

DOCUMENTATION
INVESTMENT AND ANNUAL COSTS OF FORAGE STORAGES SPREADSHEET

Brian J. Holmes, Extension Agricultural Engineer

Department of Biological Systems Engineering

University of Wisconsin-Madison

460 Henry Mall

Madison, WI 53706

608 / 262-0096

608 / 262-1228 (FAX)

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This spreadsheet was developed to help analyze the investment costs and annual costs for the following types of forage storages.

tower silo glass lined steel, oxygen limiting
tower silo cast in place concrete, oxygen limiting or top unloading
tower silo concrete stave, top unloading
bunker silo above ground, concrete walls and floor
packed pile macadam base, drive over packing
silage bag long round plastic bag
silage bale wrap individual bales wrapped with continuous plastic film by wrapping machine
dry hay bales ... either in a shed or wrapped in plastic stored outside

Some abbreviations used in the spreadsheet include:

Ownership (%) ... Factor which combines depreciation, interest, repairs, taxes and insurance. It is multiplied by the initial investment cost to obtain the annual cost for that investment.

DM Dry Matter

HR Hours

OL Oxygen Limiting

TDM Tons of Dry Matter

TU Top Unloading Silo

YRS Years

The spreadsheet only considers costs associated with placing one type and quality of silage into storage, the storage process, and removing forage from storage. Costs of harvest and transport to storage and those required to deliver feed to animals are not considered. The costs not considered should be included in any analysis which is intended to help decide the type of feed storage and handling system on the farm. Other factors not considered are multiple silo fills and the costs of snow removal, plastic disposal, and access roads. The spreadsheet user could include the cost of an access road under the "structures cost" section.

The spreadsheet is developed as an Microsoft Excel template using four pages labeled with tabs at the bottom of the screen as:

INPUTS Values for investment costs, ownership costs, dry matter (DM) losses, etc. are entered on this sheet. Total investment and investment are calculated and displayed on this page. Some results from the HELP page are also displayed on this page.

RESULTS The annual costs are calculated and displayed on this page.

HELP The HELP page allows users to enter information about their situation and then calculates sizes of some storages and some costs which are transferred to the INPUTS page.

BUNKER SIZING ... This page offers users the opportunity to enter information about their dairy herd and how it is to be fed. From this information, the quantities of each forage fed per day is calculated. This information can be used within this page to size bunker silos for each forage.

This documentation is organized to help users work through the INPUTS tab page with access to the HELP tab as information is needed in each section of the INPUTS tab.

The user is expected to enter input into parts of the spreadsheet. The main input area of the spreadsheet is contained within cells A14-I73 of the INPUTS tab (bottom of spreadsheet page). Where you would like to enter a value or change a cell value, use the mouse or arrow keys to move the cursor to the intended cell location (yellow cell background on screen). Then enter the value you want in the cell and press the **Enter** key. Some cells contain formulae which use input data, other cell values, and constants to display the results of a calculation. These cells (red text/white background) are write-protected so you cannot change them. Use the **Esc** key if a message about a protected cell appears. You are expected to enter values in some of the cells in rows 14-26, rows 30-36 and rows 52-73.

If you do not know what value to use for a particular cell, there are help areas to guide you. The first help area is listed in some of the parentheses to the right of the description. A second help area is in the HELP tab in cells A1-J205. This area is a calculator to help establish some of the values for silage piles, wrapped bales, silage bags, and bunkers. The cost of bunker silo walls has a help area in cells H161-J172 of the HELP tab. The calculator help area requires you to enter input (yellow cell background on screen). The calculated values will be displayed (red text) in cells toward the end of each calculator section. These values are transferred automatically to the main input area (INPUTS tab) of the spreadsheet. Some intermediate values calculated by the spreadsheet are displayed

as orange text. These cells are protected so the equations are preserved.

"INFORMATION ABOUT THIS ANALYSIS," cells A77-G89 in the INPUTS tab and A43-F55 in the RESULTS tab are used to record a summary of storage information you are using to analyze a specific situation. This is useful when developing multiple cases and printing the results on paper. Values in this area are linked to the spreadsheet.

Spreadsheet output can be found in two areas. Total investment costs and investment cost per ton of dry matter (TDM) are found in cells H19-I26 in the INPUTS tab. Annual costs for various components are found in cells A1-F27 in the RESULTS tab. Total annual cost is found in RESULTS cells E20-E27. Annual cost per TDM and annual cost per ton of feed fed are found in cells B33-D40 of the RESULTS tab. Since producers pay annual costs and the bank usually pays the investment costs, producers would be wise to use annual costs as the basis for decisions rather than only the investment costs.

Input

The "INPUT -- INVESTMENT COSTS COMPONENTS" column headings are described as follows.

1. Quantity: is the quantity of feed stored in the storages. The units are TDM. The quantity stored must be the same or nearly the same for all storages for a valid comparison of costs. The quantity stored should be that delivered to storage before losses occur. The forage is of a given type and quality, not the sum of several types, i.e., either corn silage or alfalfa-high quality. See the BUNKER SIZING tab for assistance in determining herd feed needs.
2. Value: is the value of the crop being placed into storage on a \$/TDM basis. For example, 15% moisture hay valued at \$70/ton has a value of \$82/TDM.
3. Storage period: is the time period during which this forage is stored before being totally consumed. Corn silage is typically stored for 360-390 days. Hay silage may be stored for 270-390 days, depending upon whether you expect to refill the storage before the end of the hay harvest season.
4. Structure cost: is an investment that is likely to have a 20-year life. Tower silos, bunker silos, gravel or concrete pads, hay sheds, plastic weighting materials (tires), etc. are examples. Tower silo values are to be entered on the INPUTS tab page. Other structure investment costs are calculated in the HELP tab page and automatically transferred to the INPUTS tab.
5. Unloader or unloader/tractor cost: is for equipment used to unload

a storage (silo unloader, front end loader tractor). The tower silo unloaders costs are entered in cells C19-C21. The costs of unloader tractors are calculated in cells C22-C26, based on the product of tractor costs entered in cells C33-C37, the "Proportion of Time Used this Forage" (cells D33-D37) for this task. The "Proportion of Time Used This Forage" is the percentage of total time that the tractor is used solely for this forage. (See 3 below, TRACTORS USED TO.)

6. Blade/bagger/blower/wrapper cost: is the initial investment cost of equipment (but not tractors) used to load a storage and wrap bales. Enter these values in INPUTS cells D19-D26.
7. Proportion of time used: is a percentage (INPUTS cells E19-E26) which allocates the proportion of time a blade, bagger, blower or wrapper is used solely for this forage. If another type of forage is handled by this equipment, the proportion of time used should be reduced accordingly. The value you enter is a whole percentage, not a decimal.

INPUTS -- TRACTORS USED TO:

1. Tractor size (HP), cells B30-B37: is the engine size needed for a tractor to perform a given task. For example, a 150 HP tractor may be needed to pack a bunker or pile.
2. Tractor cost (\$), cells C30-37: is the purchase (investment) cost of the tractor used to accomplish a given task.
3. Proportion of Time Used This Forage: is a percentage (INPUTS cells D30-D37) which allocates the proportion of time the tractor is used doing this task for this forage. Other tasks may occupy the tractor during the remaining portion of its use, including similar tasks for forage storage not considered in this analysis or for other uses on the farm. If the tractor is solely dedicated to this task, the proportion of time is 100%. This value allocates the proportion of total cost of the tractor to this task.
4. Proportion of engine capacity, cells E30-E37: is the proportion of maximum HP expended doing a task. For example, plowing may require 90% while raking may require 10% of a tractor's engine capacity. This proportion of engine capacity is used to calculate fuel and lubrication use.

HELP -- Above-Ground Bunker Silo Calculator

The above ground bunker silo calculator (HELP cells A155-J205) is used to calculate the area which needs to be excavated and the total investment cost of the bunker silo storages. A bunker silo sizing spreadsheet is provided as a fourth tab of this spreadsheet. For assistance in establishing the size and number of bunker silos needed to store the quantity of forage needed, enter this page by clicking on the BUNKER SIZING tab at the bottom of the spreadsheet.

1. Enter the silage DM density to which the silage will be packed in the bunker silo. Well packed silage may have a density of 18-20 lbs DM/ft³. A typical density is 12-14 lbs DM/ft³, while poorly packed silage is 8-10 lbs DM/ft³.
2. Storage period (days): is the length of time you expect to store this forage type. This value is automatically transferred from INPUTS cell B16.
3. Face removal rate: is the distance you will progress into the silage each day. Enter the face removal rate measured in ft/day. A minimum removal rate greater than 0.5 ft/day will result in minimum DM loss during face removal.
4. Enter the number of bunker silos you will use to store this forage type.

5. Enter the wall height (ft) for the bunker silo walls.
6. Enter the cost for the concrete floor. Typical values are \$1.50-\$2.00/ft².
7. Enter the site preparation cost/ft² including the excavation of top soil and setting grades as well as the gravel backfill which supports the concrete floor.
8. Average length of silage in bunkers: is a calculated value as is the average width per bunker. They are calculated based on quantity being stored, density, storage period, face removal and wall height you specified in 1-5 above. If reasonable values for average length and width are not produced, click on the BUNKER SIZING tab and use that page to establish reasonable bunker sizes. Then return to the HELP -- Above-Ground Bunker Silo Calculator and re-enter more reasonable values for items 1-5.
9. The average width (ft) of each bunker silo is calculated. Average width is the distance bounded by the interior surface of the silo walls measured at the wall half height.
10.Walls of bunker silos can be designed to be loaded from one side (side walls) or both sides (interior walls). Each of these walls is likely to have a different cost per foot of length. Enter the number of walls which are designed to be loaded from only one side. Zero is an acceptable entry if no walls are designed to be loaded from only one side. If zero is entered, the number of walls loaded from two sides must not be zero. If your intent is to obtain costs for silage piles, use the HELP -- Silage Pile Calculator.
11.Enter the number of walls which will be loaded from two sides. Zero is an acceptable entry if no walls are designed to be loaded from both sides. If zero is entered, the number of walls loaded from one side must not be zero.
12.Enter the length of walls loaded from only one side. Zero is an acceptable entry if no walls are loaded from only one side.
13.Enter the length of walls loaded from two sides. Zero is an acceptable entry if no walls are loaded from both sides.
14.Enter the cost per linear foot of the walls that are loaded on one side if any are used. Some wall costs based on 1993 values are suggested in HELP cells H161-J173. Move the cursor to the right to view these values.
15.Enter the cost per linear foot of the walls that are loaded on two sides if any are used. Some wall costs based on

1993 values are suggested in HELP cells H161-J173. Move the cursor to the right to view these values.

16.Bunker silo walls are constructed in a variety of ways. If the wall is supported well below the bunker floor, the floor most likely will abut the wall. In this case, the width of concrete floor between wall toes is the distance between wall surfaces measured at the floor. If the wall is an L or tee panel, the width of concrete floor between wall toes is the distance between the edges of wall panels in contact with the ground about 5 feet or so from the edge of the vertical portion of the wall. Whatever case, enter the width of the floor to be placed between the walls.

17.The apron is a slab of concrete which allows equipment to maneuver while filling and emptying the bunker. The width of the apron is the distance measured from the front end of the bunker wall to the edge of the apron. If a storage pad on the back end of the silo extends past the walls, add this pad width to the width of the front apron and enter the sum of the widths for the value of "width of concrete apron".

18.Enter the unit cost (\$/ft²) for the plastic used to cover the bunker silo. If no plastic is used, add an additional 10-15% to the DM loss under the spoilage category of the DM loss % table at bottom of INPUTS, raising it into the range of 15-20%.

19.Tires/weighting investment cost: is the initial investment to purchase tires or other material used to weight down the plastic cover. These materials are assumed to have a 20-year life and are included in the structure cost. Zero is an acceptable response if they are not used or are obtained at no cost.

20.Enter the bunker silo filling rate per person pushing up and packing the rate (TDM/hr-person). Some suggested rates are:

Harvest Tractor	Hay Silage	Hay Silage Double Windrow	Corn Silage
	- - - - - Filling/Packing Rate (TDM/hr-person) - - - - -		
150 HP	8.8*	12.3*	14.0*
220 HP	12.3*	17.5*	17.5*
Self-propelled Harvester			
450 HP	- - -	17.5**	22.8**

*One packing tractor.
**Two packing tractors.

21.Enter the unit covering labor time (person-hr/ft²) to place the plastic cover and tires.
22.Uncover pile labor: is the amount of time a person spends each day removing the plastic cover and weighting material. Zero is an acceptable answer if plastic is not used.
23.If the tractor is used to move weighting materials and the plastic cover, respond "yes" to the question, "Tractor used to uncover pile?"
24.Enter the average distance the tractor moves from the time it picks up silage from the silage face (in pile on floor) to where the silage is dumped into the feed wagon. This distance will be about 25 feet in bunkers where the wagon is driven into the bunker for filling. The average distance will be about half the bunk length if the wagon is parked on the apron while filling. The time to remove silage from the face before it is loaded from the floor is accounted for and automatically added to the empty labor time.
25.If the silage must be transported from the silo face some distance to the feed wagon, the travel time will influence the feed-out rate. Enter the travel speed (mph) at which the unloading tractor is moving to deliver feed to the feed wagon.
26.Enter the amount of forage carried in the bucket when moving it from the silo face to the feed wagon. This may be less than the rated capacity of the bucket. If the bucket is rated at 3 yd³ and you fill it 2/3 full, the capacity to enter is 2 yd³.
27.The density of forage in the bucket is difficult to estimate. It will probably be in the range of 2-8 lbs DM/ft³.
28.Length of concrete apron: is calculated as the sum of bunker average widths plus an additional 10 feet on each end.
29.Area excavated and backfilled: is calculated based on dimensions you have provided for bunker widths, wall lengths and apron dimensions.
30.The calculated component costs for excavation and backfill, concrete floor, walls loaded from two sides, walls loaded from one side, and tires/weighting as well as total bunker cost are displayed in HELP cells E189-E195. The total cost (HELP cell E195) is transferred to the structure costs in cell B22 in the INPUTS tab section of the spreadsheet.

31.Values related to bunker unloading rate are calculated and displayed.

INPUTS -- BUNKER SILO (Values Automatically Transferred from HELP -- Above-Ground Bunker Silo Calculator)

32.Bunker silo plastic cost: is the total annual cost of plastic used to cover the bunker silos. It is calculated as the surface area of the bunkers times the cost/ft². If there is a one-time cost for tires or other material to weight the plastic down, include that in the structure cost section in the HELP tab (see 19 above) as these weights will have a 20-year life.

33.Bunker silo fill labor: is the number of person-hours required to fill and pack the bunker silos. This value is also used to calculate the number of hours the bunker silo packing tractor operates. This influences the fuel and lubrication annual costs.

34.Bunker silo cover labor: is the total number of person-hours required to apply the plastic cover and tires or other covering material to the surface of the bunker silos. If the unloading tractor (35 below) is not used to remove plastic and tires, the labor for plastic and tire removal should be added to bunker silo "cover labor" in the "help" above-ground bunker silo calculator.

35.Bunker silo empty labor: is the total number of person-hours required to empty feed from the bunker silo. The hours of operation for the unloading bunker tractor are calculated from this value. This influences fuel and lubrication annual costs. If the unloading tractor is not used to remove plastic and tires, the labor for plastic and tire removal should be added to bunker silo "cover labor". (See 34 above.)

HELP -- Dry Hay Bale Storage Calculator

The dry hay bale storage calculator assumes bales are stacked on a storage pad which you must construct. You must enter the values for 14 variables. The calculator will then produce 9 pieces of information; 6 are transferred into the INPUTS tab cost calculator portion of the spreadsheet.

1. Enter the bale DM density of the bales being stored. See suggested values for density by bale type in HELP cells G45-G47.

2. Enter the bale length measured in feet.

3. If round bales are stored, enter the bale diameter measured in feet. Enter zero if bales are rectangular.
4. Enter the average of the bale height and width measured in feet for rectangular bales. Enter zero if round bales.
5. Bales can be stacked on top of each other to conserve storage pad or building size. Enter the number of bale heights that bales will be stacked on top of each other (e.g., 3 bales high).
6. Enter the width of the building or pad onto which the bales will be stacked.
7. If a pad of the same material as the storage is placed along one long side of the storage pad or building, enter the width of that apron.
8. Enter the cost (\$/ft²) to construct the storage pad or the floor of the building. If no pad or floor, enter zero.
9. Enter the storage pad or building floor unit cost (\$/ft²). Macadam may cost \$0.50/ft². Asphalt may cost \$0.75-\$1.00/ft², while concrete may cost \$1.50-\$2.00/ft².
10.Enter the unit cost to build the storage building. If no building, enter zero. The cost of a building shell will add to the cost, perhaps \$3-\$8/ft². This value, multiplied by the calculated pad area, produces the storage pad capital investment displayed below and transferred to the INPUTS tab.
11.Bales pack differently, depending on bale shape. Rectangular bales pack more efficiently than round bales. Enter your estimate of packing efficiency. Suggested values are: large square = 90%, large round = 60%, small square = 85%.
12.Unit wrap and load time (min/bale): is the time required to wrap each bale with plastic and place it into storage. For hay not wrapped in plastic (i.e., dry hay under roof), the value to enter is only the time required to move the bale into storage. This time should not include the time required to move the bale from field to storage.
13.Unit unwrap time (min/bale): is the time required to unwrap plastic from each bale. If bales are not wrapped, enter zero. This value should not include the time to unload from storage as this is included in 14 below.
14.Unit unload bale time: is the time required per bale to remove each bale from the storage area. This value should not include the time required to deliver the bale to the animal

feeding area. Include the time to unwrap the bale in 13 above.

15.Hay bale wrap plastic cost: is the unit cost of plastic for wrapping each dry hay bale. The annual cost of bale wrapping plastic is calculated when this unit cost is multiplied by the number of dry hay bales. If dry hay bales are not wrapped, enter zero.
16.Number of bales: is calculated based on the quantity of forage to be stored, the density of hay, and the dimensions of each bale. This value is automatically transferred to the INPUTS tab.
17.The following pieces of information are calculated and displayed for your information or for use in other calculations.
 - a. Number of bale rows across the pad/building.
 - b. Length of storage pad or building.
 - c. Height of bottom cord of roof truss. Allows bales to be stacked as high as you specified.
 - d. Area of storage pad and/or building.
18. Unload labor: is the total person-hours required to unload the bales from storage. It is based on the total number of bales and the time per bale you entered above.

**INPUTS -- DRY HAY BALES (Automatically Transferred
from HELP Dry Hay Bales Storage Calculator)**

19. Calculated storage pad and building investment cost: is the product of the pad cost/ft² and the area of the pad plus the cost/ft² of building times the building area. This value is transferred as a component of cell B26 in the INPUTS tab area of this cost calculator spreadsheet.
20. Number of dry hay bales: is the number of dry hay bales which will be stored.
21. Hay bale wrap plastic cost: is the total cost of plastic used to wrap bales.
22. Dry hay bale wrap/load labor: is the total number of person-hours required to operate dry hay bale wrapping equipment and move the bales to the storage area. It is calculated based on the number of bales handled and the value you entered for time per bale. This value is used to calculate labor cost as well as operating hours for the wrapping and loading tractor. When dry bales are not wrapped, this value is the labor required to load bales into storage using a tractor. If a tractor is not used to load the storage, enter a zero in each of INPUTS cells B36-E36.

23. Unload dry hay bales labor: is the total number of hours required to operate the dry hay bale unloading tractor while carrying bales from the storage area. It is calculated based on the number of bales handled and the value you entered for time per bale. It does NOT include the time to carry bales to the feeding area as this is a feeding enterprise. It could include the time to move the tractor from the tractor parking area to the bale storage area. If a tractor is not used to unload bales from storage, enter zero in INPUTS cells B37-E37.
24. Unwrap dry hay bales labor: is the total number of person-hours required to unwrap plastic from dry hay bales. It is calculated based on the number of bales handled and the time per bale you entered. This value times the labor cost rate contributes to total annual labor cost of dry hay bales. This value is zero if dry hay bales are not wrapped.

INPUTS -- TOWER SILOS

1. Tower silo fill labor: is the labor time required to fill the tower silos (INPUTS cell C52). This would include the time people spend operating the silo filling equipment. If 400 TDM are stored and the loading rate is 8 TDM/hr, the fill labor is 50 person-hr (400 T) 8 T/hr).
2. Tower silo unload rate: The average unloading rate for the tower silos (TDM/hr) is divided into the quantity of DM stored to calculate the operating time (hrs/yr) for the unloaders. The operating time for the unloaders is used with the cost of electricity to calculate the annual electricity cost. The operating time for the unloaders is used with the "tower silo attention at unloading" (see 3 below) to calculate the unload labor time.
3. Tower silo attention at unloading: is the proportion of time, as a whole (not a decimal) percentage of tower silo unloading time, that the operator spends attending the unloading process. This time may be spent adjusting the unloader position, observing the feed-out rate, or making adjustments to the unloader. The remaining proportion of time may be allocated to feed mixing or other feeding activities. This value is used with "tower silo unload rate" (see 2 above) to calculate the unload tower silo labor time

INPUTS -- LABOR/ENERGY COST

1. Labor cost: is the average total hourly labor cost to fill and empty a forage storage (INPUTS cell C61). This value should include all costs for wages, taxes and benefits. Some people may be paid more than this value, based on skills and job expectations,

and some may be paid less. This spreadsheet does NOT take these differences into consideration.

2. Electricity: is the unit cost of electricity (\$/kWh) which is used to calculate the annual cost of electricity to operate the tower silo unloaders.
3. Fuel cost: is the unit cost (\$/gal) of fuel required to operate the tractors. It is used in combination with tractor size, proportion of engine capacity and annual hours of use to calculate annual fuel and lubrication costs.

HELP -- Silage Bag Calculator

The silage bag calculator helps to establish the quantity of silage stored in silage bags and the dimensions and cost of the storage pad upon which they are stored. The calculator is found in HELP cells A115-H143.

1. Enter the DM density to which silage will be packed. This is likely to be about 13-14 lbs DM/ft³.
2. Bag length: is the length of plastic bag minus the material needed to seal the ends of the bag. For example, for an 8-foot diameter bag 200 feet long with 7 feet needed to seal each end, the length of bag to enter is 186 ft (e.g., $200' - [2 \times 7'] = 186'$).
3. Enter the diameter of the plastic bag. Bag diameter and length are used to calculate bag volume.
4. Silage bag cost: is the price you pay to purchase and obtain each plastic storage bag.
5. Enter the distance between bags (ft) needed to allow bagging equipment to operate and to allow drainage.
6. Buffers on the ends of the bags allow equipment to operate near the end of the bags while remaining on the storage pad. The buffer will be included on both ends of the bag when calculating the size of the storage pad. Ten feet on the end of each bag is reasonable.
7. Storage pad cost: is the cost/ft² to construct the storage pad. Macadam may cost \$0.50/ft². Asphalt may cost \$0.75-\$1.00/ft², while concrete may cost \$1.50-\$2.00/ft². This value multiplied by the calculated pad area results in the storage pad investment cost.
8. Silage bag fill rate: is the rate at which silage is forced into the silage bag.
9. Plastic removal time: is the time spent each day removing and disposing of plastic from the bag.
10. Average distance silage face to wagon: is the average distance the loader tractor must move to carry silage from the end of the open bag to the feed wagon. If the wagon is near the open bag end, the distance may be 25 feet. If the wagon must remain at the apron, the average distance may be half the length of the bag.
11. Travel speed transporting along bag: is the average speed the loader tractor moves carrying silage from the bag face to the feed wagon.
12. Enter the amount of forage carried in the bucket when moving it

from the bag face to the feed wagon. This may be less than the rated capacity of the bucket. If the bucket is rated at 3 yd³ and you fill it 2/3 full, the capacity to enter is 2 yd³.

13. The density of forage in the bucket is difficult to estimate. It will probably be in the range of 2-8 lbs DM/ft³.
14. Number of silage bags: See 20 below.
15. Calculated total volume: is the volume of silage placed into the bags. Calculated total weight (cell G136): is the total weight of DM placed into full bags (TDM). Compare this value to the quantity you want to store (cell H118). If it is less than the quantity you need to store, increase bag size.
16. Once the calculated quantity stored is properly established, the storage pad length is calculated and displayed. This includes the sum of the bag length and the buffer on each end of the bags.
17. Once the calculated total weight is properly established, the storage pad width is calculated and displayed. This width is the sum of all bag diameters and distance between bags.
18. Storage pad area: is the length times width of the storage pad. This area is used to calculate the storage pad cost.

**INPUTS -- SILAGE BAGS (Automatically Transferred
from HELP Silage Bags Calculator)**

19. Storage pad investment cost: is the cost to construct the storage pad. It is calculated as the cost/ft² times the area of the storage pad. This value is transferred to the structures costs in cell B24 in the INPUTS tab area of the spreadsheet.
20. Number of silage bags: is the total number of silage bags which must be obtained to store the "quantity" of this type of forage. Where a part of a bag may be needed, the total has been rounded up to the next whole number.
21. Silage bag fill labor: is the total number of person-hours required to fill the silage bags. It includes the time people spend operating the bag filling equipment. This value is used to establish the hours of operation for the bagging tractor and influences fuel and lubrication costs.
22. Unwrap silage bag labor: is the total number of person-hours required to remove the bag plastic.
23. Silage bag empty labor: is the total number of person-hours required to remove feed from the silage bags. The hours of operation for the unloading bags tractor are calculated from this value. This influences fuel and lubrication annual costs.

HELP -- Silage Pile Calculator

The silage pile calculator provides assistance in establishing the size and cost of the pad upon which the silage piles are placed. The calculator also allows you to establish the cost of plastic and labor time needed to cover the piles. Pile shape is assumed to be a trapezoidal cross-section with vertical ends. By trial and error methods, one can change inputs to yield pile sizes which hold the desired quantity of feed. Since the calculator does not consider feed-off rate (6 in/day minimum recommended), the operator should verify that a given size pile will have adequate removal rate.

1. Enter the DM density that you expect to achieve after packing the silage pile. Well packed silage may have a density of 18-20 lbs DM/ft³. A typical density is 12-14 lbs DM/ft³, while poorly packed silage is 8-10 lbs DM/ft³.
2. Enter the average length (ft) of each pile assuming a vertical surface on each end and a trapezoid cross-section.
3. Enter the height (ft) of each pile measured from the base to the peak.
4. Enter the width (ft) of the top of the silage pile which has a trapezoid cross-section.
5. Side slope of a pile: is specified as horizontal run over vertical rise. Enter the horizontal run for each vertical rise. For example, enter a 3 for a 3:1 run to rise slope. A 3:1 slope should be shallow enough to drive over to pack without excessive risk of tractor rollover.
6. A space between silage piles allows access for sealing the plastic edges and allows an area for drainage away from the piles. Enter this distance between piles measured in feet.
7. Enter the number of piles you will use to store the forage.
8. Buffer on the end of a pile: is the distance (ft) measured from the end of the pile to the edge of the storage pad. This buffer allows the tractor to maneuver on a hard packed surface while filling and emptying the piles.
9. Storage pad cost: is the cost/ft² to construct the storage pad. Macadam may cost \$0.50/ft². Asphalt may cost \$0.75-\$1.00/ft², while concrete may cost \$1.50-\$2.00/ft². This value multiplied by the calculated pad area results in the storage pad investment cost displayed below.
10. Enter the pile filling rate per person pushing up and packing

(TDM/hr-person). See similar term (item 20) under bunker silos for suggested values.

11. Enter the average distance the tractor moves from the time it picks up silage from the silage face (in pile on floor) to where the silage is dumped into the feed wagon. This distance will be about 25 feet in piles where the wagon is driven onto the storage pad for filling. The average distance will be about half the pile length if the wagon is parked on the apron while filling. The time to remove silage from the face before it is loaded from the floor is accounted for and automatically added to the empty labor time.
12. If the silage must be transported from the pile face some distance to the feed wagon, the travel time will influence the feed-out rate. Enter the travel speed (mph) at which the unloading tractor is moving to deliver feed to the feed wagon.
13. Enter the amount of forage carried in the bucket when moving it from the pile face to the feed wagon. This may be less than the rated capacity of the bucket. If the bucket is rated at 3 yd³ and you fill it 2/3 full, the capacity to enter is 2 yd³.
14. The density of forage in the bucket is difficult to estimate. It will probably be in the range of 2-8 lbs DM/ft³.
15. Plastic cost: is the cost (\$/ft²) to purchase the plastic cover.
16. Covering labor: is the number of person-hr/ft² required to cover the pile with plastic. The calculated area of plastic times the cost of the plastic is used to determine cover labor total below.
17. Calculated bottom width (ft): is established based on values you provide above for pile depth, top width and side slope, assuming a trapezoid pile cross-section.
18. Calculated surface area of the pile's exposed surface is determined to establish the area of plastic needed.
19. Calculated volume: is the volume within each pile.
20. Calculated total weight: is the weight of silage DM in all piles. The calculated TDM must be greater than or equal to but close to the value you entered in INPUTS cell B14 and printed in HELP cell J30. If not, change values in HELP cells E3-E9 until they are close to each other.
21. Storage pad length: is the sum of pile length plus two times the length of the buffer. This sum is the total length of the storage pad.
22. Storage pad width: is the sum of the calculated bottom widths

and distances between each pile to obtain a total pad width.

23. Storage pad area: is the product of pad width and length. It is used to calculate the storage pad investment cost.

**INPUTS -- SILAGE PILES (Automatically Transferred
from HELP Silage Pile Calculator)**

24. Storage pad investment cost: is the product of storage pad area and storage pad cost/ft² plus the cost of weighting material. This value is transferred as the structure costs in INPUTS cell B23.
25. Silage pile plastic cost: is the total annual cost of plastic used to cover silage piles. If there is a one-time cost for tires or other material to weight down the plastic, include that in the structure cost for the piles as tires will have a 20-year life.
26. Silage pile fill labor: is the number of person-hours required to fill and pack the silage piles. This value is also used to calculate the number of hours the silage pile packing tractor operates. This influences the fuel and lubrication annual costs.

27. Silage pile cover labor: is the number of person-hours required to apply the plastic cover and tires or other covering material to the surface of the silage piles. If the unload tractor is not used to remove plastic and tires, the labor for plastic and tire removal should be added to the "silage pile cover labor".
28. Silage pile empty labor: is the total number of person-hours required to empty feed from the silage piles. The hours of operation for the unload pile tractor are calculated from this value. This influences the fuel and lubrication annual costs. If the unload tractor is not used to remove plastic and tires, the labor for plastic and tire removal should be added to "silage pile cover labor".

HELP -- Silage Bales Calculator

1. Enter the bale DM density of the wrapped silage bales being stored. See suggested values for density by bale type in HELP cells G78-G79.
2. Enter the silage bale length measured in feet.
3. If round silage bales are stored, enter the bale diameter measured in feet. Enter zero if bales are rectangular.
4. Enter the average of the bale height and width measured in feet for rectangular bales. Enter zero if bales are round.
5. Silage bales can be stacked on top of each other to conserve storage pad size. Enter the number of bale heights that bales will be stacked on top of each other (e.g., 3 bales high).
6. Enter the cost (\$/ft²) to construct the storage pad. If no pad, enter zero. Macadam may cost \$0.50/ft². Asphalt may cost \$0.75-\$1.00/ft², while concrete may cost \$1.50-\$2.00/ft².
7. Unit wrap and load time (min/bale): is the time required to wrap each silage bale with plastic and place it into storage. This time should not include the time required to move the bale from field to storage.
8. Unit unwrap time (min/bale): is the time required to unwrap plastic from each bale. This value should not include the time to unload from storage as this is included in 9 below.
9. Unit unload bale time: is the time required per bale to remove each from the storage area. This value should not include the time required to deliver the bale to the animal feeding area.
10. Plastic cost to wrap each bale: is the unit cost of plastic for wrapping each silage bale. The annual cost of bale wrapping

plastic is calculated when this unit cost is multiplied by the number of bales.

11. Bales pack differently, depending on bale shape. Rectangular bales pack more efficiently than round bales. Enter your estimate of stacking volume efficiency. Suggested values are: large square = 90%, large round = 60%.
12. The number of bales is calculated based on the quantity of forage to be stored, the density of hay, and the dimensions of each bale. This value is automatically transferred to the INPUTS cell I45.
13. The following pieces of information are calculated and displayed for your information or for use in other calculations.
 - a. Number of bale rows and columns of bales on the pad.
 - b. Length of storage pad.
 - c. Storage pad width.

**INPUTS -- SILAGE BALES (Automatically Transferred
from HELP Silage Bales)**

14. Investment cost storage pad: is the product of pad cost/ft² and the area of the pad. This value is transferred as a component of INPUTS cell B25.
15. Number silage bales: is the total number of silage bales which will be wrapped. It is calculated based on quantity to be stored, bale volume, and density.
16. Silage bale wrap plastic cost: is the unit cost of plastic wrapping used for each silage bale wrapped. When multiplied by the number of bales, the annual cost of bale wrapping plastic is calculated and displayed in the RESULTS tab.
17. Silage bale wrap and load labor: is the total number of person-hours required to operate silage bale wrapping equipment and move the bales to the storage area. This value is used to calculate labor cost as well as operating hours for the wrapping and loading tractor.
18. Unload silage bales labor: is the total number of hours required to operate the silage bale unloading tractor while carrying silage bales from the storage area. It does NOT include the time to carry bales to the feeding area as this is a feeding enterprise. It could include the time to move the tractor to the bale storage area from the tractor parking area.
19. Unwrap silage bales labor: is the total number of hours required to unwrap plastic from silage bales. This value times the labor cost rate contributes to total annual labor cost of silage

bales.

INPUTS -- OWNERSHIP COSTS

The ownership section (INPUTS cells E51-I63) is explained below. The table at the end of this section contains reasonable values for some of the components of the ownership percentage.

1. Interest rate: is the rate of interest that must be paid to borrow money. If you are using your own money, the interest rate is the opportunity cost of investing that money in alternative investments.

Useful Life

2. Structure life: is the useful life of structures used to store the forage. Concrete floors, walls, gravel bases, and buildings contribute to the total cost of a structure. These types of items will generally last and/or be useful for about 20 years. The life of the structure is used to calculate ownership costs related to interest and depreciation.
3. Equipment life: is the useful life of equipment used to handle forage. Tractors, baggers, wrappers, silo unloaders and blowers are examples of these types of equipment. Commonly, equipment has a 10-year life expectancy. When used for small amounts of forage, the life may be extended. When used for large amounts of forage, the life may be reduced. Enter equipment life expectancies for wrappers/baggers/blowers/blades, tractors, and silo unloaders. Blades and unloaders operate in a harsh environment and may have a life expectancy of 7 years.
4. Salvage value: is the percentage of original investment you expect to recover upon sale of the capital asset at the end of its useful life. Structures usually have a limited value after an extended life, while equipment may have some resale value (perhaps 30%). Equipment which has been worked hard may have no salvage value.
5. Repairs: are the percentage of the original investment costs which must be allocated each year to cover the cost of repairs on equipment and/or structures. Structures may have repair costs in the range of 0.5-1.5% of original cost, while equipment repair costs may be in the range of 2-5% with higher values associated with equipment operated in harsh environments.
6. Taxes: are the percentage of the original investment costs of the structures which must be paid annually to cover property taxes. In Wisconsin, there is no property tax on portable equipment. Enter zero if no property tax is to be assigned. Property taxes may average about 1.5% of the original investment.
7. Insurance: is the average percentage of the original investment cost which must be paid annually to cover insurance for that capital asset. Insurance may average about 0.5%.
8. Depreciation: is calculated as: $(100\% - \text{salvage value}) \div \text{life expectancy}$.
9. Interest: is calculated as: $(\text{interest rate} \div 2) \times H \times (1 - \text{salvage rate} \div 100) + \text{interest rate} \times H \times (\text{salvage value} \div 100)$.
10. Ownership %: is the percentage of initial investment which is paid annually to cover the cost for depreciation, interest,

repairs, taxes and insurance. This percentage is multiplied times the initial investment for equipment and structures to yield the annual costs listed in the RESULTS tab.

Ownership Costs*

	Bagger/Wrapper/Blower	Tractor	Structures	Blade/Unloader
Interest Rate (%)	8	8	8	8
Life Expectancy (yrs)	10	10	20	7
Salvage Value (%)	30	30	0	0
Repairs (%)	4	3	1	5
Taxes (%)	0	0	1.5	0
Insurance (%)	0.5	0.5	0.5	0.5

*Equipment types have been grouped into columns of similar repair costs and salvage value.

Inputs -- DM Loss

The DM loss section of the INPUTS tab (cells A65-G73) allows a total DM loss to be calculated.

Proportion of forage DM loss (%): is the loss of DM which occurs during the filling, storage and emptying of the storage. The tables below give typical ranges of values.

Enter your estimate of DM losses in each of the loss categories for each storage system. The total will be summed for you. NOTE: harvest losses are generally higher for crops harvested at lower moisture content. Since this spreadsheet accounts for storage costs, harvest losses should be excluded from the costs. Therefore, consider assigning a loss to filling operations and use that value when estimating total storage DM losses for each storage. Seepage loss can be significant if forage is harvested at high moisture content. Plan to keep moisture content below 70% to avoid seepage losses. Tower silos may require lower moisture to avoid seepage.

Gaseous and surface losses will probably be higher in bunker silos and piles if sufficient packing density (greater than 14 lb DM/ft³) is not achieved. These losses will be higher in all systems (except oxygen limiting) if insufficient removal rates are used. Gaseous and spoilage losses will increase when air and precipitation have access to the silage. Not using plastic covers on tower silos, bunkers and piles and/or failure of the plastic for these units and for bags and bale wraps results in an increased DM loss.

Unloading losses are related to the rate of face removal from the storage, operator skill, and drivability of the storage floor. Significant silage DM will be lost in wet weather if the floor is not very drivable. There is a set of suggested losses associated with surface drivability to the right of the DM loss worksheet in the INPUTS tab. With good management and storage sizing, DM loss at feed-out may be in the range of 0-2-% for tower silos and wrapped bales, while for bags, piles and bunkers, DM loss may be in the range of 2-5%. Where low face removal rates and/or poor operator management is practiced, unloading losses can be as high as 10-15%. If unloading losses are included in the gaseous and/or spoilage category, do not double count them in the unloading column.

Estimate of silage harvesting and storage losses.

Based on *Forages: The Science of Grassland Agriculture*, 4th edition.

Silo Type	Moisture (%)	Field	Seepage	Gaseous	Surface	Total
		DM Loss (%)				
Conventional Tower	80	2	7	9	3	21
	70	2	1	8	4	15
	65	4	0	8	3	15
	60	6	0	6	3	15
	50	8	0	5	3	16
Gas-tight Tower	70	2	1	7	0	10
	60	6	0	5	0	11
	50	8	0	4	0	12
	40	11	0	4	0	15
Trench or Bunker, no cover	80	2	6	10	6	24
	70	2	1	9	9	21
Trench or Bunker, covered	80	2	4	9	2	17
	70	2	1	7	3	13
Stack, no cover	80	2	7	10	11	30
	70	2	1	11	19	33
Stack, covered	80	2	5	8	2	17
	70	2	0	7	4	13

Typical losses for other types of storage are as follows.

Storage Type	Moisture (%)	DM Loss (%)				Total
		Field	Seepage	Gaseous	Surface	
Silage Bags	60-70	2-6	0	5	2	9-13
Wrapped Silage Bales	60-70	2-6	0	7	5	14-18
Wrapped/Stored Inside Dry Hay	15-20	15-20	0	5	0	20-25

Estimate of Filling and Emptying Losses*

Storage Type	Filling	Emptying
	- - - - -	DM Loss (%)
	- - - - -	- - - - -
Tower Silo	1	1
Above Ground Bunker	2	3**
Packed Pile	2.5	3**
Bagger	1	3**
Wrap Silage Bales	1	1
Dry Hay	1	1

*Using good management.

**See spreadsheet INPUT cells H67-I73 for suggested values on several floor surfaces.

BUNKER SIZING

This spreadsheet will help you design a bunker silo which uses nearly vertical walls. The spread-sheet is organized into three sections. The DESIGN CRITERIA section (cells A15-E36 in blue text with yellow background in the spreadsheet) gives you the opportunity to enter information about your needs and wants in a bunker silo silage storage system. As you consider values, you may need some assistance to determine the Herd Daily Feed Need. The SILAGE DRY MATTER CALCULATOR (cells I6-T44) provides assistance in determining the values you will feed each day. You can enter the number of animals in each group in your herd (cells J14-J39 in blue text with yellow background in the spreadsheet) and the quantity of each feed type and quality (cells L14-O39 in blue text with yellow background in the spreadsheet). The output for each group in this section is found in cells Q14-T39. The HERD TOTAL values for each type and quality of silage are found in cells Q44-T44. Only one of these values at a time should be entered in cell E19 as the Herd Daily Feed Need value for the bunker silo sizing process. Once the values in the DESIGN CRITERIA section have been entered, proceed to the section labeled POSSIBLE BUNKER SILOS in cells A40-G60.

Throughout the spreadsheet, text which is shaded blue with a yellow background are values the operator is expected to enter or change. Text which is black should NOT be changed; doing so may change the appearance of the spreadsheet or destroy formulas which are programmed into those cells. These cells are protected from inadvertent change.

You may change any of the following input variables as they apply

to your situation.

Forage Type (cell E17): is the type of feed to be placed into this storage. This is for information only. The spreadsheet does not use this for any calculation.

Herd Daily Feed Need (cell E19): is the total quantity (lbs DM) of this type of forage which will be fed to the herd each day. It includes all animal groups, mature and replacements. It should be emphasized that this Herd Daily Feed Need is for one type of forage and, in fact, it may be for a specific quality of a given type of forage. For example, corn silage is usually uniform in quality and is fed from one storage structure at a time. Consequently, the value to enter is the total amount of corn silage fed per day. On the other hand, two or more qualities of hay silage may be fed to the herd each day. In that case, the bunker silos should be sized separately, based on the quantity of each being fed to the herd each day. Operate the spreadsheet, changing this value for each feed quality being stored. See SILAGE DRY MATTER CALCULATOR (cells I6-T44) below for help in estimating Herd Daily Feed Need. The combination of silage density, wall height, and removal rate with daily feed needs determines the width of the bunker silo.

Storage Loss (cell E22): is the percentage of DM lost during the fermentation and storage phases. With excellent management and a reasonable storage period, this value can be as low as 13%. With moderate management and/or a long storage period, it can be as high as 28%. This loss is affected by packing, exposure during filling, top surface sealing, top surface area, moisture content, and storage period length.

Feeding Loss (cell E25): is the percentage of DM lost during feed mixing and delivery and feed refusal. This value can be in the 3-15% range. A loss during the feed out phase is programmed into the spreadsheet. It is a function of face removal rate, moisture content and density, with the face removal rate being significant for removals less than 4 in/day.

Daily feed needs and storage and feeding losses determine the total amount of forage which must be placed into the bunker silo(s).

Silage Wet Density (cell E28): is the density achieved after packing the bunker silo during the filling process. With excellent management, this value can be as high as 60 lbs as fed silage/ft³. Typical management will achieve 40 lbs as fed silage/ft³, while poor management will produce silage in the 20-25 lbs as fed silage/ft³ range.

Silage Moisture Content (cell E30): should be in the range of 60-65% for hay silage and 65-70% for corn silage. Excessive moisture causes DM loss by juice expression, while low moisture content

limits the ability to exclude oxygen by packing tightly.

Face Removal Rate (cell E32): is the thickness of the slice of silage removed from the face of the silage mass each day. Minimum removal rates are 3 in/day in winter and 4 in/day in summer. A good design value is 6 in/day or greater. See Feeding Loss above.

Storage Period (cell E34): is the length of time you plan to feed from the storage. If no other storages exist for the feed being considered, the storage period is the amount of time between annual harvests (360 " days). Where other storages are available or where refilling part of this storage is possible, the storage period can be proportionately less than 360 days. Since silage should ferment for 14-21 days before being used, you may want to reduce the storage period by this much as you feed the animals from other sources during fermentation.

If you plan to feed from this storage only during the winter, the length of the winter storage period should be entered here. You may consider decreasing the face removal rate for winter-only feeding. However, this may reduce your flexibility of extending the use of this storage into warmer periods in the future.

Maximum Silo Length (cell E36): is the maximum distance you are willing to drive to get feed into and/or out of the bunker silo. This value will typically be in the range of 100-200 feet, with 150 feet being a reasonable value to enter.

Once you enter the necessary input values, the spreadsheet displays some of the viable silo sizes in the table labeled POSSIBLE BUNKER SILOS (Bunker Sizing cells A40-G60). From this, you can select a wall height from column one and then read other information about the design from the other columns on the same line. The AVERAGE WIDTH is the distance measured between the interior wall surfaces at a height halfway up the wall. The NUMBER OF BUNKERS is based on the removal rate, storage period, and maximum bunker silo length you specified as inputs. The bunker length accounts for a sloping (45E angle) silage surface at the rear and a sloping (30E angle) silage surface at the filling end. The taller the sidewall, the longer these surfaces will be, and the more feed will be stored in those wedges compared to shorter walled bunkers. The relationships have been established so the maximum silo length you specified will often occur for bunkers with a 10- 12-foot wall height.

The FORAGE PLACED INTO STORAGE is the sum of that needed to feed the herd and the losses that occur during storage and feeding. You have specified a storage loss in the DESIGN CRITERIA section. The spreadsheet provides an adjustment in that value, increasing the loss for wall heights less than 12 feet and decreasing the storage loss for wall heights greater than 12 feet. This adjustment emphasizes the

importance of top surface area on the amount of loss one might experience.

The values in the column titled FORAGE LOSS - Fill Through Refusal are the actual feed DM losses for this forage. These losses occur during the fermentation and storage periods as well as during feeding and after the feed manger is cleaned out. There is a built-in face removal DM loss which is based on face removal rate, moisture content, and density.

The PERCENTAGE DRY MATTER LOSS column expresses the total forage loss as a percentage of the total amount of feed which must be placed into storage.

Using the POSSIBLE BUNKER SILOS table (Bunker Sizing cells A40-G62), select a bunker silo size which gives reasonably sized bunker silos. Those with exceptionally tall sides will be difficult to empty without adequately sized equipment for removing feed from the face. Selecting a short wall height results in bunker silos which are quite wide. This contributes to a large top surface area with resulting higher feed storage loss. For medium sized dairies, bunker wall height is often in the 8- to 16-foot range.

The spreadsheet will display the words "Don't Use" in the rows where the width is less than 16 feet. A packing tractor cannot produce complete packing coverage between the walls of a bunker that is narrower than twice the width of the tractor. A 10-foot wide tractor would actually require a bunker width of at least 20 feet.

If the width of the bunker calculates to be exceptionally wide (greater than 40 feet) for the wall height you prefer, consider a slightly taller wall or increase the face removal rate in the DESIGN CRITERIA section which results in a new set of bunker silo sizes in the POSSIBLE BUNKER SILOS section. The number of bunkers may increase. More bunker silos will cost more but will increase your flexibility of feed storage. You may be able to refill some of the storages with other forages, thus reducing the total amount of feed storage capacity needed for the farm.

If the Number of Bunker Silos appears to be excessive, increase the value you entered for Maximum Silo Length and/or decrease the Face Removal Rate in the DESIGN CRITERIA section. Be sure to keep the Face Removal Rate larger than 6 inches to assure face removal DM loss within a reasonable range. Decreasing the Storage Period may also reduce the Number of Bunker Silos.

Silage Dry Matter Calculator (Cells I6-T44)

If you are not clear how much of a given forage is or will be fed and should be included as input for Herd Daily Feed Need, a dry matter calculator is provided within the spreadsheet in cells I6-T44. Enter

the number of animals in each group under the column heading Number per Group. The spreadsheet will calculate the totals for each group and list them in the TOTAL column. Under the columns labeled Hay 1, Hay 2, Hay 3 and Corn, enter the pounds of forage DM coming from each of the storages representing different feed types and quality. You need not use all columns. Enter zero for each group in a column where that feed doesn't exist on the farm. Generally, milking cows consume forage for a total of 20-30 lbs-DM/animal-day. Other groups may consume more or less.

The spreadsheet uses the information on the number of animals in each group and the DM consumed per animal to establish a group daily consumption rate for each forage listed in cells Q14-T39. These group values for a specific forage are summed to produce a total for each type/quality of feed. These totals are listed in cells Q44-T44. One of these totals is then manually entered as an input value in cell E19 as the Herd Daily Feed Need. The totals in the SILAGE DRY MATTER CALCULATOR are not linked to the DESIGN CRITERIA section, so you must enter that value yourself.

Since the SILAGE DRY MATTER CALCULATOR establishes only the quantity of feed that must be fed, the total values should not be used to establish cropping acres needed to feed the herd. These values must be modified to include losses which occur in harvest, storage, feeding, and feed refusal. For that reason, the values in the POSSIBLE BUNKER SILOS section are more useful. The FORAGE PLACED INTO STORAGE value does take all losses into consideration except for harvest/transport losses. For example, if the forage placed into storage for Hay 1 is 1500 TDM (from the POSSIBLE BUNKER SILOS section), harvest/transportation loss is 5%, and yield is 4 TDM/acre-yr. The number of acres needed to feed Hay 1 to the herd is:

$$\frac{1500 \text{ TDM}}{4 \text{ TDM} / \text{acre} - \text{yr} (1 - 0.05)} =$$

REFERENCES

Bodman, G.R. and B.J. Holmes. 1997. *Managing and Designing Bunker and Trench Silos* (AED-43). (In revision May 1, 2003) Published by MidWest Plan Service and available through county extension offices in states of the midwest.

Additional references can be obtained through the TEAM FORAGE website located at the URL:

<http://www.uwex.edu/ces/crops/uwforage/storage.htm>.

Deciding on a Silage Storage Type-Interactive Power Point presentation
 Forage Feedout Losses for Various Storage Systems
 Preventing Silage Storage Losses

Managing Forage in Tower Silos
Forage Storage Options, What's Right for You? - Power Point presentation
Choosing Forage Storage Facilities
Bunker Silo Cover Alternatives
Factors Affecting Bunker Silo Density
Bunker Silo Density Calculator - Spreadsheet
Bunker Silo Sizing - Spreadsheet and Documentation
Managing Forage in Bunker Silos
Management of Bunker Silos and Silage Piles
Capital Costs of Pads for Bunkers, Piles and Bag Silos
Silage Bag Capacity
Bagged Silage or Tower Silos? Options for the Non-expanding Dairy Farm
Bagged Silage or Tower Silos? Options for the Expanding Dairy Farm
How to Store Silage with Increased Profitability and Safety
Density and Losses in Pressed Bag Silos- article and Power Point presentation
Drive-over Silage Pile Construction
Silage Pile Capacity Calculator - Spreadsheet
Storing Silage in Piles
Successful Wrapping and Storage of Square Bales-Power Point presentation
Large Baler Research and Storage Ideas
Plastic Wrapped Bales at Different Moistures and Different Times after Baling -
Power Point presentation

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