Wastewater Treatment Strip Design

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Introduction

This guide will assist the designer in determining the size, dimensions, and application volumes and rates for wastewater treatment strips, in conformance with PA Tech Guide standard 635. The design process is based on controlled hydraulic loading of diluted wastewater onto a vegetated soil surface, with nutrient loading limited to crop utilization. The wastewater is treated and assimilated by the plants and soil within the filter area. The intent is to treat the wastewater with filtering, deposition, plant uptake, evapotranspiration, solar exposure, adsorption to soil particles, and biological degradation. To accomplish this, the wastewater must be retained within the wastewater treatment strip (WTS). The hydraulic loading is designed to avoid surface discharge and leaching below the root zone beneath the treatment strip.

The hydraulic loading criteria come from studies that showed this to be the critical factor in the success of wastewater treatment strips. In simple terms, it means that a WTS will only work if you don't overload it. To prevent extreme nutrient build up or releases, and to avoid harming the vegetation, the wastewater must be relatively dilute. Wastewater treatment strips are not meant for undiluted or prolonged flows of manure, manure liquids, and silage leachate. These types of waste can only be accommodated if they are diluted with clean water or other wastewater, and if an effective solids settling device is used in front of the WTS. The designer should consider increasing dilution and/or providing more than one filter area to provide extended rest periods for nutrient uptake and removal when more concentrated wastewaters are involved.

Hydraulic loading criteria vary with the source (type) of wastewater and the application method. Wastewater from runoff sources, such as barnyards, will vary with rainfall. A WTS must be able to handle the full range of runoff events, so that the runoff from a small storm is reasonably distributed on the WTS, and the large volume produced by the 25-year, 24-hour storm can be contained within the root zone of the WTS. A pressure dosed system is required in most cases, unless a very specific set of conditions (see PA635) can be met. In that case, the runoff from a relatively small area can be released through a perforated curb onto a WTS that has limited infiltration capacity, and therefore will disperse the runoff down the slope.

Changing weather, including freezing weather conditions, can actually assist with improved distribution of wastewater throughout the WTS.

If added protection is desired, consideration may be given to providing supplemental pervious infiltration zone for wastewater runoff down slope of the WTS. Supplemental pervious infiltration zones do not have to be dedicated to the WTS system, but may be planted with perennial or annual crops.

Frequent wastewater flows from process sources such as milking centers are handled in dosed treatment strips with pipe manifolds or sprinkler heads. The relatively small volumes can be predicted and controlled, so there is less concern about overloading the WTS. Supplemental pervious infiltration zones are recommended but not required for this type of system.

Application Depth

Maximum liquid depth per application is dependent on the type and depth of soil within the root zone of the vegetation on the WTS. Deep well drained soils will accept and hold more water than shallow poorly drained soils. The "soil group" and maximum application for the WTS can be determined from Table 1. Maximum application is the allowable dose volume over the entire WTS, expressed as gallons per 1000 ft^2. This limit applies to all types of WTS.

On a WTS with a sprinkler irrigation system, the application depth will be less than required in Table 1.

Table 1: Soil Groups and Maximum Applications

	Soil Depth			
	Mottling Depth	Deep > 40	Mod. Deep[2] 20" – 40	Shallow[2] < 20"
Soil Drainage Class	**Soil Group/Max Application[1]**			
Well drained	> 36"	1/313	2/250	3/188
Moderately Well Drained	18" - 36"	2/250	3/188	4/125
Somewhat Poorly Drained	8" - 18"	4/125	5/63	5/63
Poorly & Very Poorly Drained	< 8"	4/125	5/63	5/63

[1] Units for Maximum Application are gallons per 1000 ft^2 of WTS.
[2] The useable soil depth in the WTS should be verified on site. If there is less than 24 inches of useable soil depth, additional useable depth will have to be provided, or the site is not acceptable. Useable soil depth can be increased by adding soil on the surface, or by providing drainage up slope of the WTS.

Application Rate

On a sloped WTS with loading at the top of the slope, the application rate (inches/hour) must be designed to exceed the soil infiltration rate, so that water flows down the slope and does not percolate below the root zone at the top of the slope. Soil intake families represent soils with similar surface infiltration capacities. The numeric values of the intake families correspond to the intake (surface infiltration in inches/hour) of the soil after a period of prolonged application. The values in Table 2 were derived from Tables 2-6 and 2-9 in NEH Part 652, Irrigation, to represent the shallow sheet flow condition expected on wastewater treatment strips, which may have a history or be subjected to enough traffic that some compaction effects are present.

Table 2 only shows intake families that are expected to occur in Pennsylvania for a combination of surface soil texture and hydrologic soil group (HSG), and within the acceptable range of 0.3 and 1.0 for a WTS loaded at the top of the slope. Intake families lower than 0.3 would result in poor infiltration and exceptionally long treatment strip slopes. Intake families greater than 1.0 would require an excessively high dosing rate and design flow depths beyond sheet flow to exceed the infiltration rate and prevent deep percolation below the root zone.

Table 2. Soil Intake Families Based on Surface Soil Texture and Hydrologic Soil Group.

Surface Soil Texture	-----Hydrologic Soil Group -------			
	A	B	C	D
SC, SICL	a	**0.5**	**0.3**	b
CL, SCL	a	**0.6**	**0.4**	b
SIL, L	**0.9**	**0.7**	**0.5**	b
VFSL, FSL	c	**1.0**	**0.7**	**0.3**
SL, LVFS	c	c	**0.9**	**0.4**
LFS, LS	c	c	c	a

These intake families reflect surface soil texture and HSG only. Other conditions such as high water table or excessive compaction from prior use may make the site unsuitable for a treatment strip.

a – This combination of soil texture and HSG are not expected to occur in PA.

b – The intake family for this combination of soil texture & HSG will be too low to provide an acceptable treatment strip.

c – The intake family for this combination of soil texture & HSG will be too high to provide an acceptable treatment strip.

Factors other than surface soil texture and HSG such as high water table or excessive compaction from prior use, can affect the infiltration rate so that the assigned intake family is inappropriate.

If there is concern that the assigned intake family from Table 2 may not be appropriate for the site specific conditions, a two- cycle infiltration test should be conducted to arrive at a reasonable value for design. Such a test would be to determine the infiltration rate in inches/hour (within the range of 0.3 and 1.0).

For manifold-dosed wastewater treatment strips, the intake rate must fall within the range of 0.3 to 1.0. If a non-dosed (perforated curb) system is to be used, it must be on a soil with an intake family between 0.3 to 0.5 (inclusive) with a usable depth of at least 40 inches, or be on a soil with an intake family between 0.3 to 1.0 (inclusive) and underlain by a restrictive pan layer. All other condition in this Design Guide and Standard PA635 must also be met.

The application rate from an irrigation system shall be far less than the intake family criteria in Table 2.

Dimensions of Sloped Wastewater Treatment Strips

The hydraulic loading rate (gal/min/ft of width) is designed to establish sheet flow (≤0.5" deep) down the slope (Ss) of the WTS. Wastewater treatment strip dimensions are determined using hydraulic calculations to provide 15 minutes of retention time within the slope flow length (Ls), at a maximum constant flow depth of 0.5" throughout the length. WTS dimensions for these flow conditions are found in Table 4. (Due to infiltration, this is a conservative approach. The flow depth and velocity will actually decrease as the water flows down the slope, as has been verified using the SRFR program.)

The following equations were used to develop the data in Table 4 and meet the criteria in PA635 for settling volume and peak flow control. The Manning's n-value of 0.24 comes from the overland flow procedure used in TR-55, and is only applicable to depths up to 0.5".

a). Velocity on the WTS slope:
(Manning's equation) $v_s = (1.486/n)*H_r^{0.667} * Ss^{0.5}$
$v_s = (1.486/0.24) * ((0.0417/1)^{0.667}) * S_s^{0.5} = 0.745\ S_s^{0.5}$ ft/sec

b). Unit width discharge with 0.5" flow depth
q_s = flow depth x unit width x velocity
q_s = 0.5" x 12 "/' x 1' x v_s
$q_s = 0.042' * 1' * (0.745\ S_s^{0.5}) = 0.031\ S_s^{0.5}$ cfs/ft

c). Minimum WTS slope length (L_s):
L= Velocity x Time
L_s = 15 min (60 sec/min) (0.745 $S_s^{0.5}$ ft/sec) = 670.5 $S_s^{0.5}$ ft

d). Peak flow (Q_l) from 2 year, 5 min rain on a paved lot:
Q = area x precip. / time (Considering the small rainfall amount(0.4"), use this all runoff, no routing method. TR-55, using 2-yr 24-hr rainfall and Q=AP/T using 2-yr 5-min are equivalent.
Q_l = (A_l * 0.4") / (12"/ft * 5 min * 60 sec/min) = A_l / 9000 cfs

e). Settling Basin Storage:
$V_s = Q_l * 15 \text{ min} * 60 \text{ sec/min} = (A_l / 9000) * 15 * 60 = 0.1\ A_l\ ft^3$

(A separate analysis, based on TR-55 routings, verified that this settling basin volume provides a storage routing volume to reduce the 25-year, 5-minute peak flow to the 2-year, 5-min peak flow required in PA635)

f). Minimum WTS width (W_s measured across the slope):
$W_s = Q_l / q_s = (A_l / 9000) / (0.031\ S_s^{0.5}) = A_l / (279\ S_s^{0.5})$ ft

g): WTS area (A_s):
$A_s = L_s * W_s = (670.5\ S_s^{0.5}) * (A_l / (279\ S_s^{0.5})) = 2.40\ A_l\ ft^2$

(This is the minimum WTS area with design depth = 0.5". It can be reduced by restricting the outflow and using a lower design depth.)

Table 4 is split into two sections that are read separately. In the top portion of the table, the slope of the WTS (%), the minimum (S_l) slope length (ft) to provide 15 minute flow time, and the maximum dose rate (gal/min/ft) per foot of WTS width are related to each other. Any one of these values can be found if the other two are known.

The bottom portion of Table 4 shows the relationship among the WTS slope (S_s in %) along the left side, a delivery rate (gpm) across the top, and a minimum required WTS width (ft) within the body of the table. Again, any one of these values can be found based on the other two. The values used in the lower portion must agree, however, with those from the top portion of the table (i.e. the same slope, and the product of the maximum dose rate (gal/min/ft) times the minimum width (W_s ft) must equal the delivery rate gpm). Minimum widths can be interpolated from the table for delivery rates between those listed in the table, or can be calculated by dividing a desired delivery rate by the maximum dose rate (gal/min/ft of width).

Dosing Methods

The best wastewater treatment strip performance is achieved by intermittently dosing the WTS with a pump, siphon, or flout every three or more days. This is essential for the success of a WTS for process wastewater such as milking center waste, and is encouraged for all types of WTS. For a milking center WTS, the pump, siphon, or flout should be selected to empty the dosing tank in 5 to 20 minutes. This will produce a dose rate that exceeds the soil infiltration rate, and will force surface flow down the filter slope (L_s). A delivery rate can be initially estimated by multiplying the daily waste water volume by 3 days, and dividing by 10(target 10 minutes for discharge). A minimum of 100 gpm is recommended.

A pump's delivery rate (gpm) is taken from a pump rating curve or table provided by the manufacturer. It will be a pumping capacity for the expected total dynamic head (elevation head loss plus friction losses) on the planned installation. For an automatic siphon or flout, the manufacturer's published average discharge is used as the delivery rate in the table. For gravity flow systems, the delivery rate is a routed discharge where storage and a flow restricting orifice are used to limit the flow to the 2-year peak flow from the barnyard, or a lower desired delivery rate.

The design flow depth for sheet flow through the WTS can be less than 0.5" to meet site constraints such as a short available slope length. This can be done using Tables 5 through 8 or Figure 1. The design flow depth must be less than or equal to 0.5", regardless of the maximum application found in Table 1. If there are no site constraints on the dimensions of the WTS, the design flow depth should be kept at 0.5" to maximize surface flow down the slope.

Tables 5 through 8 are read in the same manner as Table 4. For a given slope and pump rate, Tables 5 through 8 will give shorter WTS lengths (L_s), greater widths(W_s), and larger WTS areas to provide flexibility in meeting site conditions.

A limitation on the use of Tables 7 and 8 (design depths $\leq$ 0.2") is that their dosing rates (gal/min/ft) will only exceed the infiltration rates of tighter soils. Therefore, a design depth of 0.1" should only be used on a soil in intake family 0.3 as shown in Table 2. A design depth of 0.2" should only be used on soils with an intake family between 0.3 or 0.5 (inclusive).

Figure 1 is an alternative method to Tables 4 through 8, and yields the same results. Since the values for any three of: the slope (%), WTS length (ft), design flow depth (inches), and the maximum dose rate (gal/min/ft) are known, the fourth value can be found. The two charts in Figure 1 are related to each other by the slope and the design flow depth, both of which must be kept constant when reading from one chart to the other. An added step in using Figure 1 is to divide the pump rate (gpm, found in manufacturer's rating curve or table) by the dose rate (gal/min/ft) to find the minimum filter width (W_s). As with the tables, a design depth of 0.1" should only be used with soil intake family 0.3, and a design depth of 0.2" should only be used with soils with an intake family between 0.3 to 0.5 (inclusive).

As a check on the WTS dimensions, the dose volume must be compared to the maximum application. To do this, divide the total dose volume (gal) by the WTS area (ft^2), and multiply by 1000. This value should be no higher than the maximum application rate found in Table 1 for the soil conditions on the site.

Figure 2 takes another approach to find the WTS dimensions. Using the total dose volume (gal) and the Soil Group from Table 1, the required area (ft^2) of the WTS to meet the maximum application rate can be found on the left chart in Figure 2. Reading across to the right chart, a width and flow length can be determined that meet the minimum area requirements. These dimensions do not automatically meet the minimum width or length requirements for a dose rate or 15-minute flow time. These dimensions must then be matched with a delivery rate (gal/min) that will not exceed the maximum dose rate (gal/min/ft). This can be done in Figure 1, using the length, the slope, and the design depth to find the maximum dose rate.

Figure 2 can also be used to check that the maximum application rate (gallons/1000 ft^2) from Table 1 has not been exceeded. Using the total dose volume (gal) and the Soil Group from Table 1, the required area of the WTS can be found at the left side of Figure 2. This area must be $\leq$ the product of the width and flow length determined from Tables 4 through 8, or Figure 1.

A final check of the WTS dimensions and dose volume should consider at the weekly hydraulic load on the WTS. The total allowable weekly depth, including rainfall, is two inches. The highest weekly average rainfall (highest monthly rainfall / 4) is subtracted from 2 inches. The result is the limiting design value (inches/week), which must not exceed the weekly dose volume.

For a WTS that treats milkhouse waste, the limiting value (inches/week) is then multiplied by 3 days per dose, and divided by 7 days per week. This limiting value (in/dose) is then compared to the dose volume (gal/dose) multiplied by 12 in/ft, divided by the area of the WTS (ft^2), and divided by 7.48 gal/ft^3. The resulting in/dose must be $\leq$ the limiting value.

For a WTS that treats barnyard runoff, the limiting value (in/week) is compared to the barnyard runoff volume produced by the highest weekly average rainfall. The weekly rainfall is multiplied by the corresponding monthly runoff factor (taken from AWMFH Appendix 10C, or the PA Nutrient Management Technical Manual Appendix 6), then multiplied by the area of the barnyard and divided by the area of the WTS. The resulting value (in) must be $\leq$ the limiting value.

For a WTS handling a combination of milkhouse waste and barnyard runoff, the total weekly wastewater volume must be less than the limiting value (in/week).

a) Perforated Curbs
A perforated curb (non-pressure dosed) wastewater treatment strip can be used for small paved barnyards that meet all the conditions listed in Standard PA635. The combined effect of the curb height and perforations (notches) will provide the required settling volume and routing effect to reduce the 25-year peak flow from the barnyard down to the 2-year peak flow released through the curb. The recommended vertical notch width is 1.5", which is assumed to clog 50% with trapped solids. Weir flow with a coefficient of 2.8 should be used to calculate discharge through the notches. Provide notches spaced generally 10 feet apart along the curb, or a minimum of 3 notches, to assure outlet capacity in case of plugging. The design depth will be determined from the application rate (gpm/ft) and the WTS slope, so it will be easier to use Figure 1 rather than Tables 4 through 8 for sizing the WTS. As with any WTS, the design depth must be kept to 0.5" or less to assure sheet flow conditions.

b) Gated Pipe/Manifold Distribution Systems
Table 9 provides orifice discharge capacities over the typical range needed to handle the 2-year peak flow from a barnyard, and the small (< 1") diameter orifice sizes used in a perforated distribution pipe. The table can be used to select the orifice size based on the desired discharge and the head at the maximum depth over the orifice. The table can also be used to determine the discharge through a trial orifice size, with the design head over the orifice. Whenever possible, the design head should be 3 feet or more at the distribution pipe.

Table 10 provides discharge capacities of slotted riser pipes over the typical range needed to handle the 2-year peak flow from a barnyard. The required discharge and the maximum head over the base of the riser are used to find the open slot area needed per foot of riser pipe.

c) Sprinkler Irrigation Systems
A sprinkler irrigation system can be used to dose the wastewater treatment strip. This may be necessary if the WTS has little or no slope, an irregular surface, dimensions that don't fit the requirements for a sloped WTS, or soils that can't handle the application depths or rates needed to make a sloped WTS function properly. Sprinkler irrigation is the recommended application method when the WTS slope is less than 2%, but it can be used on steeper slopes. The main distinction of sprinkler irrigation is that it is designed to avoid surface flow of applied wastewater. This is done by applying at a rate less than the soil infiltration rate (inches/hour), and applying less liquid than the soil in the root zone can hold.

The sprinkler system is designed to meet the maximum application criteria in Table 1, the 2 inches/week maximum total load, not to exceed 50% of the available water capacity of the soil in the root zone, and the application rate (inches/hour) limited not to exceed the intake family rate in Table 2. Available water capacity (AWC) is found in soil survey data, expressed as inches of water per inch of soil depth for each horizon. At full AWC, the soil profile is full and cannot accept more water. At 50% AWC, the plants may begin to show signs of stress.

Proper irrigation design will consider sprinkler overlap to provide uniform water distribution.

Nutrient Load Design

The annual nutrient load coming to the treatment strip must not exceed the annual nutrient requirement for the crop. The nitrogen content of the wastewater reaching the treatment strip will depend on the source(s) of the wastewater.

a) Wastewater from Runoff Sources

Runoff nutrient load from animal concentration areas (ACAs) can be determined using Figure 3 or 4, depending on the type of surface in the ACA. The figures indicate the amount of N released annually, in pounds per acre, from a settling basin to a wastewater treatment strip. The figures are based on the assumption that runoff will contain 150 ppm of N and 50% of the N will be trapped in the sediment basin (Livestock and Poultry Environmental Stewardship Training, lesson 22, p. 15).

To use the figures, start with the known annual rainfall (inches) and the % annual runoff from AWMFH Appendix 10c, and read an annual N delivery from a sediment basin. The area of the treatment strip must be large enough to utilize the annual nutrient load delivered to it. If the grass is to be harvested by grazing, additional nutrient input must be accounted for in the design.

For example, with annual rainfall of 40" and 55% annual runoff from a paved surface, the annual N delivery is 375 lb/acre of ACA surface per year. If a grass on average soil with a 4 ton/acre yield will need 200 lb N per year (Penn State Agronomy Guide), then each acre of ACA will need 375 lbN/ac/200 lbN/ac = 1.9 acres of treatment strip to utilize the nitrogen coming from the ACA. (Note that this is less than what will be needed in most cases to limit the total weekly hydraulic loading to 2 inches/week.) If this treatment strip will be mechanically harvested, there is adequate plant uptake for the amount of N applied.

The average N:P ratio from ACA runoff is about 4:1 (PA Holstein Assoc., WRIR 03-4036, and "Long Term Impacts of Vegetative Filter Strips), so phosphorus delivery to a treatment strip can be estimated as 25% of the nitrogen load determined using Figure 3 or 4.

Continuing with the example above, the P load will be 375 x 0.25 = 94 lb/year/acre of ACA. So the 1.9 acres determined for N would receive 94/1.9 = 49 lb P/acre/year which should be acceptable in most cases. The allowable P application rate should be based on a soil test for design.

Site specific wastewater sampling data should be used whenever it is available for ACAs, and may be the only reliable data for other runoff sources such as bunk silos or compost pads.

b) Milking Center Wastewater

The nutrient content of milking center wastewater varies with the amount of manure that is included in the effluent. Starting with the values from AWMFH Table 4-6, and accounting for 70% removal due to extended (3-day) settling in a standard, baffled septic tank the following values (Table 3) should be used for design unless site-specific data are available.

Table 3. Dairy Waste – Milking Center

Nutrient	Pipeline & Milkhouse	Milkhouse &Parlor	Milkhouse & Parlor & Holding Area with Solids Scraped	Milkhouse & Parlor & Holding Area with Solids Flushed
		(lb/1000 gallons)		
Nitrogen	0.22	0.50	0.30	2.25
Phosphorus	0.17	0.25	0.07	0.25

Wastewater volume will be the same daily volume used in hydraulic design.

Design Examples

a) Sloped WTS for a Barnyard

The runoff from a concrete barnyard 50' long (flow length) x 60' wide (across the slope) on a 3% slope is to be directed to a WTS on a 5% slope. The soil in the filter is Hublersburg silt loam, which is deep, well drained and in hydrologic soil group B.

From Table 2, find that for a silt loam & HSG "B", the soil is in intake family 0.7, which is within the desired range of 0.3 to 1.0 for a manifold-dosed WTS.

Using a 0.5" design depth, from Table 4 find minimum WTS Length = 150' and a dosing rate of 3.12 gal/min/ft:

2-year, 5-min Q_i = (50' * 60' * 0.4")/(12"/ft * 5 min * 60 sec/min) cfs
= 0.33 cfs
= 0.33 cfs * 448.8 gpm/cfs = 148 gal/min

From the lower section of Table 4, with 5% slope interpolate between 140 and 160 gpm to get w = 48'
This could also be found using: $W_s = A_i / (279\ S_s^{0.5})$ = (50' * 60') / (279 * $0.05^{0.5}$) = 48'

or since $A_s = L_s * W_s$ and $A_s = 2.40\ A_i$, so W_s = (2.4 * (50' * 60') / 150) = 48'

These formulas are based on using the full 0.5" of depth for design. If less than 0.5" of depth is desired, then use Tables 4-8 or Figures 1 and 2.

To keep within the 2 inches/week limit, check using the highest monthly rainfall, this is 4.9 inches in June. Then the highest weekly rainfall is (4.9 * 7)/30 = 1.14" and 2 – 1.14 = 0.86" on the WTS can come from the barnyard. So the allowable runoff from the barnyard is 0.86" * (150 * 48') / (50' * 60') = 2.06" > weekly rainfall

Required settling volume: V_s = 0.33 cfs * 15 min * 60 sec/min + 50' x 60' x 0.5"/12 in/ft = 300 + 125ft^3
V_s = 425 ft^3

Curb height: H_c = (2 * 425 ft^3 * 0.03ft/ft / 60')$^{0.5}$ = 0.65' = 7.8"

"Length" of settling basin back from curb: L_s = 0.65' / 0.03 ft/ft = 21.7'

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Using Figure 4, Nitrogen load, with 42" annual rainfall and 55% runoff, will be: N= 390 lb/ac, or 390 lb/ac * (50' * 60' / 43560 ft^2/ac) = 27 lb from the barnyard. ~~Since the WTS will be 2.4 times the size of the barnyard, the nitrogen load on the WTS will be 27/2.4 = 11.25 lb. or~~ (~~11.25#~~ 27# / (150 * 48)) * 43560 = 163 ~~68~~ lb/ac.
This is enough to support: 68 lb N/ac / 50 lb N/ac/ton = 1.36 ton yield which is far less than actual

Phosphorus load: P = 68 lb/ac / 4 = 17 lb P/ac which is far less than crop need.

Final design of the manifold piping can now be completed.

b) Sloped WTS for a Barnyard with a Perforated Curb

The barnyard is sloped 2% on a 50' length and is 200' wide across the slope. A perforated curb will deliver runoff to a filter on a 12% slope. The soil in the filter is Mardin channery silt loam, with a restrictive pan at 15 inches. It is deep, moderately well drained, and in hydrologic soil group "C".

From Table 2, this soil is in intake family 0.5, which is within the allowable range of 0.3 to 1.0 for a non-dosed WTS onto a soil with a restrictive pan layer.

The 2 year, 5 min Q = 50' * 200' / 9000 = 1.11 cfs * 448.8 gpm/cfs = 498 gpm

Settling volume V_s = 1.11 cfs * 15 min * 60 sec/min = 1000 ft^3

Curb height = (2 * 1000 ft^3 * 0.02 ft/ft / 200')$^{0.5}$ = 0.45' * 12 in/ft = 5.4"

Length of settling basin = 0.45 ft / 0.02 ft/ft= 22.5 ft

Flow through each notch will be q = 2.8 * (0.75"/ 12 in/ft) * 0.45 ft $^{1.5}$ = 0.053 cfs * 448.8 gpm/cfs = 23.8gpm

(Actual notch constructed width should be 1.5" to allow for 50% blockage.)

Spacing the notches 10' apart, 23.8 gpm / 10' = 2.37 gpm/ft of width

Using Figure 1, design depth = 0.32" and WTS slope length = 170 ft.

WTS area = 200' * 170' = 34000 ft^2 / (200' * 50') = 3.4 times the barnyard area

Check for 2"/week maximum load, with a 4.1" maximum monthly rainfall in July.
Max. weekly rainfall is (4.1"/month * 7 day/wk) / 31 day/month = 0.93"/wk, so 2" – 0.93" = 1.07" more can be applied from the barnyard. 1.07" * 3.4 = 3.64" can come from the barnyard each week.

Nitrogen load with 50% runoff from 38 inch annual rainfall will be 325 lb N/ac. If the expected yield is 3 tons, it can use 3 ton * 50 lb N/ac/ton yield = 150 lb N/ac.
325 lb N/ac * (50' * 200' / 43560 ft^2/ac) = 75 lb N available
150 lb N/ac * (180' * 200' / 43560 ft^2/ac) = 124 lb N can be used by crop

Phosphorus load will be ¼ that of nitrogen, or 19 lb, compared to (45 lb/ac * 180' * 200' / 43560 ft^2/ac) = 37 lb the crop can use.

c) Irrigation-dosed WTS
A milkhouse/parlor has a daily waste volume of 1500 gallons. The 3-day dose will be 4500 gallons. Highest monthly rainfall is 4.61" in June. Weekly max. is 4.61"/month * 7 day/wk / 30 day/month =1.08"/wk
Allowable waste load will be 2.0" – 1.08" = 0.92"/week
For 3 day intervals, this becomes 0.92"/wk * 3 day/dose / 7 day/wk = 0.39"/dose

The WTS soil is a fine sandy loam in hydrologic soil group "B", moderately deep & well drained, so from Table 1 it is in group 2 and can take 250 gal/1000 ft^2. From Table 2, it is in intake family 1.0. Soil survey physical properties show that the top 24 inches, which contains most of the grass roots, has an available water capacity (AWC) of 3.3".

The planned dose of 0.39"/dose is less than the allowable 50% x (AWC) = 0.5 * 3.3" = 1.65"

Min WTS area = (4500 gal / 7.48 gal/ft^3) / (0.39"/ 12"/') = 18,511 ft^2 / 43560 ft^2/ac= 0.42 ac needed
This is (4500 gal / 18,511 ft^2) * 1000 = 243 gal/1000 ft^2 so it is OK.. Now check WTS size against N and P uptake.

Check Nitrogen Loading:
Nitrogen load will be (0.5 lb N/1000 gallons) * 1,500 gal/day * 365 days = 274 lb N/year
274 lb/N/yr / 0.47 ac = 583 lb N/ac/yr.

There will be significant N loss due to spray application, so use a 40% availability factor; 583 lb N/ac/yr * 0.4 = 233 lb N/year. A hay yield of nearly 6 tons/acre will be needed.. That is achievable on this good soil with regular irrigation.

However, also need to Check Phosphorus Loading:
If expected yield is 6 tons of mixed hay per year with an average P uptake of 15#P/ac/ton = 90#P/ac/yr

From Table #3: 0.25 #P/1,000 gal x 1,500 gal / day x 365 days /yr = 137#P/ yr

137 # P produced per year / 90 # P used per acre/year = 1.52 acre needed: **use 1.5** acre (first assumption of 0.42 acres does not work)

A choice for a typical installation of spray guns could be 80' on center. The selected spray diameter should overlap the other spray diameters by 60-80% to get a uniform application. Thus, the effective area per gun is only 80'x 80'= 6400 sq ft.

Required guns for 1.5 acres is (1.5 acre * 43560sq ft/ac)/6400 sq ft / gun =10.2 guns. Use 10 guns.

Try a ¼" nozzle operating at 50 psi. Typical gun application rates are 12-15 gpm for a 100 to 120' diameter spray area. Using 13 gpm per gun the discharge time would be 4500 gal/ (10guns*13 gpm/gun) = 35 min at a 130 gpm flow rate. The average depth of application would only be 0.11" per application.

Another option would be to operate the system in 3 sections, and switch every 4 months. Then the average application would be 4500 gal over 0.5 acres or 0.38" per application, with 4500gal/ (3 guns*13 gpm/gun) = 39 gpm for 115 minutes.

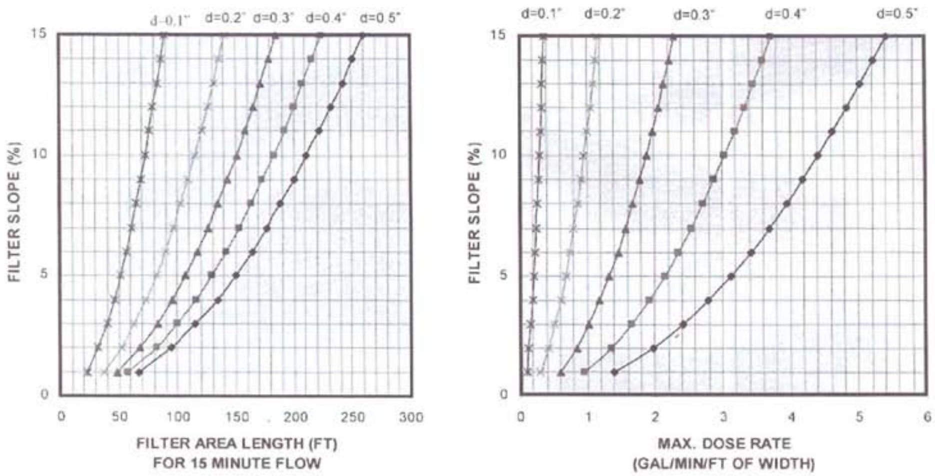
Waste Water Treatment Strip

Figure 1: Filter Area Dimensions for Design Flow Depths from 0.1 to 0.5 Inches

Design Guide # PA-5

Waste Water Treatment Strip

Figure 1: Filter Area Dimensions for Design Flow Depths from 0.1 to 0.5 Inches



AWMFH, PA-14, 3/2007 10.66.11

Figure 2: Minimum Filter Area Requirements
(to meet maximum application rate limitations for soil groups)

Design Guide # PA-5

Figure 2: Minimum Filter Area Requirements
(to meet maximum application rate limitations for soil groups)

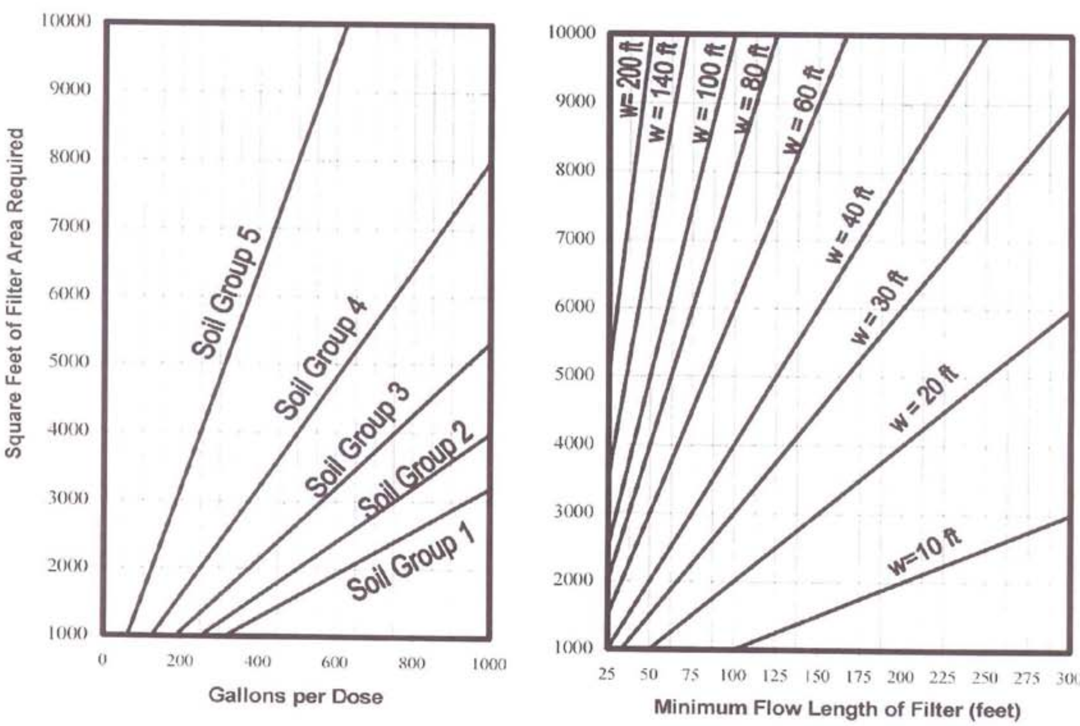


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Table 4: Filter Area Dimensions for Design Flow Depth of 0.5 Inches

Design Guide # PA-5

Table 4: Filter Area Dimensions for Design Flow Depth of 0.5 Inches

Design Flow Depth (d=0.5")	Filter Slope %														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minimum Filter Length	67	95	115	135	150	164	177	188	200	211	222	232	242	251	260
gal/min/ ft. width	1.4	1.97	2.42	2.79	3.12	3.42	3.69	3.95	4.19	4.41	4.63	4.83	5.03	5.22	5.41

	Min. Filter Width @ Delivery Rate (gpm)														
FILTER SLOPE (%)	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
1		15	22	29	36	43	50	58	65	72	86	100	115	129	143
2		11	16	21	26	31	36	41	46	51	61	72	82	92	102
3		9	13	17	21	25	29	34	38	42	50	58	67	75	83
4			11	15	18	22	26	29	33	36	44	51	58	65	72
5			10	13	17	20	23	26	29	33	39	45	52	58	65
6			9	12	15	18	21	24	27	30	36	41	47	53	59
7			9	11	14	17	19	22	25	28	33	38	44	49	55
8				11	13	16	18	21	23	26	31	36	41	46	51
9				10	12	15	17	20	22	24	29	34	39	43	48
10				10	12	14	16	19	21	23	28	32	37	41	46
11				9	11	13	16	18	20	22	26	31	35	39	44
12				9	11	13	15	17	19	21	25	29	34	38	42
13					10	12	14	16	18	20	24	28	32	36	40
14					10	12	14	16	18	20	23	27	31	35	39
15					10	12	13	15	17	19	23	26	30	34	37

Table 5: Filter Area Dimensions for Design Flow Depth of 0.4 Inches

Design Guide # PA-5

Table 5: Filter Area Dimensions for Design Flow Depth of 0.4 Inches

Design Flow Depth (d=0.4")															
	Filter Slope %														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minimum Filter Length	58	82	100	116	129	142	153	163	173	183	192	200	208	216	224
gal/min/ ft. width	0.96	1.36	1.66	1.92	2.15	2.35	2.54	2.72	2.88	3.04	3.19	3.33	3.46	3.6	3.72

		Min. Filter Width @ Delivery Rate (gpm)														
		10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
	1	11	21	32	42	53	63	73	84	94	105	125	146	167	188	209
F	2		15	23	30	37	45	52	59	67	74	89	103	118	133	148
I	3		13	19	25	31	37	43	49	55	61	73	85	97	109	121
	4		11	16	21	27	32	37	42	47	53	63	73	84	94	105
	5			14	19	24	28	33	38	42	47	56	66	75	84	94
E	6			13	18	22	26	30	35	39	43	52	60	69	77	86
R	7			12	16	20	24	28	32	36	40	48	56	63	71	79
	8			12	15	19	23	26	30	34	37	45	52	59	67	74
S	9			11	14	18	21	25	28	32	35	42	49	56	63	70
L	10			10	14	17	20	24	27	30	33	40	47	53	60	66
O	11			10	13	16	19	22	26	29	32	38	44	51	57	63
P	12			10	13	16	19	22	25	28	31	37	43	49	55	61
E	13			9	12	15	18	21	24	27	29	35	41	47	53	58
	14			9	12	14	17	20	23	25	28	34	39	45	50	56
(%)	15			9	11	14	17	19	22	25	27	33	38	44	49	54

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Table 6: Filter Area Dimensions for Design Flow Depth of 0.3 Inches

Design Guide # PA-5

Table 6: Filter Area Dimensions for Design Flow Depth of 0.3 Inches

Design Flow Depth (d=0.3")

	Filter Slope (%)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minimum Filter Length	48	68	83	96	107	117	126	135	143	151	158	165	172	179	185
gal/min/ ft. width	0.6	0.84	1.03	1.19	1.33	1.46	1.57	1.68	1.79	1.88	1.97	2.06	2.14	2.22	2.3

		Min. Filter Width @ Delivery Rate (gpm)														
		10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
	1	17	34	50	67	84	100	117	134	150	167	200	234	267	300	
F	2	12	24	36	48	60	72	84	96	108	120	143	167	191	215	239
I	3	10	20	30	39	49	59	68	78	88	98	117	136	156	175	195
L	4	9	29	26	34	43	51	59	68	76	85	101	118	135	152	169
T	5		19	23	31	38	46	53	61	68	76	91	106	121	136	151
E	6		14	21	28	35	42	48	55	62	69	83	96	110	124	137
R	7		19	20	26	32	39	45	51	58	64	77	90	102	115	128
	8		12	18	24	30	36	42	48	54	60	72	84	96	108	120
S	9		12	17	23	28	34	40	45	51	56	68	79	90	101	112
L	10		11	16	22	27	32	38	43	48	54	64	75	86	96	107
O	11		11	16	21	26	31	36	41	46	51	61	72	82	92	102
P	12		10	15	20	25	30	34	39	44	49	59	68	78	88	98
E	13		10	15	19	24	29	33	38	43	47	57	66	75	85	94
	14		10	14	19	23	28	32	37	41	46	55	64	73	82	91
(%)	15		9	14	18	22	27	31	35	40	44	53	61	70	79	87

[1] There shall be a minimum of 2 feet of soil depth between finished grade and bedrock or the seasonal high water table.

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Table 7: Filter Area Dimensions for Design Flow Depth of 0.2 Inches

Design Flow Depth (d=0.2") Filter Slope (%)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Minimum Filter Length	37	52	63	73	82	89	97	103	109	115	121	126	131	136	141
gal/min/ ft. width	0.3	0.43	0.52	0.61	0.68	0.74	0.8	0.86	0.91	0.96	1	1.05	1.09	1.13	1.17

		Min. Filter Width @ Delivery Rate (gpm)														
		10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
	1	34	67	100	134	167	200	234	267	300						
F	2	24	47	70	94	117	140	163	187	210	233	280				
I	3	20	39	58	77	97	116	135	154	174	193	231	270			
	4	17	33	50	66	82	99	115	132	148	164	197	230	263	296	
	5	15	30	45	59	74	89	103	118	133	148	177	206	236	265	295
E	6	14	27	41	55	68	82	95	109	122	136	163	190	217	244	271
R	7	13	25	38	50	63	75	88	100	113	125	150	175	200	225	250
	8	12	24	35	47	59	70	82	94	105	117	140	163	187	210	233
S	9	11	22	33	44	55	66	77	88	99	110	132	154	176	198	220
L	10	11	21	32	42	53	63	73	84	94	105	125	146	167	188	209
O	11	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200
P	12	10	20	29	39	48	58	67	77	86	96	115	134	153	172	191
E	13	10	19	28	37	46	56	65	74	83	92	111	129	147	166	184
	14	9	18	27	36	45	54	62	71	80	89	107	124	142	160	177
(%)	15	9	18	26	35	43	52	60	69	77	86	103	120	137	154	171

[1] There shall be a minimum of 2 feet of soil depth between finished grade and bedrock or the seasonal high water table.

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Table 7: Filter Area Dimensions for Design Flow Depth of 0.1 Inches

Design Guide # PA-5

Table 8: Filter Area Dimensions for Design Flow Depth of 0.1 Inches

Design Flow Depth (d=0.1")

	Filter Slope (%)														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Minimum Filter Length	23	32	40	46	51	56	61	65	69	73	76	79	83	86	89
gal/min/ ft. width	0.1	0.13	0.16	0.19	0.21	0.23	0.25	0.27	0.29	0.3	0.32	0.33	0.34	0.36	0.37

Min. Filter Width @ Delivery Rate (gpm)

		10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**120**	**140**	**160**	**180**	**200**
	1	100	200	300												
F	**2**	77	154	231												
I	**3**	63	125	188	250											
L	**4**	53	106	158	211	264										
T	**5**	48	96	143	191	239	286									
	6	44	87	131	174	218	261									
.	**7**	40	80	120	160	200	240	280								
	8	38	75	112	149	186	223	260	297							
S	**9**	35	69	104	138	173	207	242	276							
L	**10**	34	67	100	134	167	200	234	267	300						
O	**11**	32	63	94	125	157	188	219	250	282						
P	**12**	31	61	91	122	152	182	213	243	273						
E	**13**	30	59	89	118	148	177	206	236	265	295					
	14	28	56	84	112	139	167	195	223	250	278					
(%)	**15**	28	55	82	109	136	163	190	217	244	271					

[1] There shall be a minimum of 2 feet of soil depth between finished grade and bedrock or the seasonal high water table.

AWMFH, PA-14, 3/2007 **10.66.17**

Figure 3. Annual N delivered to Wastewater Treatment Strips from earthen feedlots in pounds per acre.

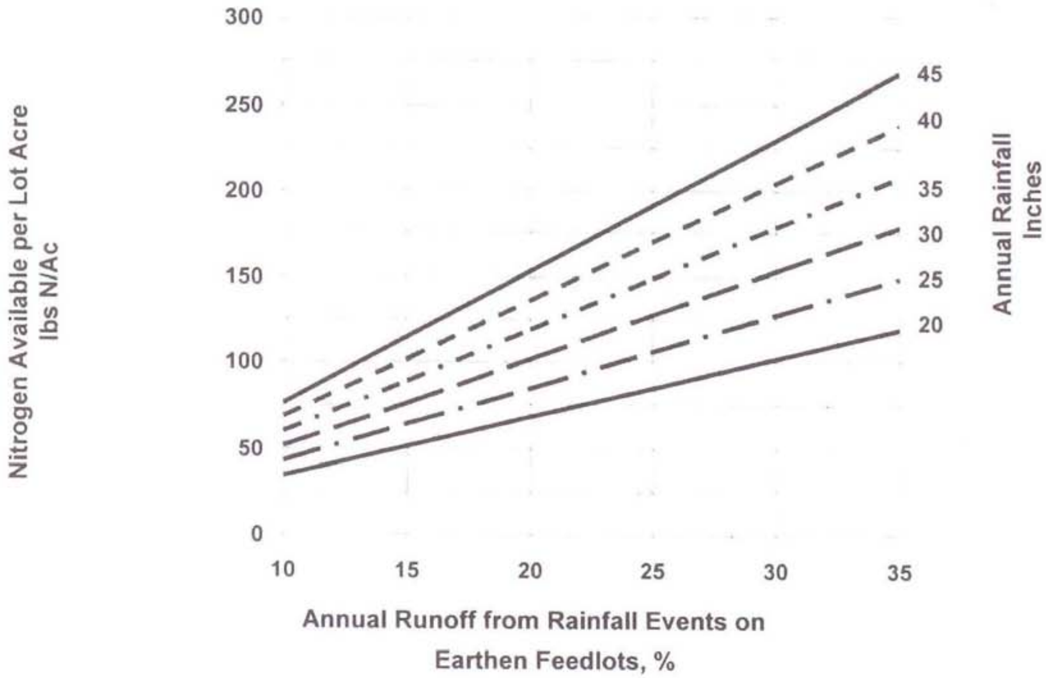
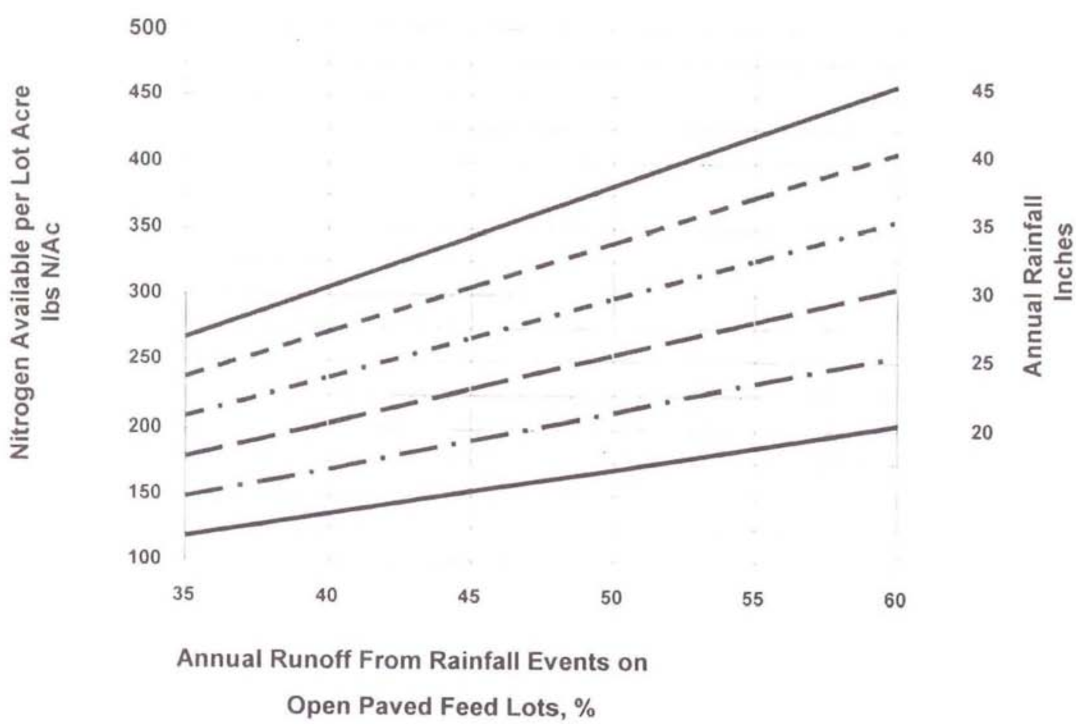


Figure 4. Annual N delivered to Wastewater Treatment Strips from paved feedlots in pounds per acre. (From LPES Figure 22-11.)



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<u>Table 9: Orifice discharge capacity</u>

For orifices to control flow rate through riser, or distribution manifold.

Based on:

$Q = (C)(A)(2gh)^{0.5}$ in cfs

C = orifice constant; assumed to be 0.61. The actual value varies with the type of orifice. The assumed value is conservative.

A = orifice area, ft^2

g = 32.174 ft/sec^2

h = head of orifice, ft

Diameter (in.)	Area (ft^2)	Head, (ft) 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
		Flow rate, (cfs)							
0.50	0.0014	0.005	0.007	0.008	0.009	0.010	0.012	0.013	0.014
0.75	0.0031	0.011	0.015	0.018	0.021	0.024	0.026	0.028	0.030
1.00	0.005	0.017	0.027	0.033	0.038	0.042	0.046	0.050	0.053
1.25	0.009	0.031	0.042	0.051	0.059	0.066	0.072	0.078	0.083
1.50	0.012	0.042	0.060	0.074	0.085	0.095	0.104	0.112	0.120
1.75	0.017	0.059	0.082	0.100	0.116	0.129	0.142	0.153	0.163
2.00	0.022	0.076	0.107	0.131	0.151	0.169	0.185	0.200	0.214
2.25	0.028	0.097	0.135	0.165	0.191	0.214	0.234	0.253	0.270
2.50	0.034	0.118	0.167	0.204	0.236	0.264	0.289	0.312	0.334
2.75	0.041	0.142	0.202	0.247	0.285	0.319	0.350	0.378	0.404
3.00	0.049	0.170	0.240	0.294	0.340	0.380	0.416	0.449	0.480
3.25	0.058	0.201	0.282	0.345	0.399	0.446	0.488	0.527	0.564
3.50	0.067	0.232	0.327	0.400	0.462	0.517	0.566	0.612	0.654
3.75	0.077	0.266	0.375	0.460	0.531	0.593	0.650	0.702	0.751
4.00	0.087	0.301	0.427	0.523	0.604	0.675	0.740	0.799	0.854
4.25	0.099	0.343	0.482	0.590	0.682	0.762	0.835	0.902	0.964
4.50	0.110	0.381	0.540	0.662	0.764	0.855	0.936	1.011	1.081
4.75	0.123	0.426	0.602	0.737	0.852	0.952	1.043	1.127	1.204
5.00	0.136	0.471	0.667	0.817	0.944	1.055	1.156	1.248	1.334
5.25	0.150	0.519	0.736	0.901	1.040	1.163	1.274	1.376	1.471
5.50	0.165	0.571	0.807	0.989	1.142	1.276	1.398	1.510	1.615
5.75	0.180	0.623	0.882	1.081	1.248	1.395	1.528	1.651	1.765
6.00	0.196	0.678	0.961	1.177	1.359	1.519	1.664	1.797	1.922
6.25	0.213	0.737	1.043	1.277	1.474	1.648	1.806	1.950	2.085
6.50	0.230	0.796	1.128	1.381	1.595	1.783	1.953	2.110	2.255
6.75	0.249	0.862	1.216	1.489	1.720	1.923	2.106	2.275	2.432
7.00	0.267	0.924	1.308	1.602	1.849	2.068	2.265	2.447	2.615
7.25	0.287	0.993	1.403	1.718	1.984	2.218	2.430	2.624	2.806
7.50	0.307	1.062	1.501	1.839	2.123	2.374	2.600	2.890	3.002
7.75	0.328	1.135	1.603	1.963	2.267	2.535	2.776	2.999	3.206
8.00	0.349	1.208	1.708	2.092	2.416	2.701	2.958	3.195	3.416

AWMFH, PA-14, 3/2007 **10.66.19**

<u>Table 10: Riser pipe outlet design</u>
For settling basins

Based on:
$Q = (C)(A)(2gh)^{0.5}$ in cfs
C = slot constant; assumed to be 0.61. The actual value varies with the type of slot. The assumed value is conservative.
A = open slot area, ft^2
g = 32.174 ft/sec^2
h = head on openings, ft. The pipe height was divided into 0.5' increment. The head on all the slots in the first 0.5' increment assumed to be 0.25'. The head on the subsequent 0.5' pipe increments increase at 0.5' increments.

Open slot area per ft of pipe height (in^2/ft)	Head, (ft)							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Flow rate, (cfs)							
4	0.034	0.093	0.169	0.259	0.361	0.473	0.596	0.728
6	0.051	0.139	0.253	0.388	0.541	0.710	0.894	1.091
8	0.068	0.186	0.338	0.518	0.721	0.947	1.192	1.455
10	0.085	0.232	0.422	0.647	0.902	1.183	1.480	1.819
12	0.102	0.279	0.507	0.776	1.082	1.420	1.788	2.183
14	0.119	0.325	0.591	0.906	1.262	1.657	2.086	2.546
16	0.136	0.371	0.675	1.035	1.443	1.894	2.384	2.910
18	0.153	0.418	0.760	1.164	1.623	2.130	2.682	3.274
20	0.170	0.464	0.844	1.294	1.803	2.367	3.980	3.638
22	0.187	0.511	0.929	1.423	1.984	2.604	3.277	4.001
24	0.204	0.557	1.013	1.542	2.164	2.840	3.575	4.365
26	0.221	0.603	1.097	1.682	2.344	3.077	3.873	4.729
28	0.238	0.650	1.182	1.811	2.525	3.314	4.171	5.093
30	0.255	0.696	1.266	1.940	2.705	3.550	4.469	5.456
32	0.272	0.743	1.351	2.070	2.885	3.787	4.767	5.820
34	0.289	0.789	1.435	2.199	3.066	4.024	5.065	6.184
36	0.306	0.836	1.519	2.329	3.246	4.260	5.363	6.548
38	0.323	0.882	1.604	2.458	3.426	4.497	5.661	6.911
40	0.340	0.928	1.688	2.587	3.607	4.734	5.959	7.275

AWMFH, PA-14, 3/2007 10.66.20

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