MILK HOUSE WASTE

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Funding for this project was provided to the Bioproducts and Biosystems Engineering Department through two US EPA 319 grants administered by the Minnesota Pollution Control Agency. Additional significant matching funding was provided by other state and local agencies and the cooperating dairy producers. The purpose of the project was to design, install and monitor sixteen milk house wastewater treatment systems in four counties in Minnesota. The results were used to develop design and management guidelines. Additional information can be found at www.manure.umn.edu/applied/milkhouse_waste.html.

MILK HOUSE WASTEWATER DESIGN GUIDE

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INTRODUCTION Milk house wastewater includes residual milk (i.e. milk that remains in the pipeline, milking units, receiver and bulk tank after emptying) and the wash water that cleans them, the miscellaneous equipment, and the milk house floor. This wastewater commonly includes, cleaning chemicals (i.e. detergents, sanitizers and acid rinses) water softener recharge water, and small amounts of manure, bedding, feed, grit and dirt.

The Minnesota Pollution Control Agency currently does not regulate the design, construction or inspection of milk house wastewater treatment systems under Chapter 7080 or specifically under the feedlot rules Chapter 7020. However, milk house wastewater can be a significant pollution hazard that cannot be discharged into the waters of the state. The University of Minnesota has conducted a significant amount of research on alternative treatment and disposal systems for milk house wastewater. This design guide will aid in milk house wastewater treatment system selection, design and siting. Three systems are discussed in this guide. All three systems include a primary septic tank prior to the treatment systems discussed, which are:

Milking equipment cleaning.

- Bark Beds: A large soil infiltration area covered by wood or bark shreds,

- Aerobic Treatment Units (ATUs) or Recirculating Media Filtration (RMF) followed by subsoil infiltration area,
- Frequent (typically daily) irrigation to pasture or cropland.

Other feasible milk house wastewater handling options NOT covered in this design guide include temporary storage with land application, chemical flocculation, and dosing systems to a vegetative treatment area.

Bulk tank cleaning.

Storage and land application options are acceptable methods of milk house wastewater disposal provided that the effluent is applied to cropland in accordance with Chapter 7020. Chemical flocculation and dosing systems are still in the experimental phase of development and can be installed on a case by case basis.

Note also that this design guide DOES NOT address the handling, treatment and disposal of effluent from milking parlors using Bark Beds or Aerobic treatment. The cleaning of milking parlors, flat parlors, step up parlors, herringbone, parallel, swing, rotary parlors, etc., generate significantly amounts of wastewater (per cow) with high concentrations of solids and nutrients. Irrigation systems have been designed and constructed to handle this wastewater but more data on these systems are needed. Methods to handle this stronger waste are currently under development.

This design guide also DOES NOT address the treatment and disposal of colostrum from fresh cows and waste milk from treated cows or other large milk discharges (i.e. bulk tank failures). This waste milk should be disposed of with the manure handling system or separately from any treatment option discussed in this publication.

If human waste is added to the milk house waste, the dispersal system must be designed according to MN Chapter 7080 rules that deal with household septic systems. The systems presented here are not designed to meet MN Chapter 7080 rules for household septic systems.

Wastewater Flow

Wastewater flow is the primary design parameter for all milk house treatment systems. Most milk house wastewater is generated during the cleaning of the milking units, milk pipelines, receiver, and bulk tanks. Depending on the milking schedule, the milking units and milk pipeline are cleaned two or three times per day. Bulk tanks are cleaned immediately after the tank has been emptied, typically once per day or once every other day. Water softener regeneration water also contributes to this waste stream.

Water flow meters provide the most accurate estimate of wastewater flow. Correct placement of these flow meters in the water supply line is critical and sometimes tricky. Often there are faucets in the milk house that are used for other purposes such as supplying water for mixing milk replacer for calves, washing of tractors and other farm implements, or filling of fertilizer or herbicide tanks. This water might be recorded by the flow meter but the water would not enter the wastewater treatment system. Farmers should document and subtract this usage to accurately determine the flows actually entering the wastewater handling system. Typically, the majority of water used in the milk house passes through a water softener so this is often the best location to install the flow meter. A minimum of two months of daily flow data provide adequate information for estimating design wastewater flows but continued flow monitoring should be part of the system operation and maintenance plan.

An alternative to a water meter are estimates based on average per cow water use data. A study conducted at the University of Minnesota on 16 milk house waste systems (Schmidt et al., 2005) found typical flows to be between 2 to 7 gal/cow/day with most farms using less than 5 gal/cow/day. Without any site specific data (water meter data), an estimate flow of 5 gal/cow/day should be used for designing the milk house wastewater treatment system. Note that this flow estimate is for milk house wastewater only and does not include any parlor washing or other wastewater.

Water meter for documenting water usage.

Waste Characterization

Milk house only characteristics

The second critical input into the system design is the wastewater characterization. Depending on the specific system, some of the wastewater constituents are more important than others. For instance, Biochemical Oxygen Demand (BOD_5) concentrations are critical for sizing an aerobic treatment system and soil infiltration area but are not critical in a surface irrigation system. Rather, the sizing of the irrigation application area is based on the amount of nitrogen and/or phosphorus in the wastewater.

Milk house wastewater strength (concentration of organic material, solids, nutrients, and fats) is quite variable as it leaves the milk house and is a function of the time of day and wash cycle. As such, treatment system designs are based on the wastewater concentration as it leaves the septic tanks. In all treatment system designs there are one or two septic tanks installed prior to the final treatment. The waste strength leaving the septic tanks is a function of concentrations in the raw wastewater from the milk house and the Hydraulic Retention Time HRT in the septic tanks. Table 1 shows the typical concentrations of milk house wastewater leaving the first and second septic tanks.

The BOD_5 concentration is the primary waste parameter used in the design of Bark Beds, Aerobic Treatment Units (ATUs), and Recirculating Media Filtration Systems (RMFs). Nitrogen and phosphorus loading (lbs produced per year) are the main parameters used for the design of irrigation systems. Total Suspended Solids (TSS) and Fats Oils and Grease (FOG) are some other general measures that quantify the strength of the waste and are used with other wastewater treatment system designs.

TABLE 1. Milk house wastewater characteristics*

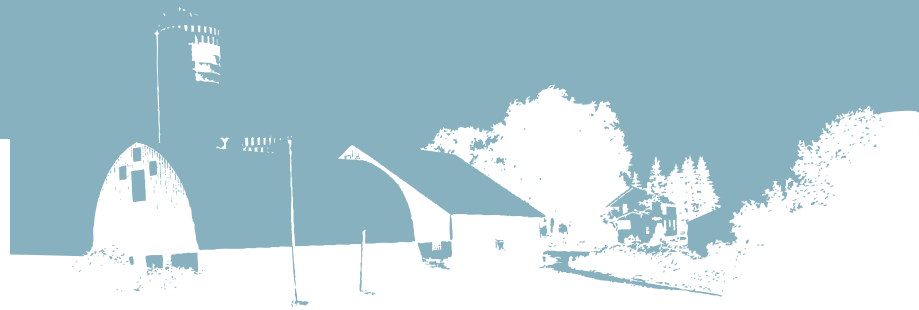
	First Tank mg/L (lbs/1000 gal)	Second Tank mg/L (lbs/1000 gal)
BOD_5	1200	750
TSS	450	240
Fats Oils and Grease	220	110
Total Nitrogen	65 (0.54)	55 (0.46)
Total Phosphorus	55 (0.46)	55 (0.46)

*Average values based on 5 gal per cow per day from unpublished data from the University of Minnesota.

CAUTION - On a dairy farm there are situations when there is waste milk that cannot be added to the bulk tank (milk from fresh and treated cows) or there is a bulk tank failure or spill. Since milk has a BOD_5 concentration of 100,000 mg/L (Wright et al., 1998), the addition of waste milk to the wastewater treatment system will significantly overload the aerobic treatment systems and bark beds. Typical milk house waste contains effluent approximately 2 to 3 gallons of residue milk per day generated during the washing of the equipment, pipeline, and bulk tanks. Depending on the situation, waste milk from fresh or treated cows would add two to five times that amount of milk per day to the wastewater treatment system, significantly impacting the organic loading and system performance. As such, all waste milk should be kept out of the milk house wastewater treatment system and disposed of with the manure.

Parlor systems

Effluent and flow sampling from two parlor systems was collected monthly over a two year period. One of the farms was averaging about 11 gallons per cow per day while the other was averaging about 7 gallons per cow per day. Concentration and mass loading data suggest this difference is primarily dilution water (additional water used in washing.) Average BOD5 concentration for the two sites was 955 and 1600 mg/L, P concentrations were 22 and 36 mg/L and total nitrogen concentrations were 125 and 190 mg/L. Mass loading on a per cow per year basis was similar between sites with values of 31 lbs/c/d BOD5, 0.7 lbs/c/d P, and 4 lbs/c/d TKN. This sample data was from samples coming out of the second septic tank.



Specific System Design Criteria

Primary Treatment

All of the treatment systems discussed in this guide require a primary septic tank with inlet and outlet baffles, figure 1. These tanks should meet all state-specific standards for construction or placement. The primary septic tank reduces settleable solids, fats, and grease, and also serves as a buffer between the final treatment system and the bulk tank should the entire bulk tank need to be dumped due to contamination. Because of these criteria, the primary septic tank should be sized for a minimum three-day Hydraulic Retention Time (HRT), the volume of the bulk tank, or 1000 gallons, whichever is greater. The recommended procedure for dumping a contaminated bulk tank is outlined below. Effluent from the primary septic tank is pumped or flows by gravity into a second septic tank or to the specific treatment system.

Primary Septic Tank Installation

Septic tank installed for primary treatment on all systems.

All septic tanks must meet the minimum design specifications outlined in MN Rules Chapter 7080 and be installed with a minimum of two feet and a maximum of four feet of soil cover over the top. See Section 7 of the University of Minnesota Onsite Sewage Treatment Program Manual for more information on septic tanks. If the site conditions do not allow for two feet of soil cover, two inches of insulation should be placed over the top of tank before being covered. The insulation reduces the chance of the system freezing in cold weather. At times the site elevations may require an initial sump be installed to move the effluent from the milk house to the first septic tank.

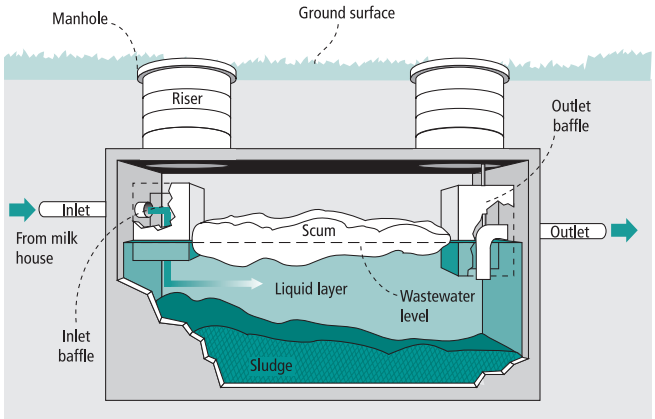


Figure 1. Septic Tank

Effluent Filter

A commercial size effluent filter should serve as the last baffle before exiting the septic tank. This will help reduce any suspended material from exiting the tank. This effluent filter should be checked monthly after installation and cleaned with water if needed. If monthly inspections show no signs of sludge buildup filter inspections can be done quarterly.

Dumping a Bulk Tank

If the bulk tank milk is contaminated and needs to be dumped, the septic tank can be pumped and then the bulk tank drained into the septic tank and the septic tank (with the waste milk) can be pumped again. This waste milk can be land applied. Contact your milk cooperative for alternative methods of disposing of this waste milk.

Bark Bed

How a Bark Bed Works

A bark bed is a relatively flat, soil infiltration area covered with bark or wood shreds. Effluent from the septic tank(s) flows into a dosing tank where it is then pumped via a pressure distribution system to the soil infiltration area. Effluent is then pumped through distribution pipes to either a chamber system or drainfield rock. The entire area is then covered with 18-24 inches of inches of bark or wood shreds. The bark covering allows good oxygen transfer to the effluent/soil interface which speeds the organic matter breakdown. The bark also keeps the infiltration area from freezing in northern climates and aids in effluent evaporation. Figure 2 shows a schematic of a bark bed.

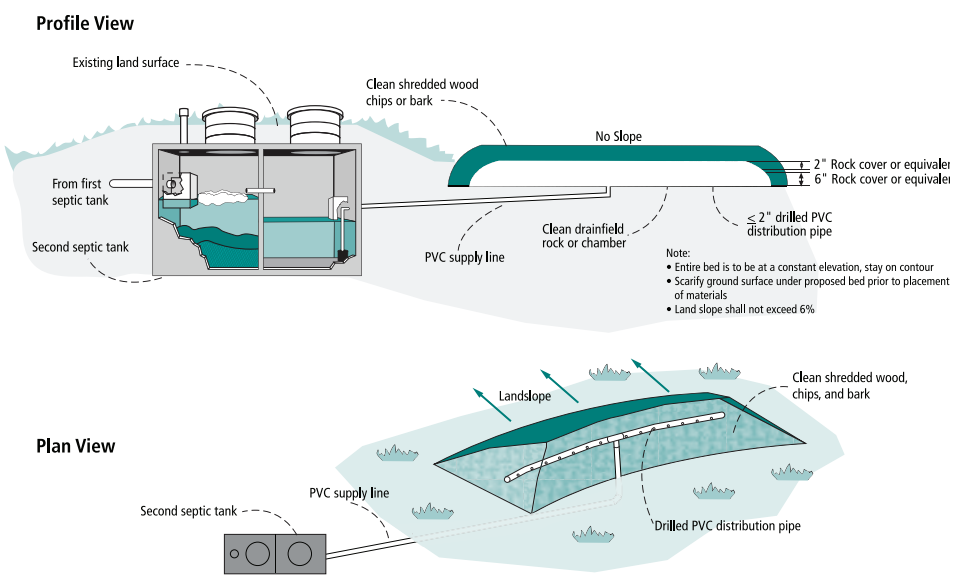


Figure 2. Schematic of Bark Bed

Pretreatment

Effluent entering a bark bed must be pretreated in a primary septic tank with a minimum 3-day HRT, the volume of the bulk tank, or 1000 gallons, whichever is greater. All bark bed systems require a second septic tank with a three-day HRT (for a total system HRT of six days) and commercial size effluent filter for treatment prior to distribution in a bark bed.

Infiltration Area

Bark bed size is based on the infiltration capacity of the soil which is a function of soil type. In addition, treatment requires a minimum two-foot separation distance (soil depth) to groundwater or bedrock. This two-foot separation removes the remaining organic material and reduces nutrients in the wastewater and assures that the system functions hydraulically. (Note that household septic systems require a three-foot separation to groundwater or bedrock to treat human pathogens.)

The infiltration area can be located on previously farmed cropland, pasture, or wooded areas where trees and small vegetation have been removed. It is important that this location be uncompacted, natural soils to insure good soil infiltration. In addition, the bark bed should not be located within 100 feet of wells or sinkholes or 150 feet of any lakes streams or wetlands.

Bark Bed Sizing

A combination of organic (BOD_5) and hydraulic loading are the basis for sizing the infiltration area. Table 2 shows

the recommended size of infiltration area needed based on average effluent strength from the second septic tank of 750 mg/L BOD_5. These sizing factors are based on the soil texture and the ability of the soils to breakdown the organic matter and are approximately six or more times larger that of typical home septic systems. Dividing the Loading Rate, found in Table 2, by the total daily wastewater volume per day will determine the size of the soil infiltration area. Note that these Loading Rates are based on the concentrations listed in Table 1. Additional wastewater treatment to reduce these concentrations, significant deviation in water usage, or additions of manure to the system (e.g. parlor waste), would change these factors.

TABLE 2. Loading Rates for bark bed systems with 2 septic tanks for pre treatment

Soil Texture	*Loading Rate (gpd/ft^2)
Coarse sand, medium sand, and loamy sand	0.32
Fine sand, sandy loam or loam	0.16
Silt loam, silt, or clay loam	0.12
Sandy clay, silty clay or clay	0.06

*Loading Rate based on a BOD_5 of 750 mg/L and flow of 5 gpd or a BOD_5 loading rate of 0.0062 lbs/gal.

Bark Bed Siting and Layout

To perform properly, Bark Beds must be constructed with 0% slope in all directions. Due to construction practices and pumping requirements, the recommended maximum bed width is 30 feet and the maximum bed length is 220 feet. If there is a choice, the infiltration area should be narrow (10 feet wide) and long rather than wide and short. Multiple beds can be used to meet the infiltration area requirements but should be avoided if possible.

If the area is level and covered with vegetation, the surface should be roughened with backhoe teeth to assure that the wastewater will not be impeded. If there is no naturally level area, the site should be excavated to achieve a 0% slope. No more than two feet of top soil should be cut, Figure 3. Filling in is not allowable as the natural soil structure is required for good infiltration. Soil surfaces should not be smeared or compacted during excavation. In addition, the design infiltration rate should match the exposed subsoils. (Often excavation could uncover different soils than the topsoil.) Do not select areas with more than 6% original slope. Berms are not necessary to keep the effluent inside the bark bed. However, runoff water from other areas should be excluded from the infiltration area using berms or site excavation. Large animals must be kept off the bark bed to avoid disturbing the bark or compacting the infiltration area. During and after construction, heavy traffic on the soil infiltration area should be avoided to minimize soil compaction.

A backhoe is used to roughen the infiltration area.

Distribution System Layout

Effluent is distributed to the soil infiltration area using a pressure distribution system which insures good distribution of the wastewater over the entire infiltration area. (Gravity distribution to the bed is not recommended.) Pump requirements and piping design must be sufficient to deliver two feet of head (water column) to the bark bed area after accounting for pressure losses for elevation and pipe friction.

A standard effluent pump is used to supply the pressure distribution system. The pump is set in the pump compartment of a two compartment tank or in a separate dosing tank sized for a one-day HRT or a minimum of 500 gallons. To avoid

pumping solids into the infiltration area, the pump intake should be located a minimum of six inches off the bottom of the tank.

The pump is controlled with a high-low float switch. Pump floats should be adjusted so the bark bed is dosed at least once per day to minimize system freeze up in very cold weather. The minimum dosing should be a volume of five times the distribution pipe volume. This minimum pumping volume insures even pressures and distribution throughout the infiltration area. A high alarm float must also be installed to warn of a system failure such as a pump failure or excess surface water entering the system. Details on pump and piping calculations can be found in Section 9 of the the University of Minnesota OSTP Manual.

Gravel, distribution pipe, geotextile fabric and bark media being installed.

Effluent distribution in the soil infiltration area can be done in two ways. Pressure distribution pipe can be laid on top of a gravel spreader or hung in a chamber designed specifically for wastewater distribution. A gravel spreader of drainfield rock must at least six inches deep and five feet wide. The distribution pipe is laid on top of the gravel spreader, covered in two inches of rock and then covered with synthetic landscape fabric to limit plugging of the gravel with the fines from the bark or wood shreds. When using a chamber system, the distribution pipe is suspended at the top of the chamber with plastic ties or mounted per the manufacture's specifications. All pressure distribution pipe laterals must be placed at the same elevation for uniform distribution. If this is not possible, see Section 12 of the University of Minnesota OSTP Manual for specific design changes related to elevation differences in pressure distribution systems.

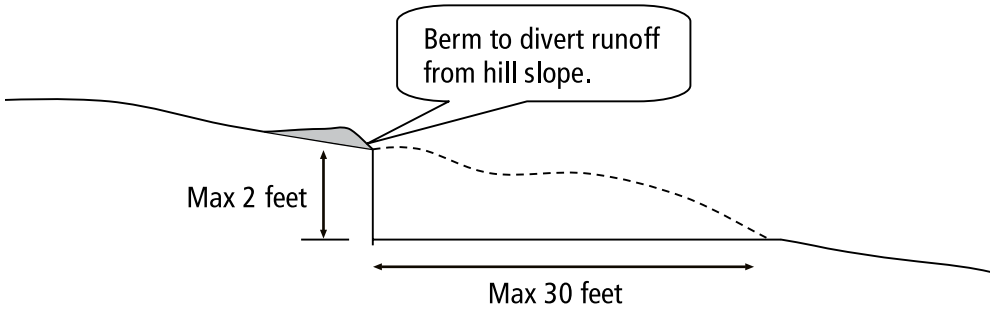


Figure 3. Bark Bed layout on a hillslope

Each pressure distribution lateral will feed a soil infiltration area 10 ft wide (5 ft on each side of the pipe). As such, the minimum distance between lateral distribution lines is ten feet. Bark or woodchip covering must extend five feet from the centerline of the pipe in both directions and on the ends. Note that the five foot of covering on the ends of the laterals are included in the effective infiltration area of the bark bed.

The sizing of the pipe and pump is critical in the design and performance of a bark bed. The distribution laterals are fed by a manifold pipe. This manifold can feed the laterals from either the center or an end as shown in figures 4 and 5. The sizing of the manifold and other design parameters are based on the geometry of the distribution system.

Pipe Sizing and Hole Spacing

Several factors are critical in determining the lateral pipe sizes, manifold size, and hole spacing and size in the lateral pipes. All of these parameters are interrelated and used to determine the size of the pump. In general, two-inch Schedule 40 PVC pipe is used with ¼ inch holes drilled every five feet. (For designs with other hole spacings see Section 12 of the University of Minnesota OSTP Manual). Holes are drilled on the bottom side of the pipe when gravel spreaders are used. When using chambers, refer to the manufacturer specifications for hole location, making certain that some of the holes are on the bottom side of the pipe so the pipes drain completely after the pump shuts off. In addition, a ¼ inch hole should be drilled into the end cap of each of the lateral pipes to release air pressure during filling of the pipe.

Holes are drilled in distribution pipe.

Distribution pipe is hung in chamber.

To maintain good distribution along the length of a single distribution pipe, a maximum number of 22 quarter-inch holes can be drilled. Therefore, with a hole spacing of five feet the maximum length of any lateral pipe length is 110 (5 foot spacing x 22 holes.) Systems with a center manifold (Figure 5) can distribute effluent over a bed length of 220 feet (5 foot spacing x 22 holes x 2 directions).

The pressure in these lateral distribution pipes should be maintained at 2 feet of head (0.86 psi). With this pipe, hole sizing, and pressure, the flow rate through each hole is 1.04 gallons per minute and the velocity in the pipes will be greater than the minimum recommended velocity of two feet per second. To determine the total flow rate in the system, multiply the total number of holes in the system by 1.04.

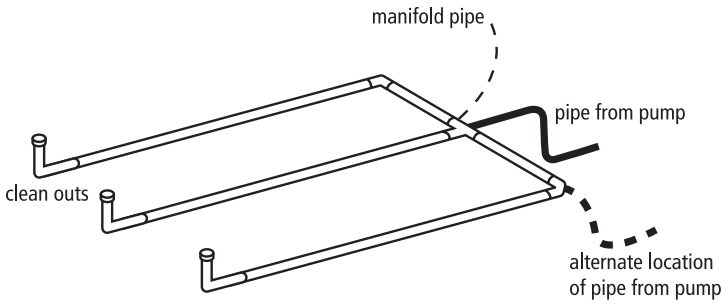


Figure 4. End manifold design

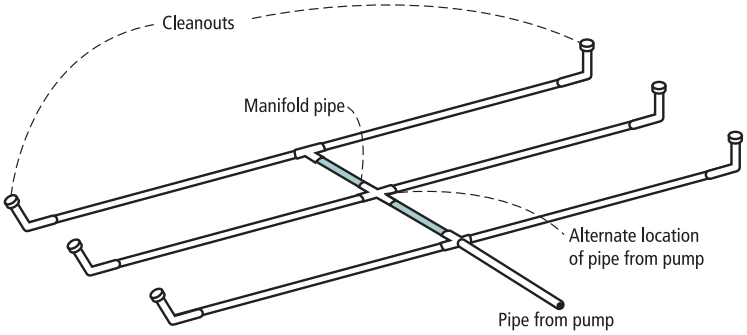


Figure 5. Center manifold design

Manifold sizing is based on the number and spacing of distribution laterals. Laterals are

spaced at ten-foot intervals along the manifold. With only one distribution line there is no need for a manifold as the supply line will feed the lateral directly. With two laterals the length of the manifold pipe is ten feet. With three laterals, the manifold length is 20 feet. Manifold diameter should be the same size as supply line or larger. The supply line should enter the bottom of the manifold to allow for good drainback and can be placed at any location along the length of the manifold.

Pump Sizing

Pumps are sized using the design flow rate and pressure. Pressure is required to evenly distribute the effluent to the infiltration area, account for elevation differences between the pump and the lateral distribution lines, and overcome friction losses in the piping system.

To provide even distribution in the distribution laterals two feet of head is recommended.

Pressure loss due to elevation differences is a function of the individual site layout. The pressure is the difference in elevation between the bottom of the pump and the distribution line.

TABLE 3. Friction losses in supply main

Flow (gpm)	Main (ft head loss/100 ft pipe)	
	Nominal Pipe Diameter	
	2 inch	3 inch
15	0.42	–
20	0.73	–
25	1.11	–
30	1.55	0.23
35	2.06	0.3
40	2.64	0.39
45	3.28	0.48
50	3.99	0.58
60	5.6	0.82
70		1.09
80		1.39
90		1.73

Values in italics mean that the combination of flow rate and pipe diameter will result in a velocity less than the required 2 feet per second.

Pressure loss due to friction in the supply line, manifold and laterals is a function of the flow rate, pipe diameters, and pipe lengths. Table 3 shows the friction loss in the main supply line (per 100 ft of length). Friction pressure losses in the manifold and lateral distribution lines are minimal and are taken into account with the hole sizing and spacing.

In addition to the friction losses along the length of the supply line pipe, there are additional friction losses in each pipe connection (elbows, joints, etc). These losses can be calculated individually (per pipe connection using various tables or charts) or can be estimated by adding 25% more to the length of supply line to account for these losses. Note that if the supply line is very short and there are several joints in the system this 25% increase may not account for all the friction losses. Conversely, if there are few joints and elbows with a very long supply line the friction losses may be significantly less than the 25% value.

Example 1: Pressure loss calculation.

Calculate the total head loss in a piping system that has a total flow rate of 50 gpm, 200 feet of 2 inch main supply line, two 75 foot 2-inch distribution line, and an elevation difference between the bottom of the pump and the lateral distribution pipes of 10 feet.

To work effectively, the system should be pressurized at 5 ft of head. The elevation difference from the bottom of the septic tank to the distribution pipe is 10 feet. The total pipe length is 350 feet but friction losses are only calculated in the supply line (not the perforated distribution lines or manifold). Using Table 3, the friction loss per 100 feet of pipe with a flow of 50 gpm is 3.99 ft. Therefore, the pressure loss due to pipe friction is 7.8 feet. (200 ft x 3.99 ft/100 ft). Adding the 25% for additional losses due to joints and elbows the pressure requirements of the pipe is 9.8 feet. The sum of these losses is 21.8 feet (5+10+9.8).

Distribution Line Slopes

Placement of the dose tank and piping must insure that supply lines and manifold pipes drain back into the dose tank. Final slopes of 1% or more back to the tank are sufficient. To achieve

this minimum final slope at all locations in the system, all pipe trenches should be dug at a slopes of 1.5 to 2%. The manifold pipe must be installed below the distribution laterals so the entire system can drain back into the pump tank.

Bark Bed Covering

Once the distribution system is in place, the infiltration area should be covered with 18 to 24 inches of bark or wood shreds. Currently, there are no design specifications on the bark or wood shreds used. The purpose of the shreds is to insulate the infiltration area, allow good oxygen transfer to the soil, and enhance evaporation. As such, the primary criteria are to have large pore spaces in the material. Breakdown of the wood material over time will reduce the porosity and restrict oxygen transfer to the soil interface thus increasing the risk of soil plugging and seepage from the edge of the bark bed. As such, hardwood bark or wood chips/shreds are preferred to softwoods. Avoid material with lots of small particles or fines.

Chambers are covered in bark.

Avoid driving on the infiltration area during the placement of the wood or bark. This will help maintain soil infiltration capacity.

Inspection and Maintenance

Install inspection pipes, vertical capped 4-inch PVC pipe, at the ends of all distribution pipes for inspecting the soil infiltration area. The bottom of the pipe should extend through to the bottom of the rock spreader or through the chamber. This inspection pipe should rise approximately 12-inches above the finished height of the bark or wood and be anchored firmly in place. These inspection pipes allow a visual assessment of ponding in the infiltration area. Excessive ponding is an indication that the soil is plugging due to excessive organic loading to the system or too much water is getting to the system.

Typical layout of a bark bed system using chambers.

Every three months the system should be checked. This monitoring includes a check of the effluent filter, ponding in the infiltration area, and seepage around the perimeter of the bark bed. Excessive buildup of solids on the effluent filter indicate high organic loading. If this occurs, investigate the equipment and management practices in the milk house that might allow excessive waste milk or manure into the system. Seepage around the edges of the bark bed indicates system failure. Seepage could be due to excessive water getting in the treatment system from water leaks in the milk house, soil plugging of the infiltration area due to high organic loading, or channeling of the effluent in the infiltration area. The source of the problem should be investigated and the system repaired.

A finished bark bed.

Add additional bark when depth over the spreader or chamber is less than twelve inches.

Irrigation

How Irrigation Systems Work

Irrigation systems are used to distribute milk house wastewater on pasture or cropland. These systems are designed to distribute the effluent at agronomic rates on large areas with minimum erosion potential defined as flat areas (less than 3% slope) with minimal ground cover or well vegetated areas with up to 15% slopes. Components of the irrigation system include a primary septic tank, a dosing tank, pump, piping, and irrigation heads. Critical design inputs for the system are the daily effluent volume, the effluent nitrogen and phosphorus concentrations, pump and piping requirements to meet the pressure and flow needs of the irrigation heads, and all site elevations. Figure 6 is a schematic of a typical irrigation system. The irrigation system can handle all wastewater from the milk house and unlike the other systems can handle some waste milk.

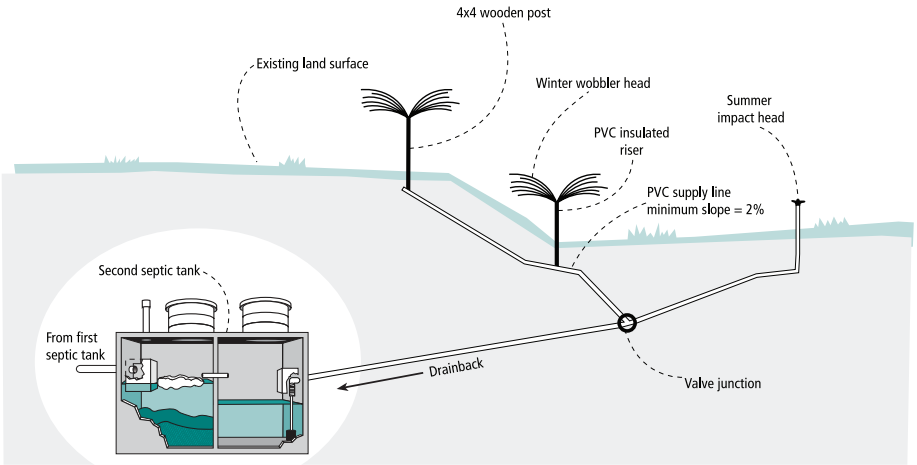


Figure 6. Irrigation System Schematic

Pretreatment

Effluent from the milk house must be pretreated in a primary septic tank with a minimum three-day Hydraulic Retention Time (HRT) to remove large solids and some of the fats and oils. The primary tank must also be larger than the bulk tank and have a capacity of at least 1,000 gallons. Effluent from the primary septic tank flows into a second septic tank, sized to provide an additional three-day HRT, that serves as the dosing tank for the system. Additional storage capacity in the dosing tank provides a margin of safety if a system failure occurs or if irrigation needs to be suspended for crop harvesting. Both the primary septic tank and the dosing tank must be constructed and installed according to MN Rules Chapter 7080. Additional tanks for pretreatment can be used for additional solids settling. However, the longer the HRT, the greater potential there is for odor emissions during irrigation.

Sizing the Irrigation Area

The primary design consideration for sizing the irrigation system application area is the amount of pasture or cropland required for using the nutrients in the effluent at agronomic rates. The nutrient distribution requirements can be based on either phosphorus (P) or nitrogen (N). Wastewater volumes and effluent characteristics suggest that a milk house will produce 0.98 lbs/c/yr of N per year and 0.84

TABLE 4. Fertilizer recommendations for typical crops

Crop	Yield range	N removed	P_2O_5 removed	*Elemental P removed
Corn	Corn 100-200 bu/acre	~0.8 lbs/bu (80-160 lbs/acre)	0.34 lbs/bu corn (34-68 lbs/acre)	0.15 lbs/bu (15-30 lbs/acre)
Soybeans	Soybeans 30-50 bu/acre	3.5 lbs/bu (105-175 lbs/acre)	0.82 lbs/bu (25-41 lbs/acre)	0.36 lbs/bu (11-18 lbs/acre)
Corn-Soybean Rotation (2-yr average)		92.5-167 lbs/acre/yr	29-54.5 lbs/acre	13-48 lbs/acre
Pasture or Grass	2-5 tons/acre	27 lbs/ton (54-135 lbs/acre)	8.9 lbs/ton (18-45 lbs/acre)	3.9 lbs/ton (7.9-19.8 lbs/acre)

*Multiply by P_2O_5 by 0.44 to convert to elemental P.

lbs/c/yr of P. Approximately 60% of the total N in the effluent is in the ammonia form (NH_3) and will likely be lost through volatilization during irrigation. This means approximately 0.39 lbs of N are available in milk house wastewater per cow per year.

For systems where the effluent will be spread to permanently vegetated areas or flat areas where there is little risk of soil erosion, the irrigation area should be based on the N removed (i.e. in the harvested crop) from the area. These values are given in University of Minnesota Extension Publication #BU-06240 Fertilizer Recommendations for Agronomic Crops in Minnesota which are summarized in Table 4. For irrigation sites where the effluent will be spread on cropland that has a high potential for soil erosion the irrigation area should be based on the P removal of the crop. Irrigation areas based on P removal will be significantly larger than those based on N removal.

Using these recommended values the following equations can be used to determine approximate areas needed for nutrient distribution from milk house wastewater only (no parlor water).

Where

AP and AN are the area in ft² required for wastewater application based on either P or N rates.

$$A_P = \frac{0.84\frac{lbsP}{cow \cdot yr} * 43{,}560\frac{ft^2}{acre} * 2.27\frac{P}{P_2O_5} * \#\ cows}{F_P} = \frac{80{,}060 * \#cows}{F_P} \quad (1)$$

$$A_N = \frac{0.39\frac{lbsN}{cow \cdot yr} * 43{,}560\frac{ft^2}{acre} * \#cows}{F_N} = \frac{17{,}000 * \#cows}{F_N} \quad (2)$$

FP and FN are the crop nutrient uptake in lb/acre for P_2O_5 or N respectively.

Irrigation Zones and Heads

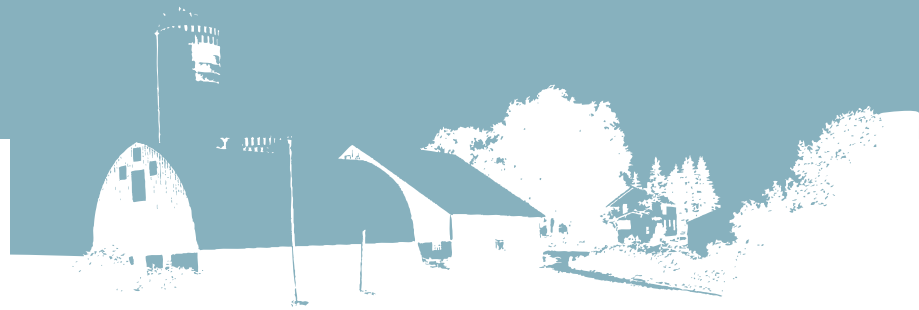
Milk house wastewater irrigation systems typically are designed with a minimum of two separate irrigation areas or zones. One or more zones are used for winter application and one or more zones for summer application. When effluent is applied to pasture or cropland the zones can be managed to allow one zone to dry prior to harvest or grazing. Additional zones (more than two) may be required based on pumping and pressure requirements but may also be desirable because of the increased flexibility in nutrient distribution and hydraulic loading of the zones to better manage crop harvest or pasture use (e.g. more flexibility drying of zones for harvest or grazing). Multiple zones also offers some backup should one zone fail due to freezing or clogging of the sprinkler heads. The total area required for nutrient distribution is the sum of all the zone areas used.

Wobbler™ head used for winter or summer application.

Irrigation zones are often designated by the type of irrigation head used. During winter, a Wobbler™ head with a 9/32 inch orifice diameter is used. This is a frost-resistant head that emits effluent in a 50 foot diameter circular pattern which covers an area of approximately 2000 ft^2. These heads are designed in such a way that they do not freeze during winter application. Wobbler™ heads can also be used in the summer but typically a traditional impact head is used because of their larger spread pattern.

Impact irrigation head used for summer irrigation.

Traditional impact heads have a 100-150 foot diameter distribution pattern (areas of 7800 ft^2 to 17,700 ft^2). The impact heads should be brass (vs plastic for a longer life) and have a minimum orifice diameter of ½-inch to handle the solids that may be in the effluent. Some impact heads allow for part-circle irrigation giving greater flexibility in the layout and management of irrigation zones. Impact heads used can have either a low or standard trajectory (angle of water leaving the irrigation head), either is fine for this use. These heads can be installed on the edge of crop fields and the effluent can be spread over growing crops. Effluent has been spread on pasture, soybeans and corn with no negative effects. Application to alfalfa should be avoided due to its intolerance to high moisture conditions. Two to three days prior to harvest or grazing, the irrigation should be discontinued (switch irrigation zones) to allow for adequate drying of the area.



Effective Application Area

The effective area covered by a system with multiple risers and sprinkler heads is a function of the diameter of the spread pattern and the amount of overlap which is determined by the spacing of the risers. The overlap pattern is shown in figure 7 and calculations to determine the effective application area with systems that overlap is calculated below. Good overlap (spacing between risers less than 70% of the spread diameter) for good nutrient distribution in an area. However, it is typically more economical to not have any overlap between the sprinkler heads because more area will be covered with fewer heads. In calculating the application area with systems where the riser spacing is greater than 100% use the area covered per head (calculated by $\pi D^2/4$) multiplied by the number of heads in the system. This area should be equal to or greater than the required application area based on nutrient loading.

Application Area with Heads with 360° Spread Patterns with Overlap

The effective area for systems of head with 360° spread patterns can be calculated using the following equation. Note that this equation slightly overestimates the application area of the irrigation heads.

$$EAA = \left[(N_L - 1) * S_L + D\right] * \left[(N_W - 1) * S_w + D\right] \quad (3)$$

Where

EAA= Effective Application Area (ft^2)
NL= Number of heads along the length of distribution lines
NW = Number of rows of distribution lines
SL = Spacing of heads along distribution lines (ft)
SW = Spacing between distribution lines (ft)
D = Diameter of spread pattern (ft)

For example, a typical winter zone using Wobbler™ heads supplied wastewater at 10 psi will have a a spread diameter of 52 ft (D).

Assuming a head spacing of 30 ft along the length (SL) and a 30 ft width spacing (SW), the effective area for 8 sprinklers in two lines (NW = 2) with four heads per line (NL = 4) as shown in the figure 7 below would be

((4-1) x 30 +52) x ((2-1) x 30+52) = 142 x 82 = 11,600 ft^2

Application Area with Heads with 180° Spread Patterns with Overlap

For a single row of impact heads set to apply only in a 180° spread pattern (such as on a fence line) the effective distribution area is calculated using the following formula.

$$EAA = \left[(N_L - 1) * S_L + D\right] * \frac{D}{2} \quad (4)$$

For example, consider four impact heads (NL = 4) with 100 foot spread diameter (D) set along a fence line as per figure 8. Using a spacing of 80 feet (SL) between heads and setting the heads to only spray 180° the effective application area would be calculated as follows.

Effective Application Area (ft^2) = ((4-1) x 80 +100) x 100/2 =17,000 ft^2

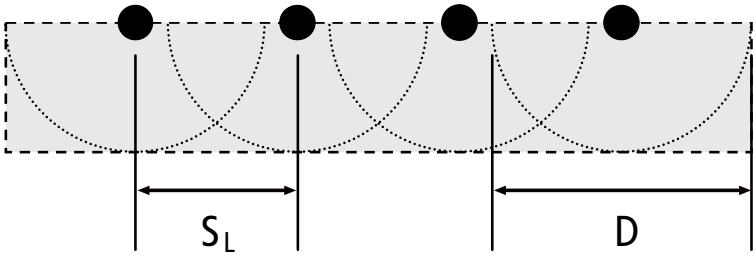


Figure 8. Typical field layout for summer irrigation along a fenceline

Table 5 was created using equations 3 and 4 and is applicable with the noted spread diameters and spacings.

TABLE 5. Effective Application Area (ft^2) using standard heads and spacing

	Wobbler Heads		Impact Head	
#heads/row	55' dia	55'dia	Full circle 135' dia	Half circle 135'dia
	1 row	2 rows	1 row full circle	1 row half circle
1*	2375	–	14300	7150
2	5150	–	30983	15491
3	7260	–	43740	21870
4	9378	15942	56498	28249
5	11495	19543	–	–
6	13613	23141	–	–
7	15730	–	–	–
8	17848	–	–	–
9	19965	–	–	–
10	22083	–	–	–

Spacing between heads is 70% of the spread diameter.
*Single head calculation = 3.14 * D^2 / 4

TABLE 6. Performance data for select irrigation heads

Wobbler™ #18 purple 9/32 orifice						
psi	10	15	20	25	30	35
gpm	7.2	8.8	10.2	11.4	12.5	13.5
dia (5 ft ht)	52.0	54.5	55.5	56.0	56.5	57
Rainbird™ Part Circle 85EHD-LA 1-1/4 inch, 0.5 inch nozzle						
psi	25	30	35	40	45	–
gpm	34	37	40	43	46	–
dia (6 ft ht)	120	130	142	150	154	–

Irrigation Head Selection

Performance data for the Wobbler™ and a select impact head is given in Table 6. Avoid designs based on the minimum pressures listed in Table 6. Although it is possible to operate at those pressures the distribution pattern is not as even. The selection of the type and number of irrigation heads and number of zones is a function of several factors that will be discussed later. These decisions impact the pump selection.

Pumping and Piping

Effluent is pumped from the dosing tank through Schedule 40 PVC distribution pipe to the irrigation heads using a high-head effluent pump with high/low floats and a high-alarm. A simple 24-hour timer is recommended to allow for effluent pumping at certain times of the day. Timing of the irrigation is done to avoid odor problems during certain times of the day or to allow for irrigation during periods when the system can be observed. The timer could also be used to schedule winter irrigation during the warmer time of the day to minimize freezing potential.

Pump pressure requirements are a function of the type and elevation of the irrigation

heads and the friction losses in the pipes. Table 6 provides information on the irrigation head pressure requirements. Friction losses in the distribution pipes are based on the values in Table 3. Besides the friction losses in the pipe, there are additional pressure losses due to joints in the pipe. These can be calculated on a per joint basis or can be estimated by adding an additional 25% of pipe length and respective friction loss. Note that the individual riser pipes have minimal flow and length and therefore minimal friction loss. Note also that the conversion of pressure in psi to feet of head is done by multiplying the psi by 2.3. For instance, the Wobbler™ head listed in Table 6 requires an operating pressure of 15 psi for a flow of 8.8 gpm. This pressure is equivalent to 34.5 feet of head loss.

Pump flow specifications are based on the number and type of irrigation heads and operating pressures. For any single zone the flow is the sum of all the flow for all irrigation heads in that zone. Pump selection is based on the zone with the highest pressure and flow requirements. Use the calculated pressures and flows and manufacturers' pump selection curves to select the correct pump. A typical pump curve is shown in figure 9.

For more information on pump sizing and calculating of pressure losses in the system see Section 9 of the University of Minnesota OSTP Manual.

Distribution Pipe

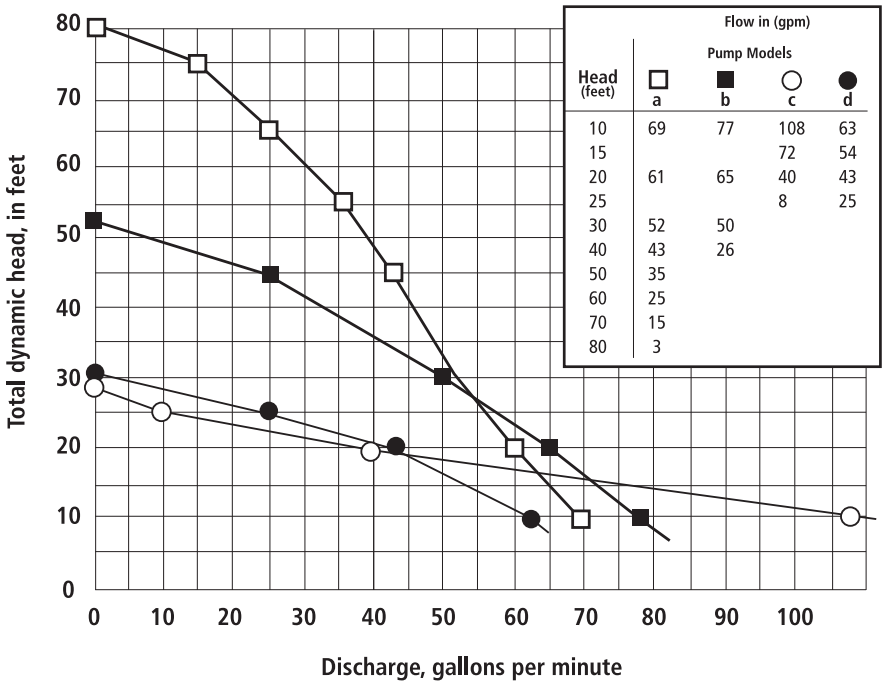
The diameter of the distribution pipe is based on flowrate and expected pressure losses but is typically two or three inches. Distribution pipe (schedule 40 PVC) is placed in trenches at least 18 inches into the soil to avoid freezing. Distribution lines must have a final minimum slope of 1% to insure drainback to the dosing tank. During construction, the distribution pipe trenches should be excavated on a 1.5% to 2% grade to insure the minimum 1% final grade requirements are met throughout the length of pipe. Standard installation practices for pressure pipes should be followed.

Wobbler™ Heads

Wobbler™ heads are fed by one to two-inch riser pipes coming off the distribution lines. Wobbler™ heads, which are necessary in the winter but can also be used in the summer, must be mounted above the maximum snow depth, typically five to six feet above the soil surface. Risers are spaced every 25-30 feet to allow 50% overlap of the 50 to 60 feet diameter irrigation spray pattern. This overlap provides good distribution of the nutrients on the irrigation area. The elevation of all heads in a single zone should be within one-foot of each other to insure equivalent pressures at the heads and even effluent distribution between heads.

Summer irrigation with Wobbler™ heads.

Winter irrigation with Wobbler™ heads.



Head (feet)	Flow in (gpm) Pump Models □ a	■ b	○ c	● d
10	69	77	108	63
15			72	54
20	61	65	40	43
25			8	25
30	52	50		
40	43	26		
50	35			
60	25			
70	15			
80	3			

Figure 9. Typical pump curve for high head effluent pumps

Impact Heads

Impact heads are fed with two-inch PVC riser pipes. Heads are typically mounted at five to six feet above the soil but can be mounted higher to spray above the crop canopy. This higher mounting height is critical when the effluent is to be irrigated on a corn crop where the heads need to be above the corn.

Generally, use spacing between heads of 70% of the spread diameter. For instance, with a spread diameter of 100 feet, the spacing between heads would be 70 feet.

Summer application with impact heads.

Riser Pipes

Riser pipes, the pipes between the distribution lines and the irrigation heads, have been constructed with ¾-inch diameter PVC pipe wrapped in expanded foam and covered with 2” diameter PVC pipe. Successful systems have also been constructed with 2-inch diameter non-insulated PVC riser pipe. With rapid system drainback non-insulated riser pipes should be adequate.

Riser pipes must be well anchored to minimize vibration. Pipes are typically attached to 4-inch x 4-inch treated wooden posts or larger using galvanized pipe clamps. Posts should be set in the ground three to four feet in well compacted soil or set in concrete to insure maximum stability. Riser pipes in pastures need to be protected from animal damage using electric fencing. All riser pipes and posts need to be well marked for good visibility to minimize chances of mechanical damage by farm equipment.

Control Valves

Valves for controlling the flow to different irrigation zones must be accessible throughout the year and insulated or protected from freezing. Control valves can be brass slide-gate or ball valves. Large diameter PVC pipe (8 to 24 in. in diameter) can be used to provide below ground (i.e. manhole) access to valve assemblies. Some type of valve handle extension must be constructed to reach the valves when a small diameter pipe is used for valve access rather than a manhole.

Valve access must be insulated to prevent freezing. Covering the access cover with a straw bale or filling the access pipe with insulation have both proven successful. Placing the control

Valves for controlling irrigation zones located in manhole.

valves on top of the septic tanks also protects against frost.

The control valve manholes should be backfilled with six to ten inches of rock or gravel to prevent rodents from burrowing into the access pipe and covering the valves. The rock should extend 8-12 inches below the bottom of the valve assembly.

Design Steps

1. Determine the number and size of primary septic tanks and the dosing tank based on the number of cows and flow estimate or water meter data.
2. Determine the amount of land needed based on crops and estimated nutrients (use phosphorus rates if area is in a cropping system where there is potential for soil erosion, use nitrogen rates when applying to permanent grasses).
3. Determine the number of zones and the number of irrigation heads per zone to meet the land application area requirements. This can be calculated using a trial and error method using equations 3 and 4 or by using Table 5.
4. Determine the flow and pressure requirements for each zone of the system using the irrigation head information for flow and pressure, the difference in elevation between the pump and the irrigation heads and the friction losses in the pipe.

Aerobic Treatment Units and Recirculating Media Filtration

How Aerobic Treatment Units and Recirculating Media Filtration Systems Work

These treatment systems consist of a primary septic tank, an Aerobic Treatment Unit (ATU) or Recirculating Media Filter (RMF), and a subsoil infiltration area. Both the ATUs and RMFs are designed to reduce the organic loading of the milk house wastewater to concentrations similar to household septic wastewater (i.e., 200 mg/L BOD_5). This reduction in wastewater strength allows the effluent to be distributed into a standard sized septic soil infiltration system.

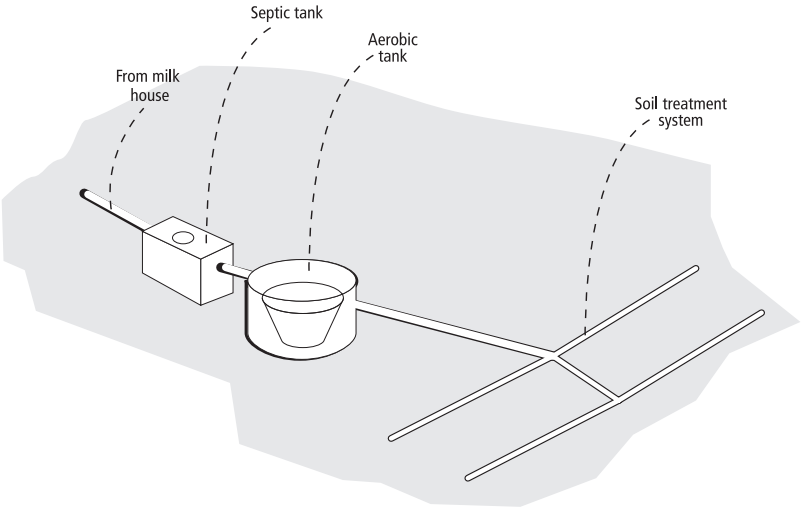


Figure 10. Aerobic Treatment System Schematic

System Design

Both ATUs and RMFs are commercially available. These systems are sized based on the BOD_5 concentrations and daily flow. Both systems use aerobic microorganisms to reduce the BOD_5 prior to discharge to a standard septic infiltration area. To maintain these organisms, oxygen is added to the system with blowers, pumps or venturi systems. Many ATUs employ an inert support material to maintain microbial populations (fixed film.)

RMFs add oxygen by pumping the effluent over a porous media filter. The

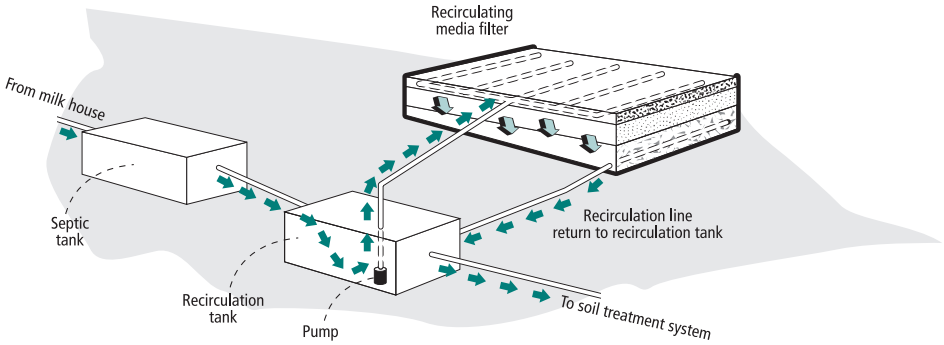


Figure 11. Schematic of a Recirculating Media Filter

Completed Recirculating Media Filter.

Aerobic pump supplies air to wastewater.

biological community, attached to the surface of this media, break down the organic matter. The media is contained in a watertight vessel either below the surface of the ground or wholly or partially elevated in a containment vessel. Proper function requires that influent to the RMF be distributed over the media in frequent, cycled, uniform doses. To achieve accurate dosing, these systems require a timer-controlled pump with associated pump chambers, electrical components and liquid distribution network. This frequent, cycled dosing keeps the media constantly wet. The effluent is collected in the bottom of the filter and returned to the recirculating/mixing tank where it either mixes with fresh septic tank effluent or a portion is discharged to the infiltration area. Flow splitting mechanisms are used to control recirculation and discharge to the subsoil infiltration area.

Infiltration Area Design

Infiltration areas are sized based on an assumed treated waste strength of 200 mg/l BOD_5, the daily flow from the particular site (gallons per day), and the soil characteristics of the infiltration area. Soil Sizing Factors (SSF) are given in Table 7.

For milk house systems, the infiltration trenches must have at least 2 feet of separation from bedrock or the seasonally high water table to deal with the remaining BOD_5 and hydraulic loading. Note that this is less restrictive than the household wastewater requirements of three-foot separation due to the lack of human pathogens in the waste. Infiltration areas should maintain a 100 foot setback from wells and 50 foot setback from water bodies (or follow applicable local and state requirements).

TABLE 7. Loading Rates based on BOD_5 effluent concentration of 200 mg/L

Soil Texture	Loading Rates (gpd/ft^2)
Coarse sand[a] medium or loamy sand	1.20
Loamy sand, fine sand, sandy loam or loam	0.59
Silt loam, silt, or clay loam	0.45
Sandy clay, silty clay or clay[b]	0.24

[a]For these soils, clean sand should be hauled in to achieve the 2 foot separation.
[b]System should be built above ground as digging in clay soils causes smearing

Installation and Management

Installation of ATUs and RMFs and the related infiltration areas should be done by trained professionals. Manufactures' recommendations should be followed for all operation and management of these systems. More information on ATU and RMF system installation and management can be found the University of Minnesota OSTP Manual Section 10.

Gravel trench for effluent distribution

Milk House Wastewater Treatment System Selection

Choosing a milk house waste treatment system is not always easy. Each of the treatment systems described above have site limitations. Sites with high water table or limited soil depth to bedrock, less than 2 ft, may limit the viability of bark beds, aerobic systems, or recirculating media filter systems that discharge into subsoil infiltration areas. Some farm sites may not have enough available land for an irrigation system or site elevations do not allow for proper drainback of below ground distribution pipes. Some bark beds, irrigation areas, or infiltration areas have been located over 350 feet from the milk house because of site conditions.

In some cases, a combination of systems may be appropriate. Combinations might include a bark bed for winter and cropland irrigation for the summer. This combined system would make some of the wastewater nutrients available for crop production and enhance the bark bed's useful life. Combination systems can be more complex because of the different piping and pumping requirements for the different systems. Combination systems are also likely to be more expensive than a single treatment system.

Regulatory Considerations

Locating the septic tanks and infiltration areas of the milk house waste systems may require some investigation of state regulations and local ordinances or building codes. For Minnesota the following guidance should be used

Septic tanks and infiltration areas must be at least 50 feet from most wells but 100 feet from sensitive water supply wells as defined by the Minnesota Department of Health.

Irrigation systems should follow, at a minimum, Minnesota Feedlot Rules Chapter 7020 and stay 300 feet away from lakes, streams, intermittent streams, unbermed drainage ditches and public waters wetlands.

There must be a minimum of two feet of separation between the bottom of the infiltration area and the periodically saturated water table or limiting condition (this could be bedrock). The infiltration area should not be located on course sand. Most research indicates sufficient BOD_5 removal and ammonia transformation within 2 feet of unsaturated soils.

General Considerations

Currently, in Minnesota, these systems will be permitted as part of the feedlot.

In general, the following items should be considered when choosing an appropriate system.

- Available area
- Depth to bedrock or seasonally high water table
- Site elevations to allow for system drainback
- Existing milk house effluent pipe elevation
- Soil texture
- Capital investment
- Operating cost
- Operation and maintenance requirement
- Owner preference

Operation and Maintenance

All milk house wastewater treatment systems require regular operation and maintenance.

Septic Tank and Treatment Tanks

Excessive solids buildup in the septic tanks reduces the effective hydraulic retention time and allows settled solids to move into the secondary treatment or soil infiltration area. These secondary treatment systems and soil infiltration areas are not designed for this additional solids loading. Excessive organic and solids loading will shorten the useful life of the soil infiltration area.

Septic tanks should be pumped on an annual basis and more frequently if solids accumulate at a faster rate. Septic tanks should be inspected quarterly for scum and sludge buildup to determine when the tanks should be pumped. Tanks should be pumped when solids are 18 inches or more deep on the bottom of the tank or the floating scum layer is 4 to 6 inches thick. This effluent can be land applied.

Solids accumulation in treatment tanks reduces the treatment efficiency of these systems. Monitoring and pumping should be done as recommended by the manufacturer but quarterly monitoring and annual pumping is likely required.

Effluent Filter

Effluent filters are commonly installed in the outlet of the primary septic tank to reduce the loading on the secondary treatment system by filtering out suspended solids in the effluent. These filters should be inspected and cleaned monthly initially and less often if these monthly inspections show no signs of buildup. Solids buildup on the effluent filter may indicate a sludge buildup in the septic tank or excessive organic loading to the system. If there is significant buildup on these filters on a regular basis the management and operation of the milk house should be evaluated to determine if waste milk is getting into the system.

Effluent filter from outlet of first septic tank ready for cleaning.

Scum layer on top of septic tank.

Waste Milk Handling

The Bark Bed, ATU and RMF systems are not designed to treat waste milk (colostrum from fresh cows, waste milk from treated cows or bulk tank failures, or milk spills). The irrigation system can handle some waste milk but excessive amounts may cause odors and will fill the septic tanks with scum.

All waste milk should be diverted from the wastewater treatment system. It is critical that

all employees know that waste milk and colostrum cannot enter the treatment system. Plumbing within the milk house will facilitate the diversion of this waste milk from the milk house wastewater system. Check with the milk inspector for requirements regarding milk house plumbing options that will divert waste milk to the manure handling system. Waste milk is often fed to other farm animals.

Human wastes

Milk house wastewater systems are not designed to treat human wastes. Do not allow human sewage to enter the milk house wastewater treatment system.

Rodent control

Rodent control may be needed in valve access pipes, Bark Beds, or drainfields.

Water usage

Excessive water use could alter the treatment efficiency and long term viability of the treatment system. As such, flow monitoring is a integral part of the treatment system operation and management. Monitoring this usage aids in troubleshooting any system problems and is used to determine if excessive water is getting to the treatment system (more than what the system was designed for). Monitoring of flow must include notations about any water use measured by the flow meter but not entering the treatment system such as water used for washing vehicles or water used for feeding calves.

System Specific Maintenance

Beyond these general items, operation and maintenance required for all systems are the system specific items. They are as follows:

- **Bark Bed** – Inspect for seepage around the perimeter of the bark bed every three months. If necessary add additional bark when bark depth is less than 12 in. Over time, the bark will decompose and additional bark will be needed to maintain adequate cover over the soil infiltration area both to protect and insulate the soil.
- **Irrigation** – Irrigation zones must be manually controlled for summer and winter operation or if soils become saturated. Monthly checks should be done to insure that irrigation heads are not plugged and no runoff from the irrigation area is occurring. Excessive manure solids and animal hair can plug irrigation heads.
- **ATU or RMF** – The life of the soil infiltration area following an ATU or RMF is directly related to the treatment efficiency. Monthly visual observation of the effluent will help indicate the unit's performance. Semi-annual testing of the effluent will document system performance. BOD_5 concentrations in this effluent should remain below 200 mg/L. Follow other maintenance requirements recommended by the vendor.

Design Procedure Overview

Design of milk house wastewater handling or treatment systems can be broken into four phases; 1) site evaluation, 2) preliminary designs for multiple options, 3) final design selection and 4) completion of final design. Proper design and installation are required to complete the process.

1. Site evaluation includes an interview with the dairy producer and a walk around the site to assess the status and location of current milk house wastewater disposal, and options for locating a new treatment system. This step should provide the producer with an overview of system options, assessing their preferred treatment options, and estimating wastewater flows. A water meter could be added at this time and flows monitored for two or more months to better estimate the wastewater flow volume. Soil borings should be taken to determine if sufficient separation to ground water or bedrock is available and to determine soil type if a bark bed, ATU or RMF are being considered as system options. Two borings in the designated infiltration area is sufficient.

2. Data collected during the site evaluation is use to prepare preliminary designs for a variety of system options that were not eliminated during the site visit due to farmer preference, farm layout or soil conditions.

3. Design options, including price estimates are then presented to the producer and a final decision made on the appropriate system for the site.

4. Additional data such as more accurate wastewater flow data, more details on site elevations, soil type and texture, water table information, etc. can now be collected and used in the final system design.

Location of milk house, location of infiltration area, and elevations are key design criteria

Proper installation of all system components is required.

The design guidance provided in this document will assist in the selection and proper design of milk house wastewater treatment options that are currently available. Over time it is anticipated that more treatment options will become available and more detailed and specific design guidance given on these existing and future options.

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EXAMPLE - Bark Bed System

Assume a 60 cow dairy has an 800 gallon bulk tank. The producer has decided to install a bark bed on a silt loam soil with a maximum width of 25 feet. The elevation difference from the bottom of the septic tank to the top of the lateral lines is 8 feet, and the distance from the septic tank to the bark bed is 150 feet. Assume that no wells, sinkholes, lakes, streams or wetlands are located within 150 feet of the proposed bark bed site. Find the following.

- Required number and size of septic tanks
- Bark bed dimensions
- Length and spacing of the distribution pipes in the bark bed
- Amount of bark or wood shreds needed
- Pump pressure and flow required for the system.

1. Sizing of the septic tanks

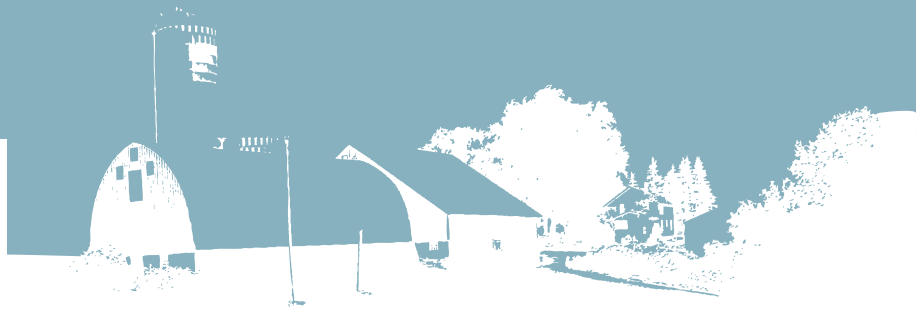
- Estimated flow per day is 300 gallons (60 cows x 5 gallons/cow/day).
- The primary and secondary treatment septic tanks are each 1000 gallons. The two design parameters are the 3-day HRT or 900 gallons and the 800 gallon bulk tank. Therefore the smallest septic tank is the maximum of these two values. However, septic tanks are commonly found in 500 gallon increments hence the 1000 gallon septic tank would be specified in the design.
- The dosing tank size is sized with a minimum 1-day HRT so at a minimum a 300 gallon tank is required (larger is OK)
- An effluent filter (Zabel or similar) should be placed between the second tank and the dosing tank.
- The tanks selected could be a 2000 gallon tank with two 1000 gallon chambers followed by a second 500 gallon tank for dosing or a 1000 gallon tank followed by a 1500 gallon tank with a 1000 gallon chamber and a 500 gallon chamber used for the dosing tank.
- Consider future dairy herd expansion when sizing the septic tanks.

2. Calculate the sizing of the soil infiltration area

- The required size of the infiltration area (bark bed) is 2500 ft^2 based on the daily flow (300 gpd) and a loading rate of 0.12 gpd/ft^2 (from Table 2) for loam soil.

3. Calculate the piping requirements and layout of system

- The total length of the bed would be 250 feet using one distribution line (2500÷10), 125 feet using two distribution lines or 83 feet using three distribution lines. This is based on the 5 foot effective area on both sides of the distribution pipe.
- Using two lateral distribution lines with a center manifold (figure 5) gives a total bed length of 125 feet. The total length of the distribution line is 10 feet shorter than the bed length because of the requirement for 5 feet of cover on each end of the lines. With center distribution each of the two distribution pipes are 57 feet ((125 ft ÷ 2)– 5 ft).



4. Calculate the amount of bark needed for the system

- The total bark bed area is 2500 ft^2. The minimum bark depth is 2 feet so the total bark required is approximately 5000 cubic feet or 185 cubic yards (cubic feet divided by 27 cubic feet per yard). An additional 10% of bark should be included for wastage. A total of 200 cubic yards (185 yd^3 * 1.1).

5. Determine system flow rate

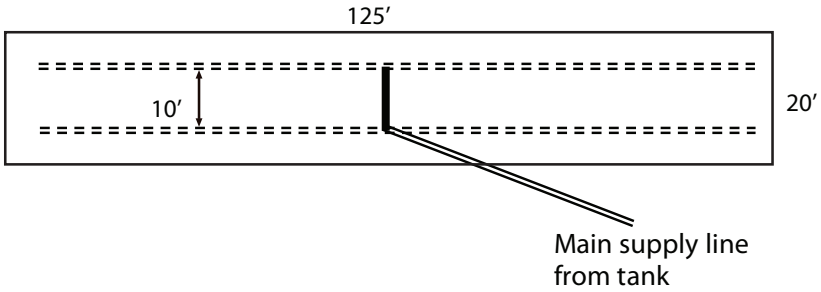
- The number of perforations for the system is 46 (115 ÷ 5 ft hole spacing = 23 holes per lateral x 2 laterals). With 46 holes, the flow required is 48 gpm (46 holes x 1.04 gallons per hole).

6. Determine the pipe sizing and determine pressure requirements

- The head required in the system is 5 ft.
- The elevation difference was stated as 8 feet.
- In general, 2 or 3 inch pipe is used for the mainline, depending on flow and distance. Distribution pipe are usually 1.5 inch diameter. Using Table 3, the friction loss at a flow rate of 50 gpm is 3.99 per 100 feet of pipe. For a distance of 150 feet this total loss is 6.0 feet (3.99 x 150 feet ÷100). An additional 25% of loss or 1.5 ft (0.25 x 6 ft) due to elbows and joints. This results in total pipe friction loss of 7.5 ft.
- No additional friction losses for the lateral pipes are added
- No additional friction loss for the manifold. Manifold sizing is the same as the mainline or slightly larger.
- Total head needed in the pump is (8 + 5 + 7.5) or 21 feet (always round up).

7. Determine the pump size

- From the pump sizing chart below and the calculated requirements of 50 gpm and 18 feet the pump sizing pump "c" would be selected for this site. Pumps "b" and "a" would also meet or exceed these requirements.



Example Layout of System

EXAMPLE - Irrigation System

Assume a 60 cow dairy has an 800 gallon bulk tank. The producer has decided to install an irrigation system. Effluent will be applied on pasture land in the winter and cropland in the summer. The pasture land yields approximately 3.5 tons/acre while the cropland is in a corn soybean rotation with corn yields of 150 bu/acre and soybean yields of 45 bu/acre. The proposed application area is flat and is about 300 feet away from the milk house. The elevation difference from the bottom of the septic tank to the top of the lateral lines is 14 feet. There are no wells, sinkholes, lakes, streams or wetlands are located within 150 feet of the proposed application sites. Determine the following.

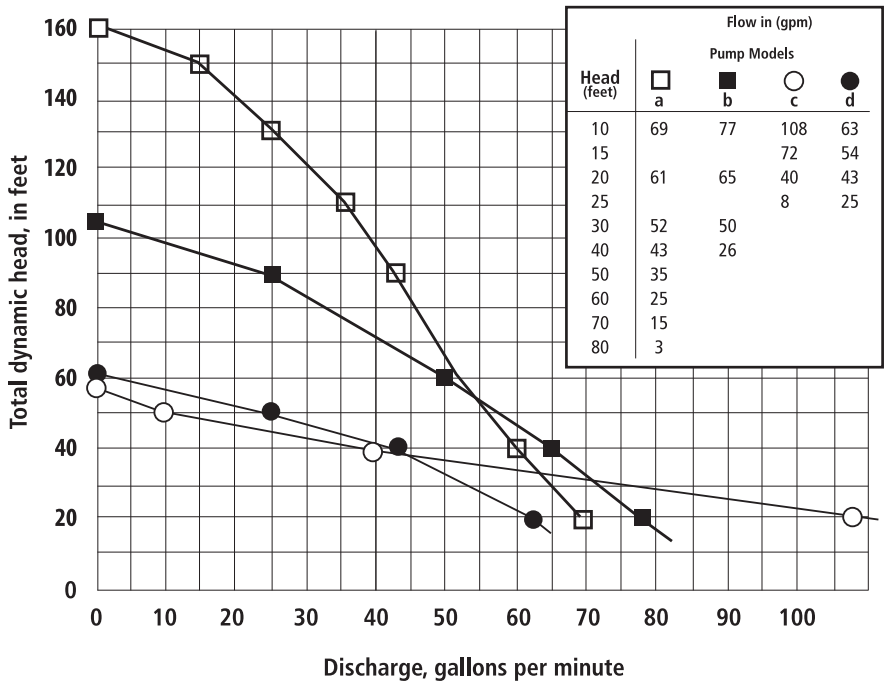
- Number and size of septic tanks.
- Size of the application areas.
- Number, spacing, and type of irrigation heads and zones.
- Flow and pressure requirements and specify pump.
- Other critical system elements.

1. Sizing of the septic tanks

- Estimated flow per day is 300 gallons (60 cows x 5 gallons/cow/day). The primary septic tank size must be 1000 gallons. This exceeds the minimum of 3-day HRT, bulk tank volume, or 1000 gallon minimum. The dosing tank size is also 1000 gallons to provide the minimum of 3-day HRT.

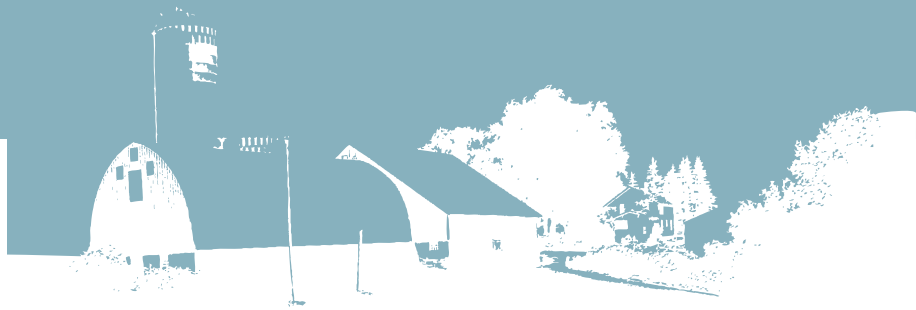
2. Sizing of the irrigation area

- Because the application area is flat the application area should be sized based on N requirements. Using 3.5 T per acre yield and a nitrogen utilization of 27 lbs/ton (Table 4) the amount of nitrogen required on the pasture is 95 lbs. Using Equations 2, the application area required using the N requirements on the pasture land is 10,900 ft^2. For the cropland the average N use in the corn soybean rotation would be 138 lbs/year ((150 * 0.8 + 45 * 3.5)/2) requiring approximately 7400 ft^2 of application area. Assuming that effluent is applied 5 months on the pastureland and 7 months on



Head (feet)	Flow in (gpm) Pump Models □ a	■ b	○ c	● d
10	69	77	108	63
15			72	54
20	61	65	40	43
25			8	25
30	52	50		
40	43	26		
50	35			
60	25			
70	15			
80	3			

Typical pump curve for high head effluent pumps



the cropland the area requirements for the winter and summer zones would be 10,900 * 5/12 and 7400 x 7/12 winter application area required is 4500 ft^2 and the summer application area is approximately 4400 ft^2.

3. Determining the number of zones and irrigation heads per zone

- Using Table 5, the minimum number of Wobbler® heads required is two. One impact head with half circle application will be enough to distribute the effluent to the cropland in the summer. Both the two winter heads and the single summer head will cover more area than is required as calculated in Step 2.

4. Determine the pump size for the system

- From Table 6, the lowest operating pressure recommended for the winter heads is 15 psi. The lowest operating pressure recommended for the impact heads is 25 psi. This is equivalent to 34.5 and 69 feet of head respectively. (The multiplier to convert from psi to feet of water pressure is 2.3).
- The flow rates for the Wobbler® and impact heads at these pressures is 8.8 gpm and 37 gpm respectively. With two Wobbler® heads the total flow would be 18 gpm in the winter.
- Using Table 3, the friction loss in 100 feet of 2-inch PVC pipe at a flow of 40 gpm (summer) or 18 gpm (winter) is 0.73 and 2.64 feet, respectively. With 300 feet of pipe used, the total friction loss in the pipe in winter is 3.33 and 7.92 feet. Since this friction loss is minimal, there is no need to use 3-in PVC pipe.
- If the irrigation heads are set at 6 feet, the elevation difference between the pump and the irrigation heads is 20 feet.
- The total pressure on the system is the sum of all the head pressure, friction loss and elevation difference for the zone. The winter zone total pressure is 57 feet (34.5 + (2.2 * 1.25) + 20). The summer zone total pressure is 97 feet (69 + (7.92 * 1.25) + 20).
- Using the pump chart (figure 9) and the winter requirements of 18 gpm and 57 feet of head, the correct pump would be pump "a". For the summer zone, the requirements are 37 gpm and 97 feet of head. Irrigation systems require the use of high very head effluent so it is best to consult with a pump supplier when selecting the proper pump.

5. Additional Information

- Two valves are required, one for each zone in the system to allow switching between the summer and winter zones. These valves are typically installed in the system where the main supply line splits to the two zones.

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