [(4 \times 2.6 \text{ x } 2.6) + (3 \times 5.2 \text{ x } 5.2)]$

$= 0.3406\text{ m} \times [(4 \times 6.76\text{ m}^2) + (3 \times 27.04\text{ m}^2)]$

$= 0.3406\text{ m} \times [27.04\text{ m}^2 + 81.12\text{ m}^2]$

$= 0.3406\text{ m} \times 108.16\text{ m}^2$

$= 36.8\text{ m}^3$ is the volume of the partial sphere

The volume of the pile is:

Total windrow volume ($V_{windrow}$) $= V_{cylinder} + V_{sphere}$

$= 166.5\text{ m}^3 + 36.8\text{ m}^3$

$= 203.3\text{ m}^3$ is the total volume of the rounded windrow

tip

Due to exposure to the elements, the surface density of a pile is often different than the interior density. If the outer weathered layer is relatively thin (i.e., less than 15 cm), scrape off the surface of the pile until moist material is reached. If the pile has a thick weathered layer, use a core-sampling device such as a manure sampling probe (Chapter 4.2).

tip

Using "book" values for the bulk density of a manure pile, rather than determining the actual density, can lead to large errors in estimated total weight.

Measure Bulk Density of a Pile

Manure nutrients are applied on a weight basis. As a result, the volume of manure in a pile must be converted to weight by using the bulk density of the material. The procedure for determining bulk density of solid manure, poultry litter or compost is simple:

1. Measure and record the weight and volume of an empty container. Conversion factors for volume and weight measurements are provided in Table 4.1.3 and 4.1.4.
2. Sample the pile, being sure that the samples reflect the composition of the pile (i.e., proportions of bedding and manure). Take samples perpendicular to the face of the pile, to get a better representation of the layering profile within the pile. Try to go as deep as possible, at least 50 cm (Figure 4.1.7).
3. Fill the container without excessively packing or compacting the material, trying to achieve a similar consistency as in the pile. Measure and record the weight of the filled container. Calculate bulk density by dividing the weight by the volume.
4. Repeat this procedure 10 to 20 times (depending on the variability and size of the pile) from various sites on the pile. Large, variable piles will require a greater number of samples. Determine the average bulk density for the pile from the samples collected.

Table 4.1.3 Factors for Converting Between Units of Volume

Start Units	Multiply start units by factors in the appropriate column to get:					
	ft³	yd³	m³	L	US gal	Imp gal
Cubic feet (ft³)		0.0370	0.0283	28.32	7.481	6.229
Cubic yards (yd³)	27.0		0.7646	764.6	202.0	168.2
Cubic metres (m³)	35.31	1.308		1000	264.2	220.0
Litres (L)	0.0353	0.0013	0.001		0.2642	0.2200
US gallons (US gal)	0.1337	0.0050	0.0038	3.785		0.8327
Imperial gallons (Imp gal)	0.1605	0.0059	0.0045	4.546	1.201	

Table 4.1.4 Converting Between Units of Weight or Mass

Start Units:	Multiply start units by factors in the appropriate column to get:			
	lb	tn	kg	t
Pounds (lb)		0.00050	0.45359	0.00045
Short tons (tn)	2000.0		907.18	0.90718
Kilograms (kg)	2.2046	0.00110		0.00100
Tonnes (t)	2,204.6	1.1023	1000.0	

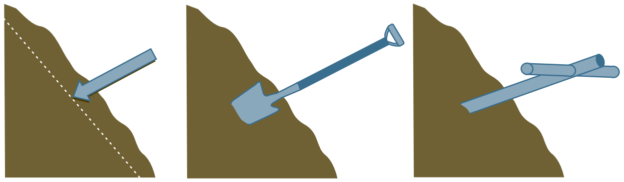


Figure 4.1.7 Sampling Perpendicular to the Pile Surface

Calculating Bulk Density

A 20 L (5 gal) pail filled with material from a manure pile weighs approximately 19.48 kg (42.95 lbs). The bulk density of the material in the pail is:

Pail volume (m^3)

= pail volume (L) x conversion factor (Table 4.1.3)

= 20 L x 0.001 m^3/L

= 0.02 m^3

Bulk density (kg/m^3)

= weight ÷ pail volume

= 19.48 kg ÷ 0.02 m^3

= 974 kg/m^3 is the approximate bulk density of the material in the pail

» Determining Bulk Density of Poultry Litter in the Barn

For most broiler operations, it may be just as easy to determine bulk density of the litter before it is removed from the barn, particularly if it is to be spread immediately. This is convenient if manure is sampled for analysis at the same time. Bulk density can be determined using the same procedure outlined above with two differences:

- Instead of sampling from different points on the pile, sample litter from different points in the barn.
- Scraping off the surface layer of the pack before sampling is not required.

Calculate Weight of a Pile

Total weight of solid manure in a pile or windrow is calculated by multiplying bulk density of the material by the estimated volume of the pile:

Total weight of pile (t) = Bulk density, kg/m^3 × Volume, m^3 ÷ 1000 kg/t

Calculating the Weight of a Pile of Manure

After taking several samples at different points of the pile, the average weight of material in a 20 L (5 gal) pail is estimated to be 19.48 kg. The estimated density is 974 kg/m^3. Putting this together with a volume of 203 m^3:

Total weight of pile (t)

= (Bulk density, kg/m^3 × Volume, m^3) ÷ 1000 kg/t

= (975 kg/m^3 x 203 m^3) ÷ 1000 kg/t

= 197,925 kg ÷ 1000 kg/t

= 198 t is the total weight of the pile of manure

tip

Bulk density can be expressed as kg/m^3 or kg/L and volume as m^3 or L. The numerical result from the weight calculation will be the same.

Estimating the Volume of Liquid Manure in Storage

Many liquid manure storage facilities in Alberta are constructed in a cylindrical or tapered prism shape (Figure 4.1.8). The tapered prism shape is commonly seen in earthen manure storage facilities and the cylindrical shape can be commonly found in aboveground (typically glass lined steel) and below grade (concrete lined) storages.

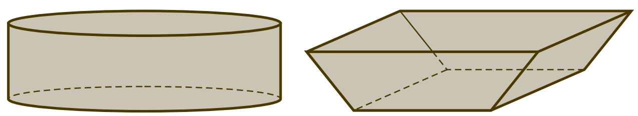


Figure 4.1.8 Cylindrical and Tapered Prism Liquid Manure Storage Facilities.

In contrast to solid manure, nutrient content of liquid manure is expressed as weight of nutrient per unit volume (e.g., kg per 1000 L). The strategy for estimating manure volume involves subtracting the volume not filled with manure from the maximum capacity of the structure. Calculate the volume of liquid manure in storage by:

- Estimating or determining dimensions of the storage facility.
- Inserting the dimension values (i.e., height, diameter) into the appropriate equation to calculate volume (Figure 4.1.9 and Figure 4.1.10).

Hazards Associated with Liquid Manure Storage Facilities

Liquid manure storage facilities present several hazards to personal safety. Gases such as hydrogen sulphide (H_2S) and ammonia (NH_3) can cause symptoms ranging from headaches and eye irritation to death depending on length of exposure and gas concentration.

There is also the risk of falling into the storage. Never work around a liquid manure storage facility alone. Use a tether or harness connected to a solidly fixed object (e.g., tractor, vehicle or sturdy fencepost) to minimize the risk of falling into the storage.

Estimating Manure Volume in Cylindrical Storage Facilities

To calculate the volume of a cylindrical storage facility the following dimensions are needed (Figure 4.1.9):

- Height of the manure in storage.
- Diameter of the storage facility.

To calculate the height of the manure, subtract the freeboard from the total height of the storage facility. Next, use the circumference of the facility to calculate the diameter (Figure 4.1.10).

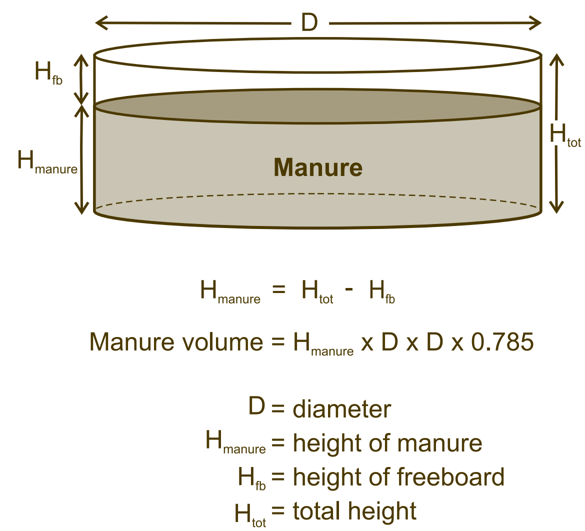


Figure 4.1.9 Dimensions and Calculations for Estimating the Volume in a Cylindrical Storage Facility

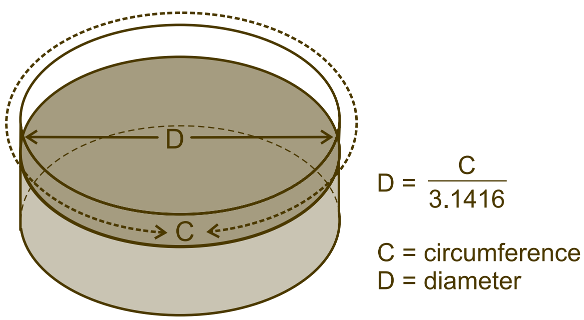


Figure 4.1.10 Relationship between the Circumference and Diameter of a Circle

Calculating Diameter of a Cylindrical Storage Facility Using Circumference

The circumference of a below grade, concrete cylindrical storage facility is measured as 124 m. Based on this information, the diameter of this manure storage is:

Diameter = Circumference ÷ π

Diameter of a cylindrical storage facility (m)

= 124 m ÷ 3.1416

= 39.5 m is the diameter of the cylindrical storage facility

Knowing the facility dimensions, volume can be estimated using the following calculation:

Manure volume = height of manure x (diameter^2) x 0.785

more info

For more information on managing hazardous gases found in liquid manure storage facilities, check out these factsheets, which can be obtained from the publications office of AF by calling toll free 1-800-292-5697 or on Ropin' the Web.

- **AF. 1998. Ammonia Emissions and Safety. Agdex 086-6**
- **AF. 1998. Hydrogen Sulfide Emissions and Safety. Agdex 086-2**
- **Ontario Ministry of Agriculture, Food and Rural Affairs. 2004. Hazardous Gases. Agdex 721. www.omafra.gov.on.ca/english/engineer/facts/04-087.htm**

Calculating Volume of Manure in a Cylindrical Manure Storage Facility

The total height (h_{tot}) of a cylindrical liquid manure storage facility is 4.75 m. The diameter (d) is 40 m. The current freeboard (h_{fb}) is 1.9 m. The estimated volume of manure currently in the facility is:

Height of Manure (h_{manure}) = total height (h_{tot}) – height of freeboard (h_{fb})

= 4.75 m – 1.9 m

= 2.85 m is the approximate height of the manure

Manure volume (m^3) = height of manure (h_{manure}) x (diameter^2) x 0.785

= 2.85 m x (40 m)^2 x 0.785

= 3,579.6 m^3 is the approximate volume of the manure

Converting cubic meters to litres = 3,579.6 m^3 x 1000 L/m^3

= 3,579,600 L is the approximate volume of the manure

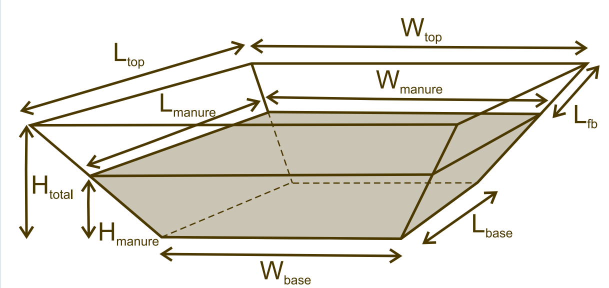
Estimating Volume in Tapered Prism Storage Facilities

To calculate the volume of a tapered prism storage facility the following dimensions are needed:

- Top length and width
- Slope of storage facility walls
- Length of sloped wall of the facility
- Length of freeboard

These measurements are used to estimate the dimensions required to calculate volume of manure in the facility (Figure 4.1.11).

- Estimating height (depth) of manure in a storage facility
- Width and length of the facility base
- Width and length of the manure surface in storage



Volume =

$$H_{manure} \times (A_{base} + A_{manure} + \sqrt{A_{base} \times A_{manure}}) \div 3$$

Where:

$A_{base} = W_{base} \times L_{base}$

$A_{manure} = W_{manure} \times L_{manure}$

H = height	W = width
L = length	A = area

Figure 4.1.11 Estimating Volume in a Tapered Prism Storage Facility.

» Top Length and Width

Measure the length and width of the top of the storage facility by marking the corners with wooden stakes and using a tape measure.

» Slope of Storage Facility Walls

Slope on the wall of the storage facility (expressed in degrees) is used to estimate base length and width and height (depth) of manure in the facility. It is only necessary to determine the slope on one wall because all walls of professionally designed facilities should be the same. If this is not the case, measurements will need to be collected for each wall.

To calculate the slope, the following materials are needed:

- minimum 2 m length of un-warped lumber (e.g., 2 × 4)
- carpenter's level
- pencil
- protractor from a school geometry set

tip

The ideal time to measure length is when a facility is empty; however, this is not always possible or practical. Verify measurements made when the facility was full once the facility has been emptied out.

tip

Before taking measurements, consult the producer, the contractor who built the facility, or any facility design documents to see if the storage facility dimensions are available. This can save considerable time and will eliminate the element of personal risk associated with these facilities.

Key Mathematical Relationship of a Right Angle Triangle

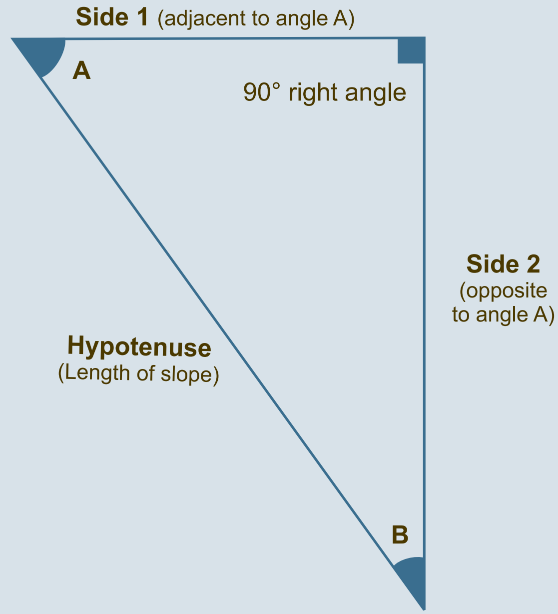


Figure 4.1.12 Labeled Right Angle Triangle (rotate 90 degrees)

The graphic (Figure 4.1.12) represents a right angle triangle with the sides labeled in terms of angle 'A'. Any of the sides or angles of a right-angled triangle can be solved if the measurement for at least one angle (in addition to the 90 degree angle) and one side are known. This mathematical principle will be used to calculate the height (depth) of manure in a tapered prism storage facility.

Rest the board on the slope of the storage wall with at least 30 cm (1 ft) projecting above the top of the storage wall. Place the board on its narrow edge such that the broad face is visible in side profile (Figure 4.1.13A).

Place the carpenter's level against the face of the board above the top of the storage wall (Figure 4.1.13B). Draw a level horizontal line along the face, using the carpenter's level as a guide. Use the protractor to measure the angle formed between the line and the bottom edge of the board that rested on the wall of the manure storage (Figure 4.1.13C). This will be referred to as the measured slope angle of the facility wall.

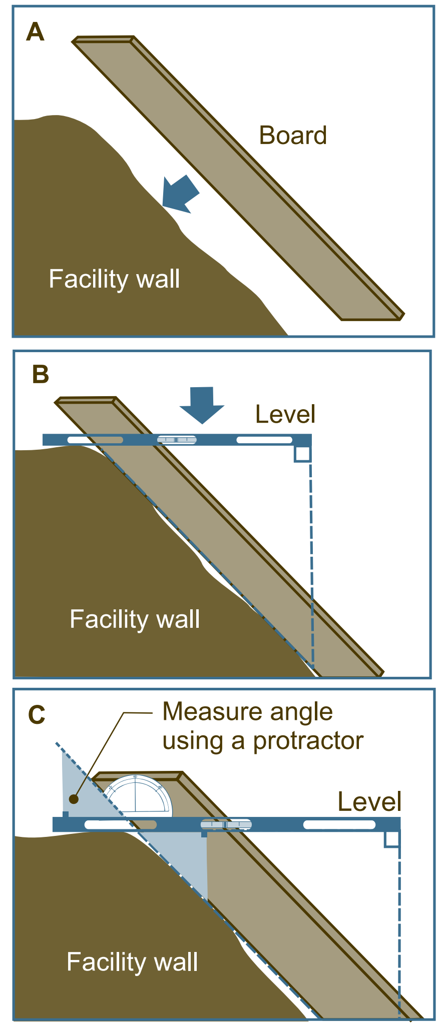


Figure 4.1.13 Estimating Slope on the Wall of an Earthen Manure Storage Facility

» Length of Sloped Wall of a Facility

Safe and practical measurement of the length of sloped wall in a storage facility is difficult, particularly when the facility is full. The preferred option is to consult plans or design schematics for the facility. If these are unavailable, the alternative is to make a direct measurement once the facility has been emptied. When using this strategy take special care to minimize risk of damage to the liner, particularly if the liner is synthetic. Damage to the liner can result in leaks and can be costly to repair. This measurement will be used to estimate the height (depth) of manure, the width and length of the facility base and the width and length of the manure in the storage facility.

» Length of Freeboard

The length of freeboard can be measured using a weighted rope or tape measure.

Estimating Height (Depth) of Manure in a Storage Facility

The height of manure in a facility is calculated using the mathematical principles for a right-angled triangle (Figure 4.1.12). The height (depth) of the manure is calculated using the freeboard length measurement, the slope angle of the wall reported in degrees and length of the sloped wall.

The slope of the wall is determined by subtracting the measured slope angle from 90˚. The 'cosine' of the calculated angle from the slope, referred to as 'cosine' factor, is provided in Table 4.1.5.

Calculated slope angle = 90˚ - measured slope angle

The height of manure is calculated as:

Manure height = cosine factor of calculated slope angle x (length of sloped wall – freeboard)

Table 4.1.5 'Cosine' Factor[1] for Measured Slope Angles (degrees)

Measured Angle[2] (degrees)	'Cosine' Factor of Measured Angle	Measured Angle (degrees)	'Cosine' Factor of Measured Angle
5	0.9962	50	0.6428
10	0.9848	55	0.5736
15	0.9659	60	0.5000
20	0.9397	65	0.4226
25	0.9063	70	0.3420
30	0.8660	75	0.2588
35	0.8192	80	0.1736
40	0.7660	85	0.0872
45	0.7071	90	0.0000

1 This table provided the 'cosine' value for various measured angle degrees.

2 Round the measured angle off to the nearest value in the table or take the 'cosine' of your measured angle to determine the appropriate angle ratio for the calculation.

Estimating Height of Manure in an Earthen Manure Storage

The measured slope along the wall of an earthen manure storage facility is 70º, and the length of the sloped wall is 8.7 m. The length of freeboard is 2.1 m. The height of manure in the facility is:

Calculated slope angle = 90˚ - measured slope angle

= 90˚ - 70˚

= 20˚ is the calculated slope angle of the wall from the vertical

Cosine factor of 20° is 0.9397, from Table 4.1.5.

The height of manure =‘cosine’ of calculated slope angle x (length of sloped wall-length of freeboard)

= 0.9397 X (8.7 m – 2.1 m)

= 0.9397 X 6.6 m

= 6.2 m is the height (depth) of the manure in the storage

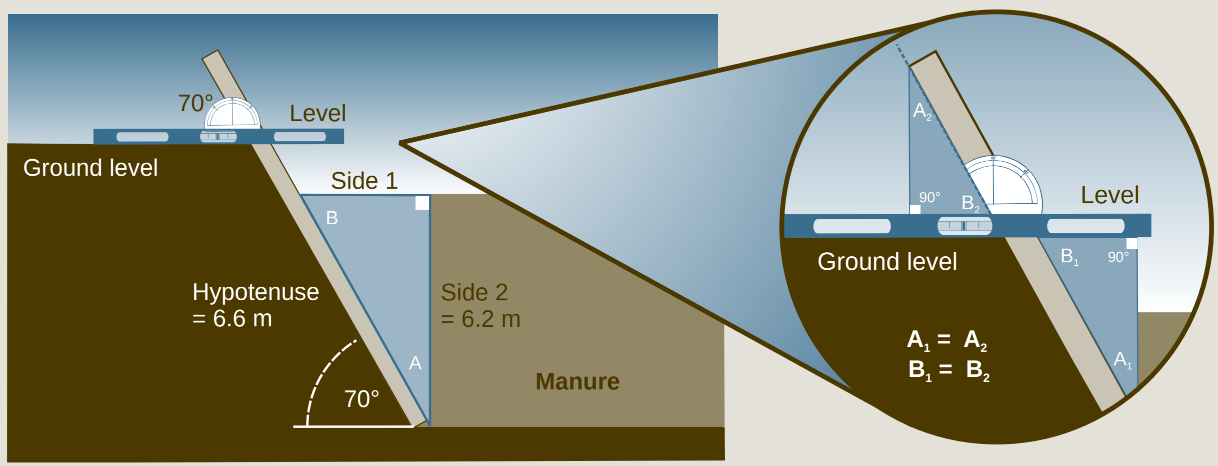


Figure 4.1.14 Using a Board to Estimate the Angles of the Manure Storage Wall to Estimate the Depth of the Manure in the Storage.

Width and Length of the Facility Base

The width and the length of the facility base can be estimated using the length and slope angle on the storage facility walls.

The width of the base is calculated as:

Base width = top width – 2 ('cosine' factor of the measured slope angle x length of sloped wall)

Similarly, the length of the base is calculated as:

Base length = top length – 2 ('cosine' factor of the measured slope angle x length of sloped wall)

Calculating Width and Length of a Facility Base

A storage facility has a top width of 24 m and a length of 30 m. The facility walls have a measured slope angle of 70º and a length of 8.7 m.

The width of the base is estimated by:

Base width (m) = top width – 2 ('cosine' factor of the measured slope angle (Table 4.1.5) x length of sloped wall)

= 24 m – (2 x (0.3420 x 8.7 m))

= 24 m – (2 x 2.98 m)

= 24 m – 5.96 m

= 18.0 m is the estimated base width of the storage facility

The length of the base is estimated by:

Base length (m) = top length – 2 ('cosine' factor of the measured slope angle (Table 4.1.5) x length of sloped wall)

= 30 m – (2 x (0.3420 x 8.7 m))

= 30 m – (2 x 2.98 m)

= 30 m – 5.96 m

= 24.0 m is the estimated base length of the storage facility

Width and Length of the Manure Surface in Storage

To estimate width and length of the top surface of the manure use the exact same calculations as those used to estimate the width and length of the base of the storage facility. Rather than using the length of the facility wall, use the difference between the length of the facility wall and the length of the freeboard.

sidebar

These calculations assume that the angle and length of the sloped walls of the facility are the same for all walls. If this is not the case, measurements will need to be collected for each wall.

Calculating Width and Length of the Manure Surface

A storage facility has a top width of 24 m and a length of 30 m. The sidewalls have a measured slope angle of 70º and length of 8.7 m. The length of the freeboard is 2.1 m. The difference between the total length of the facility wall and the length of the freeboard is:

Difference in length (m) = slope length (m) – length of freeboard (m)

= 8.7 m – 2.1 m

= 6.6 m

Figure 4.1.15 Dimensions for Calculating the Width and Length of the Surface of the Manure in Storage

The width of the top surface of the manure in storage is estimated as:

Manure width = bottom width + (2 x (cosine factor of measured slope angle (Table 4.1.5) x slope length))

= 18 m + (2 x (0.342 x 6.6m))

= 18 m + (2 x 2.26 m)

= 18 m + 4.52 m

= 22.5 m is the width of the top of the manure in the storage facility

The length of the top surface of the manure in storage is estimated as:

Manure length = bottom length + (2 x (cosine of measured slope angle (Table 4.1.5) x slope length))

= 24 m + (2 x (0.342 x 6.6m))

= 24 m + (2 x 2.26 m)

= 24 m + 4.52 m

= 28.5 m is the estimated length of the top of the manure in the storage facility

Calculate Volume of Manure in Storage

Once the facility dimensions are known, the volume of manure in the facility can be calculated.

Calculating Volume of Manure in an Earthen Manure Storage

Figure 4.1.16 shows the dimensions of a manure storage facility. The volume of manure in this earthen manure storage facility can be calculated using these dimensions.

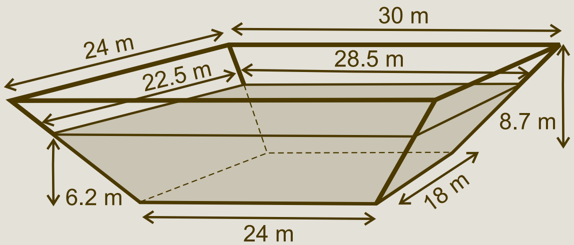


Figure 4.1.16 Liquid Storage Facility with Estimated Dimensions

The base surface area of the facility is calculated as:

Base Surface Area (A_{base}) = length of base x width of base

= 24.0 m x 18.0 m

= 432 m^2 is the estimated base surface area of the storage facility

The upper surface area of the manure is calculated as:

Upper Surface Area (A_{manure}) = length of the top of the manure x width of the top of the manure

= 28.5 m x 22.5 m

= 641 m^2 is the upper surface area of the manure in the facility

The volume of manure is calculated using the answers from the two equations above, and is as follows:

Manure volume (m^3) $= \text{height}_{manure} \times [A_{base} + A_{man} + \sqrt{(A_{base} \times A_{man})}] \div 3$

$= 6.2\text{ m} \times [432\text{ m}^2 + 641\text{ m}^2 + \sqrt{(432\text{ m}^2 \times 641\text{ m}^2)}] \div 3$

$= 6.2\text{ m} \times [1{,}073\text{ m}^2 + \sqrt{(276{,}912\text{ m}^4)}] \div 3$

$= 6.2\text{ m} \times [1{,}073\text{ m}^2 + 526\text{ m}^2] \div 3$

$= 6.2\text{ m} \times 1{,}599\text{ m}^2 \div 3$

$= 9{,}915\text{ m}^3 \div 3$

$= 3{,}305\text{ m}^3$ is the estimated volume of the manure in the storage

The volume of manure can be converted into litres (L) (or any other measurement) using the conversion factors in Table 4.1.3.

Manure volume (L) $= 3{,}305\text{ m}^3 \times 1000\text{ L/m}^3$

$= 3{,}305{,}000$ L is the approximate volume of manure

sidebar

Representative sampling of liquid manure for laboratory analysis requires that manure be agitated prior to sampling because nutrients settle into layers in a storage facility over time.

Ideal Time to Estimate Volume and Weight

Estimate weight or volume as close to the time of application as possible. Solid manure will settle and lose moisture over the first few weeks, altering volume and density. This is a lesser concern for volume measurements with liquid manure.

Length of slope of liquid storage facility walls, if not available from design schematics or plans, should be measured when the facility is empty. Similar to solid manure, volume should be estimated as close to the time of application as possible, but before manure in the facility is agitated. Agitation releases potentially harmful gases such as H_2S, which increase personal risk when working around these facilities.

summary

- Three reasons for getting an accurate estimate of manure volume or weight: to estimate the required land base for manure utilization, to determine if the operation is subject to additional requirements under AOPA and to develop a time estimate for manure application.
- Estimating the weight of solid manure involves determining pile shape, measuring or estimating key dimensions, calculating pile volume and determining density.
- Estimating the volume of liquid manure involves determining shape of the storage facility and obtaining key dimensions.
- To calculate the volume of a cylindrical storage facility the height of the manure in storage and the diameter of the storage facility are required.
- To calculate the volume of a tapered prism storage facility the following dimensions are needed: top length and width, slope of storage facility walls, length of sloped wall of the facility and length of freeboard.
- Ideally, manure volume and weight should be determined as close to the time of application as possible. Liquid manure volume should be estimated prior to agitation of manure in the facility.