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Flush Gutters for Dairies

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Many factors influence the design and layout of flush gutters for dairies. Flushed areas must be sized to perform the desired function of the area. Flushed freestall alleys are typically 7 to 10 feet wide to accommodate cow traffic, and to allow vehicular traffic for scraping and servicing freestalls. Flushed alleys with freestalls on one side and a feed bunk on the other are typically 12 to 16 feet wide. Return alleys from milk parlors may be 3 to 6 feet wide. Flushed holding pens may be 20 feet wide for the conventional herringbone design, to as wide as 30 feet for the parallel parlor layout.

In general, narrow flush alleys are cheaper and easier to flush than wide alleys because less water is required and the water does not have to be released at such a high rate. However, alley widths are usually determined by the function of the alley rather than ease of flushing. Also, a system to flush a few long alleys can be implemented at less expense than a system to flush a greater number of short alleys, even though the two systems may be serving the same number of cows. So, in laying out the total system, the designer should try to maximize flush alley length, and minimize the number of individual flush alleys. Figure 1 is an example of an efficient flush layout.

Experience with flushing dairies has shown that a flush velocity of 5 feet/second, flowing 3 inches deep for a minimum of 10 seconds duration will usually provide acceptable cleaning. A gutter slope of 3 percent will provide these flow conditions with the least flush water volume and discharge rate requirements. In practice, some designers or operators may wish to flush new or existing facilities that have flatter or steeper slopes. In these situations, greater quantities of water and/or faster release rates may be required.

Gutter floors and slopes

Gutters/alleys flush best if they have a constant width or become narrower in the direction of flow. Flush volumes and discharge rates should always be determined on the basis of the widest portion of the gutter if the gutter does not have a constant width. Gutter floors should be level (no cross slope) perpendicular to the direction of flow. However, alley floors with free-stalls on both sides may benefit from a slight crown in the center (about 1 inch) so that water flows deeper along the curbs where manure and bedding congregate. A disadvantage is that a crown interferes with scraping when weather conditions preclude flushing. A slope of 3 percent is optimum

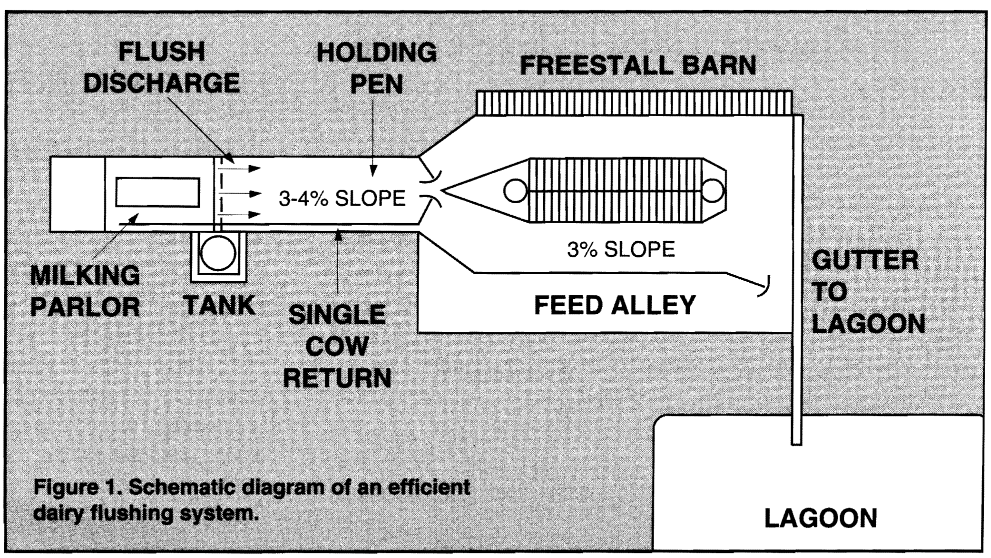

Figure 1. Schematic diagram of an efficient dairy flushing system.

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for flushing and does not cause difficulty for cows as they move about. Flatter slopes require deeper flow depths and larger flow rates (more total volume of water) to achieve the necessary velocity (about 5 feet/second) to clean the floor. Floors with little or no slope can be flushed by discharging large volumes of water at very high rates. However, this approach should only be used in flushing existing facilities, and any new design should be developed with the proper slopes. Any flushed area should have sufficient slope to drain the water away (no "flat spots") because pooled flush water which does not drain away or dry out can cause foot problems in cows.

Curbs

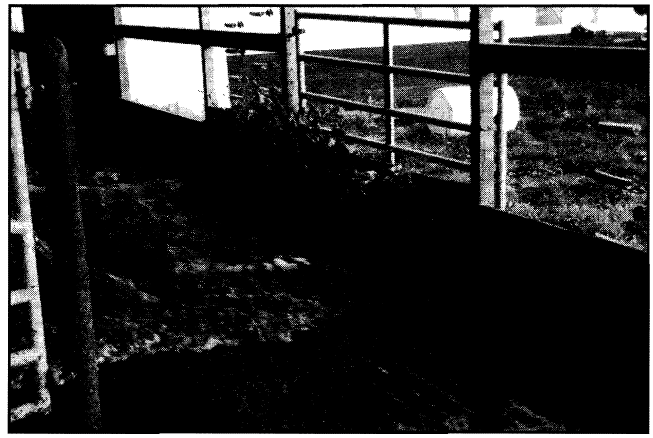
Curbs are an important component in flush systems because they maintain flow depth and direct the water flow as desired. In general, curbs should be at least 10 inches high to prevent water from splashing out of the gutter. Manure tends to collect against curbs along rows of freestalls, and this manure can be particularly difficult to remove by flushing. Some handwork may occasionally be required to remove manure collections along freestall curbs.

Flush systems should always be designed, if possible, so that flush water is discharged directly down the gutter in the direction of flow by the water release device. Also, the ideal gutter layout is straight over the entire length of the gutter with no changes in direction of water flow. In cases where this criteria cannot be met, higher curbs may be necessary to direct the water around a turn with no "splash-over." In general, required curb heights in these situations can be estimated from the following formula.

$$CH = FD + (V \times \sin\theta)^2 \times 0.186 + SF \qquad \textbf{(Eq. 1)}$$

CH = curb height, inches
FD = flow depth of water approaching curb, inches
V = velocity of water striking curb, feet per second
θ = angle at which water strikes curb, degrees
SF = safety factor, inches (3 to 6 inches typically)

It is important to estimate velocity as accurately as possible when using this formula. Velocities close to water-release devices may be significantly higher than design flow velocities for the flush gutter. For example, design flow velocity for a gutter may be 5 feet per second, but local velocities near the water-release device may be as high as 10 to 20 feet per second. Water striking curbs in these areas will splash higher than slower-moving water further down the gutter. Table 1 gives minimum curb heights calculated using the above formula. The builder may want to increase curb heights slightly over the calculated value for a safety factor, especially if flow velocities may be higher than estimated.



Curbs should be designed with sufficient height to prevent "splash-over"

Most curbs are cast-in-place concrete 6 to 10 inches wide with appropriate reinforcing in the concrete. Curbs may be coincident with building walls or fences with poles or posts built into the curb. When curbs must be built tall to eliminate "splash-over," the upper part of the curb may be made of other material, such as treated wood.

Table 1. Curb heights for various flow velocities and striking angles, calculated from equation (1).

	Angle at which water strikes curb, degrees			
	30	45	60	90
	Curb height, inches			
Flow velocity, ft/s				
5	8	9	11	12
10	12	16	21	26
15	17	28	38	49

Note: a flow depth of 3 inches and safety factor of 4 inches were used in the above calculations.

Receiving gutters

Receiving gutters are concrete channels which carry the flow from flush gutters to the lagoon at essentially the same rate at which the flush gutter is discharging the flush water. Little or no "surge storage" is provided in the receiving gutter. Figure 2 shows a typical receiving gutter configuration. Receiving gutters should be hydraulically designed to carry the anticipated flow with velocities above 3 feet/second to prevent settling of solids. Typical receiving gutters may be 1.5 to 3 feet wide by 1 to 2 feet deep with a bottom slope of 1 to 2 percent. The size of a receiving gutter (width and depth) depends upon the width of alley being flushed, flow depth and velocity of the water flowing into the receiving gutter, the flush volume, and the roughness and slope of the receiving gutter. Table 2 gives acceptable values

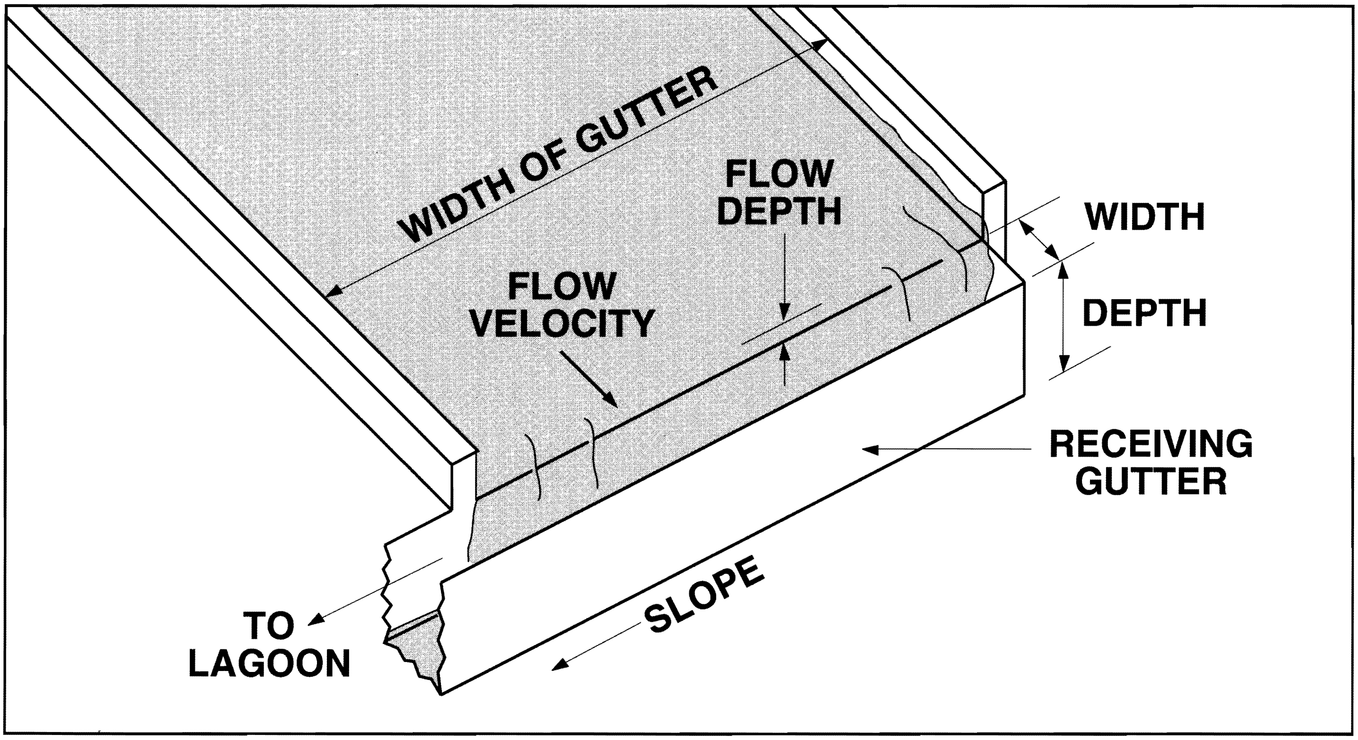


Figure 2. Typical receiving gutter configuration.

of width and depth for a receiving gutter serving a 12-foot wide flush alley.

Primary advantages of receiving gutters are their ability to maintain flow velocities which prevent settling, and to handle large amounts of solids without plugging or clogging. Receiving gutters are most applicable where flush water is carried only a short distance. Concrete channels covering long distances are expensive compared to sewer lines or pipes.

Often, it is necessary to have human, cattle or vehicular traffic cross a receiving gutter at the end of a flush alley. The use of expanded metal grates over the receiving gutter (or any type of grate) should be avoided, due to plugging problems. Where possible, receiving gutters should be located outside or "downstream" from fences which direct cattle, so they do not need to be covered. Where vehicles must cross receiving gutters for feeding or freestall maintenance, a temporary or permanently hinged "bridge cover" can be used such that the cover is raised or removed when not needed for crossing. Receiving gutters can also be constructed with raised, permanent lids so that flush water flows under the lid and into the channel. With a relatively small lid opening (4 to 6 inches) such a "step" is not prohibitive to cattle or vehicular traffic.

Table 2. Receiving gutter dimensions for a 12-foot wide flush alley. Flush volume is 1200 gallons, flow conditions in the flush alley are 3-inch depth, and 5 feet/second velocity, and channel roughness is 0.02.

	Slope of receiving gutter		
Receiving	1%	2%	3%
Gutter width, inches	Receiving gutter depth, inches		
12	39	30	25
18	23	18	15
24	17	13	12
30	14	11	9
36	12	9	8
42	10	8	7

***Note:** This table is for 12-foot wide flush alleys only.

Catch basins

Catch basins are an alternative to receiving gutters at the end of flush alleys. Catch basins provide some "surge" storage of the flush water as it is allowed to drain to the lagoon via a sewer line or pipe. The primary advantage of catch basins over receiving gutters is the lesser cost in laying a sewer pipe to the lagoon versus the concrete receiving gutter. Hence, catch basins are most often utilized when the distance from the flushed area to the lagoon is relatively great. The primary disadvantage of catch basins is that solids settling and deposition can take place even during the relatively short time water is stored before draining out through the sewer line. Additionally, typically sized sewer lines (8 to 12 inches) are not capable of carrying large "slug" loads of

Receiving gutters carry flush water to the lagoon at a high rate.

solids and fibrous material as are receiving gutters. Also, catch basins and their associated sewer lines to the lagoon, typically require more elevation difference between the end of the flush gutter and the water level in the lagoon to work properly than that required by a receiving gutter in a similar setting.

Catch basins are sized on the basis of the flush volume for the associated flush alley, and the capacity of the sewer line which drains the catch basin to the lagoon. The larger the conduit or sewer line to the lagoon, the smaller the required volume of the catch basin. Catch-basin volume is always smaller than the volume of water being flushed because some water drains from the basin immediately after its arrival. The design of catch basins should be based on a hydraulic "flood-routing" approach which takes into account the inflow rate from the gutter, and the outflow capability of the sewer line to the lagoon. Catch basins should be designed to drain completely in 2 to 3 minutes or less, otherwise solids settling in the

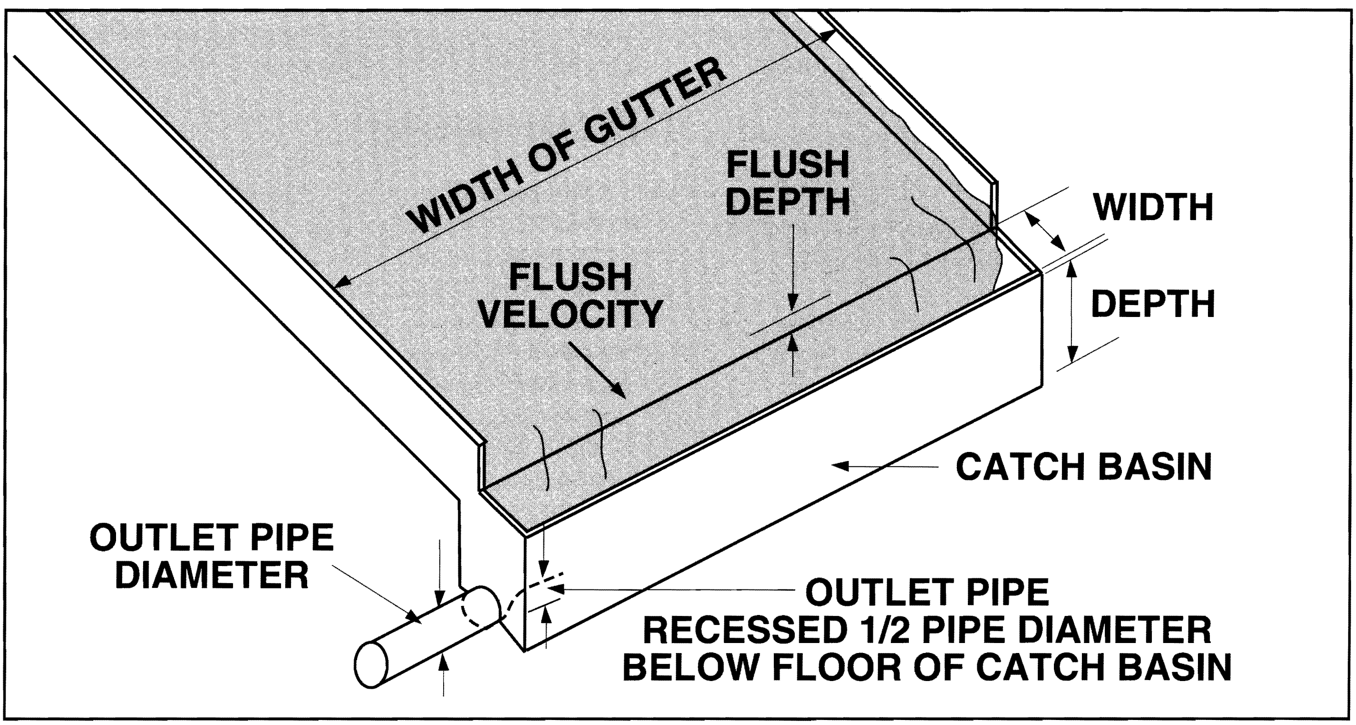


Figure 3. Typical catch basin configuration showing recessed discharge pipe with smooth transition into the pipe.

basin may be a problem. Some residual solids in corners and floor/wall intersections will likely be evident even with this short residence time.

Catch basins should be designed with as small an area in "plan view" as possible. This reduces the floor area available for solids settling. A limitation on depth is the available elevation difference between the end of the flush gutter and the lagoon water level. Catch basins are usually built with one horizontal dimension equal to the width of the associated flush gutter, and the other dimensions are adjusted to obtain the needed volume. Maximum discharge rate from a catch basin is obtained with a bottom outlet in the floor of the basin, followed by an elbow to direct the sewer line to the lagoon. However, this configuration also requires the greatest elevation difference between the lagoon and the flush gutter. Nearly similar discharge characteristics can be obtained by installing the exit pipe "horizontally" in the floor of the basin as shown in Figure 3. The pipe outlet should be at least one-half pipe diameter below the floor of the basin with a smooth transition into the pipe to minimize entrance losses and solids deposition. This configuration requires less elevation difference, and has discharge characteristics similar to the bottom outlet. Table 3 gives catch-basin dimensions for different size outlet pipes. Assumptions are a 12-foot wide alley flushed with 1200 gallons of water discharging into the basin at a velocity of 5 feet/second and a flow depth of 3 inches.

Since catch basins are usually wider than receiving gutters it is more difficult to "bridge" across them for vehicular or animal traffic. However, if adequate structural support is provided, they can be covered as noted above in the discussion of receiving gutters.

Table 3. Catch-basin dimensions for a 12-foot wide gutter flushed with 1200 gallons, and a gutter flow velocity of 5 feet/second and flow depth of 3 inches.

	Outlet pipe diameter, inches		
	8"	10"	12"
Catch basin width, inches	Catch basin depth, inches		
18	—	—	52
24	—	51	43
30	49	43	36
36	42	37	32
42	36	33	28
48	32	29	25
54	29	26	23
60	26	24	21
66	24	22	20
72	22	20	18

***Note:** This table is for 12-foot wide gutters only.

Flumes, sewer lines to lagoons

Concrete flumes (extensions of receiving gutters) may be used to transport water from the receiving gutter to the lagoon or a pipe conduit can be used in conjunction with a catch basin. Concrete flumes require less total "head" between the level of the end of the flushed gutters and the lagoon than the catch-basin/pipe route. Considerable forming expense may be involved in constructing long flumes. For long runs with sufficient slopes, pipe conduits may be most economical. Transport channels and conduits should be designed with capacity to handle the flow at sufficient velocity (3 feet/second or more) to prevent settling of solids (deposition). Flushing large "slugs" of water can allow flatter pipe slopes than "trickle flows" without causing deposition problems because the pipe runs fuller with a higher velocity.

Sewer pipes should enter the lagoon below the minimum lagoon pumpdown level, or above the full pool level. Otherwise, ice formation around the pipe may break or heave the pipe. Generally, entrance below the minimum pumpdown level is preferred. This approach prevents freezing at the end of the pipe as often occurs with "exposed" entrances. A disadvantage of the "underwater" entrance is the "standing" water in the pipe. If the pipe is carrying small trickle flows with high solids (as might be typical with a milk parlor drain), these solids can collect and float at the standing water level in the pipe, and eventually cause plugging. If the pipe is flushed with a large volume of water periodically, this problem is usually eliminated. Regardless of the entrance configuration, any sewer pipe carrying animal waste should have cleanouts every 50 feet.

Floor design

Floors need to be slip resistant for dairy cows to be confident while walking. If cows are confident of the floor surface, they tend to show signs of heat better and generally produce better. Grooved floors have continually been shown to be a good non-slip surface for cows. Grooves should be oriented so water can drain down the slope of a floor. The grooves provide a place for water to drain and helps keep cow's feet dryer.

New floors can be grooved with a "float" tool as the concrete is poured. A steel float equipped with one-half inch or three-fourths inch steel rods welded on 3- to 5-inch centers to the underside of the float has been used successfully in grooving new floors. The float is pulled over the freshly poured concrete to form grooves parallel to the slope of the alley. Water can then drain from the grooves. A light broom finish is applied to the "high" areas between the grooves.

If grooving is not acceptable, an alternative is to add aluminum oxide to the surface when the concrete

Grooved flush alleys reduce slippage and allow cows to move about with confidence.

is poured. Aluminum oxide grit (same material as used to make sandpaper) is spread evenly on the surface at the rate of one-fourth to one-half pound/square foot before the concrete sets. Coarse grit (4 to 6 mesh/inch) is recommended. This material may wear off leaving an unacceptably smooth surface after long periods of heavy use.

Existing floors, poured without grooves, sometimes become so smooth due to normal wear that slipping becomes a problem. Grooves can be cut into existing concrete with a concrete saw. As with freshly poured concrete, grooves should be cut one-half inch to three-fourths inch wide (depth equal to width), and 3 to 5 inches on centers. Grooves should be parallel to alley length for good drainage and to prevent "catching" of a scraper blade on the grooves should a scraper be used. Some floors have been roughened using a machine called a "scabber." This machine pounds the concrete surface with a series of hammers, creating individual indentations in the concrete. Roughening existing floors which have not been grooved is expensive.

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