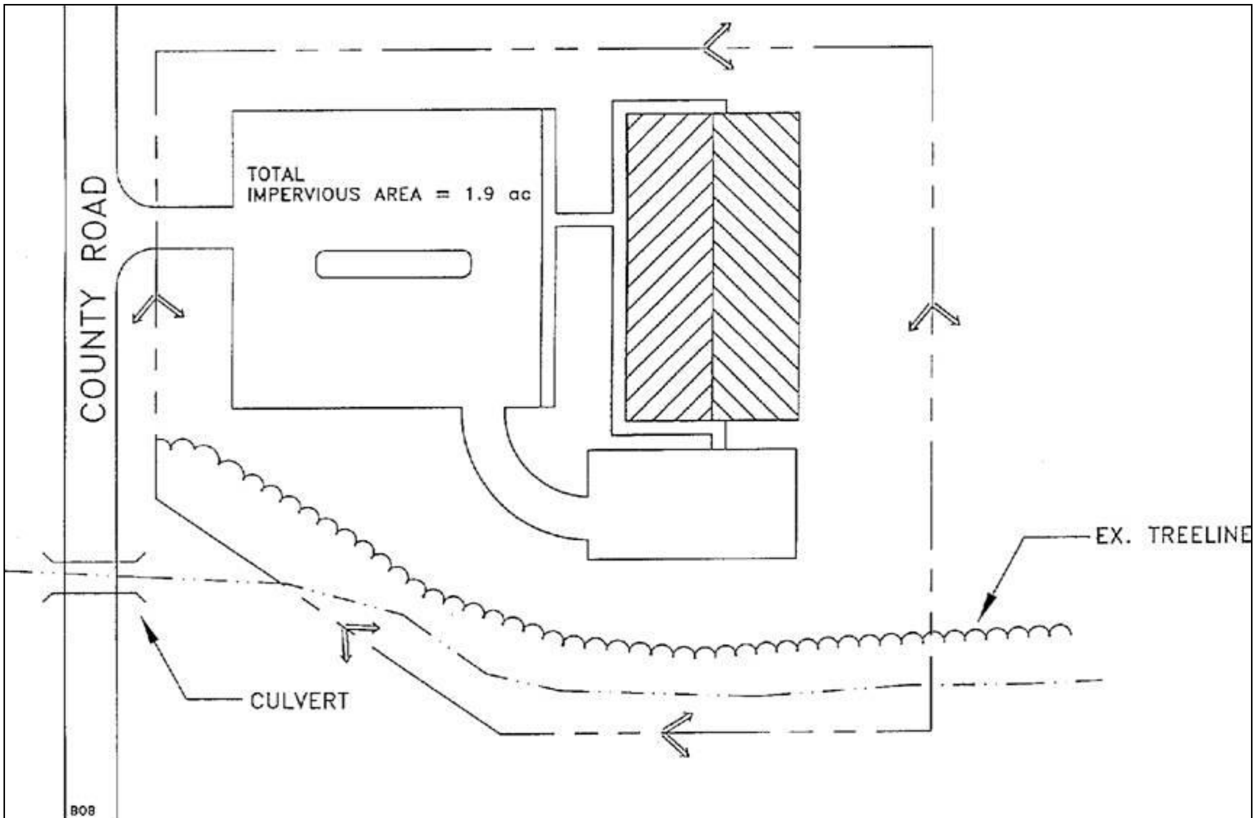
Appendix D-4

Infiltration Trench Design Example



Base Data	Hydrologic Data		
Site Area = Total Drainage Area (A) = 3.0 ac		Pre	Post
Impervious Area = 1.9 ac; or I = 1.9/3.0 = 63.3%	CN	57	83
Soils Types: "B"	t_c	.36	.15

Figure 1. Georgia Pines Community Center Site Plan

This example focuses on the design of an infiltration trench to meet the water quality treatment requirements of the site. Channel protection and overbank flood control is not addressed in this example other than quantification of preliminary storage volume and peak discharge requirements. It is assumed that the designer can refer to the previous pond example in order to extrapolate the necessary information to determine and design the required storage and outlet structures to meet these criteria. In general, the primary function of infiltration trenches is to provide water quality treatment and groundwater recharge and not large storm attenuation. As such, flows in excess of the water quality volume are typically routed to bypass the facility. Where quantity control is required, the bypassed flows can be routed to conventional detention basins (or some other facility such as underground storage vaults).

NOTE: This real life example uses the overbank protection volume of Q_{p25}. However, Columbia County requires an overbank protection volume of Q_{p50}.

The layout of the Georgia Pines Community Center is shown in Figure 1.

Step 1 -- Compute runoff control volumes from the Unified Stormwater Sizing Criteria.

Compute Water Quality Volume, (WQ_v):

- Compute Runoff Coefficient, R_v

  $$R_v = 0.05 + (63.3)(0.009) = 0.62$$

- Compute WQ_v

  $$WQ_v = (1.2")(R_v)(A)/12$$
  $$= (1.2")(0.62)(3.0\ ac)(43{,}560\ ft^2/ac)(1\ ft/12\ in)$$
  $$= 8{,}102\ ft^3 = 0.186\ ac-ft$$

Compute Stream Channel Protection Volume (Cp_v):

For stream channel protection, provide 24 hours of extended detention for the 1-year event.

- Develop Site Hydrologic and Hydrologic Input Parameters and perform Preliminary Hydrologic Calculations

  Per Figures 2 and 3. Note that any hydrologic models using SCS procedures, such as TR-20, HEC-HMS, or HEC-1, can be used to perform preliminary hydrologic calculations.

Condition	CN	$Q_{1\text{-year}}$	$Q_{1\text{-year}}$	$Q_{25\text{-year}}$	$Q_{100\text{-year}}$
		Inches	*cfs*	*cfs*	*cfs*
Pre-developed	57	0.5	0.6	6.0	9.0
Post-developed	83	1.9	5.5	17.0	22.0

- Utilize modified TR-55 approach to compute channel protection storage volume

  Initial abstraction (Ia) for CN of 83 is 0.41: (TR-55) $[Ia = (200/CN - 2)]$

  $$Ia/P = (0.41)/3.6\ inches = 0.11$$

  T_c = 0.15 hours

  q_u = 590 csm/in

  Knowing q_u and T (extended detention time), find q_o/q_i for a Type II rainfall distribution.

  Peak outflow discharge/peak inflow discharge (q_o/q_i) = 0.03

  $$Vs/Vr = 0.683 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 - 0.804(q_o/q_i)^3$$

  Where Vs equals channel protection storage (Cp_v) and Vr equals the volume of runoff in inches.

  Vs/Vr = 0.64

  Therefore, $Vs = Cp_v = 0.64(1.9")(1/12)(3\ ac) = 0.30\ ac-ft = 13{,}068\ ft^3$

- Define the average ED Release Rate

  The above volume, 0.30 ac-ft, is to be released over 24 hours.

  $$(0.30\ ac-ft * 43{,}560\ ft^2/ac)/(24\ hrs * 3{,}600\ sec/hr) = 0.15\ cfs$$

Determine Overbank Flood Protection Volume (Q_{p25}):

For a Q_{in} of 17 cfs, and an allowable Q_{out} of 6 cfs, the Vs necessary for 25-year control is 0.52 ac-ft or 22,677 ft^3, under a developed CN of 83. Note that 7.9 inches of rain fall during this event, with 5.9 inches of runoff.

Analyze for Safe Passage of 100 Year Design Storm (Q_f):

At final design, prove that discharge conveyance channel is adequate to convey the 100-year event and discharge to receiving waters, or handle it with a peak flow control structure, typically the same one used for the overbank flood protection control.

Table 1 Summary of General Design Information for Georgia Pines Community Center

Symbol	Control Volume	Volume Required (cubic feet)	Notes
WQ_v	Water Quality	8,102	
Cp_v	Channel Protection	13,068	
Q_{p25}	Overbank Flood Protection	22,677	
Q_f	Extreme Flood Protection	NA	Provide safe passage for the 100-year event in final design

Step 2-- Determine if the development site and conditions are appropriate for the use of an infiltration trench.

Site Specific Data

Table 2 presents site-specific data, such as soil type, percolation rate, and slope for consideration in the design of the infiltration trench.

Table 2 Site Specific Data

Criteria	Value
Soil	Sandy Loam
Percolation Rate	1” / hour
Ground Elevation at BMP	20’
Seasonally High Water Table	13’
Stream Invert	12’
Soil Slopes	< 1%

PEAK DISCHARGE SUMMARY				
JOB:	Georgia Pines Center			EWB
DRAINAGE AREA NAME:	Pre-Developed Conditions			3-Jan-00
COVER DESCRIPTION	SOIL NAME	GROUP A, B, C or D?	CN FROM TABLE 2.1.5-1	AREA (in acres)
meadow (good condition)		B	58	2.40
meadow (good condition)		B	55	0.60
		Area Subtotals:		3.00
Time of Concentration	Surface Cover	Manning 'n'	Flow Length	Slope
2-yr 24-hr Rainfall = 4.1 in	Cross Section	Wetted Per	Avg Velocity	Tt (Hrs)
Sheet Flow	dense grass	'n' = 0.24	150 Ft.	1.50%
				0.30 Hrs
Shallow Flow	unpaved		500 Ft.	2.00%
			2.28	0.06
Channel Flow				
Total Area in Acres =	3.00	Total Sheet Flow = 0.30 Hrs	Total Flow = 0.06 Hrs	Total Channel Flow = 0.00 Hrs
Weighted CN =	57			
Time of Concentration =	0.36 Hrs			
Pond Factor =	1	RAINFALL TYPE		
STORM	Precipitation (P) inches	Runoff (Q)	Qp, Peak Discharge	Total Storm Volumes
1 Year	3.6 In.	0.5 In.	0.6 CFS	4,943 cu. ft.
2 Year	4.8 In.	1.0 In.	1.8 CFS	10,887 cu. ft.
5 Year	6.0 In.	1.7 In.	3 CFS	18,252 cu. ft.
10 Year	6.7 In.	2.1 In.	4 CFS	23,186 cu. ft.
25 Year	7.9 In.	2.9 In.	6 CFS	32,076 cu. ft.
50 Year	8.9 In.	3.6 In.	8 CFS	39,672 cu. ft.
100 Year	9.8 In.	4.4 In.	9 CFS	47,613 cu. ft.

Figure 2. Georgia Pines Community Center Pre-Developed Conditions

PEAK DISCHARGE SUMMARY

JOB:	Georgia Pines Center	EWB
DRAINAGE AREA NAME:	Post-Development Conditions	3-Jan-00

COVER DESCRIPTION	SOIL NAME	GROUP A, B, C or D?	CN FROM TABLE 2.1.5-1	AREA (in acres)
open space (good condition)		B	61	0.50
woods (good condition)		B	55	0.60
impervious		B	98	1.90
		Area Subtotals:		**3.00**

Time of Concentration	Surface Cover	Manning 'n'	Flow Length	Slope
2-yr 24-hr Rainfall = 4.1 in	**Cross Section**	**Wetted Per**	**Avg Velocity**	**Tt (Hrs)**
Sheet Flow	**short grass**	**'n' = 0.15**	**50 Ft.**	**1.50%**
				0.09 Hrs
Shallow Flow	**paved**		**600 Ft.**	**2.00%**
			2.87 F. P. S.	0.06 Hrs
Channel Flow		**'n'=0.024**	**50 Ft.**	**2.00%**
Hydraulic Radius = 0.75	X-S	WP estimated	7.25 F. P. S.	0.00 Hrs

Total Area in Acres =	**3.00**	**Total Sheet Flow = 0.09 Hrs**	**Total Flow = 0.06 Hrs**	**Total Channel Flow = 0.00 Hrs**
Weighted CN =	**83**			
Time of Concentration =	**0.15 Hrs**			
Pond Factor =	**1**	**RAINFALL TYPE**		

STORM	Precipitation (P) inches	Runoff (Q)	Qp, Peak Discharge	Total Storm Volumes
1 Year	3.6 In.	1.9 In.	5.5 CFS	21,159 cu. ft.
2 Year	4.8 In.	3.0 In.	8.6 CFS	32,602 cu. ft.
5 Year	6.0 In.	4.1 In.	12 CFS	44,555 cu. ft.
10 Year	6.7 In.	4.8 In.	14 CFS	51,881 cu. ft.
25 Year	7.9 In.	5.9 In.	17 CFS	64,262 cu. ft.
50 Year	8.9 In.	6.8 In.	20 CFS	74,281 cu. ft.
100 Year	9.8 In.	7.7 In.	22 CFS	84,372 cu. ft.

Figure 3. Georgia Pines Community Center Post-Developed Conditions

Step 3 -- Confirm local design criteria and applicability.

Table 3, below, summarizes the requirements that need to be met to successfully implement infiltration practices. On this site, infiltration is feasible, with restrictions on the depth and width of the trench.

Table 3 Infiltration Feasibility

Criteria	Status
Infiltration rate (f_c) greater than or equal to 0.5 inches/hour.	Infiltration rate is 1.0 inches/hour. OK.
Soils have a clay content of less than 20% and a silt/clay content of less than 40%.	Sandy Loam meets both criteria.
Infiltration cannot be located on slopes greater than 6% or in fill soils.	Slope is < 1%; not fill soils. OK.
Hotspot runoff should not be infiltrated.	Not a hotspot land use. OK.
Infiltration is prohibited in karst topography.	Not in karst. OK.
The bottom of the infiltration facility must be separated by at least two feet vertically from the seasonally high water table.	Elevation of seasonally high water table: 13'. Elevation of BMP location: 20'. The difference is 7'. Thus, the trench can be up to 5' deep. OK.
Infiltration facilities must be located 100 feet horizontally from any water supply well.	No water supply wells nearby. OK.
Maximum contributing area generally less than 5 acres. (Optional)	3 acres. OK.
Setback 25 feet down-gradient from structures.	Fifty feet straight-line distance between the parking lot and the tree line. OK if the trench is 25' wide or narrower.

Step 4 -- Compute WQ_v peak discharge (Q_{wq}) & Head.

- Water Quality Volume:

  WQ_v previously determined to be 8,102 cubic feet.

  The peak rate of discharge for the water quality design storm is needed for the sizing of off-line diversion structures, such as sand filters and grass channels. Conventional SCS methods have been found to underestimate the volume and rate of runoff for rainfall events less than 2". This discrepancy in estimating runoff and discharge rates can lead to situations where a significant amount of runoff by-passes the filtering treatment practice due to an inadequately sized diversion structure or leads to the design of undersized bypass channels.

  The following procedure can be used to estimate peak discharges for small storm events. It relies on the volume of runoff computed using the Small Storm Hydrology Method (Pitt, 1994) and utilizes the NRCS, TR-55 Graphical Peak Discharge Method (USDA, 1986). A brief description of the calculation procedure is presented below.

  $$\mathbf{CN = 1000/[10 + 5P + 10Q - 10(Q^2 + 1.25\,QP)^{1/2}]}$$

  where P = rainfall, in inches (use 1.2" for the Water Quality Storm)
  and Q = runoff volume, in inches (equal to WQ_v / area)

- Once a CN is computed, the time of concentration (t_c) is computed (based on the methods identified in TR-55, Chapter 3: "Time of concentration and travel time").

- Using the computed CN, t_c and drainage area (A), in acres; the peak discharge (Q_{wq}) for the Water Quality Storm is computed (based on the procedures identified in TR-55, Chapter 4: "Graphical Peak Discharge Method"). Use appropriate rainfall distribution type (either Type II or Type III in State of Georgia).

- Read initial abstraction (I_a), compute I_a/P
- Read the unit peak discharge (q_u) from Exhibit 4-II or 4-III for appropriate t_c
- Using the water quality volume (WQ_v), compute the water quality peak discharge (Q_{wq})

$$Q_{wq} = q_u * A * WQ_v$$

where: Q_{wq} = the peak discharge, in cfs

q_u = the unit peak discharge, in cfs/mi^2/inch

A = drainage area, in square miles

WQ_v = Water Quality Volume, in watershed inches

For this example, the steps are as follows:

Compute modified CN for 1.2" rainfall

P = 1.2"

$$Q = WQ_v / area = (8{,}102\ ft^3 / 3\ ac / 43{,}560\ ft^2 / ac * 12\ in / ft) = 0.74"$$

$$CN = 1000/[10 + 5P + 10Q - 10(Q^2 + 1.25 * Q * P)^{1/2}]$$

$$= 1000/[10 + 5 * 1.2 + 10 * 0.74 - 10(0.74^2 + 1.25 * 0.74 * 1.2)^{1/2}]$$

$$= 95.01$$

<u>Use CN = 95</u>

For CN = 95 and the T_c = 0.15 hours, compute the Q_{wq} for a 1.2" storm. With the CN = 95, a 1.2" storm will produce 0.74" of runoff. I_a = 0.105, therefore $I_a / P = 0.105 / 1.2 = 0.088$. From Section 2.1, q_u = 625 csm/in, and therefore $Q_{wq} = (625\ csm/in)(3.0\ ac/640\ ac/\ sq\ mi)(0.74") = 2.2\ cfs.$

Step 5 -- Size the infiltration trench.

The area of the trench can be determined by the following equation:

$$A = \frac{WQ_v}{(nd + kT/12)}$$

Where:

A = Surface Area

n = porosity

d = trench depth (feet)

k = percolation (inches/hour)

T = Fill Time (time for the practice to fill with water), in hours

Assume that:

n = 0.32

d = 5 feet (see above; feasibility criteria)

k = 1 inch/hour (see above; site data)

T = 2 hours

Therefore:

$$A = 8{,}102\ ft^3 / (0.32 * 5 + 1 * 2/12)\ ft$$

A = 4,586 ft^2

Since the width can be no greater than 25' (see above; feasibility), determine the length:

$$L = 4{,}586\ ft^2 / 25\ ft$$

L = 183 feet

Assume that ⅓ of the runoff from the site drains to Point A and ⅔ drains to Point B. Use an L-shaped trench in the corner of the site (see Figure 4 for a site plan view). The surface area of the trench is proportional to the amount of runoff it drains (e.g., the portion draining from Point A is half as large as the portion draining Point B).

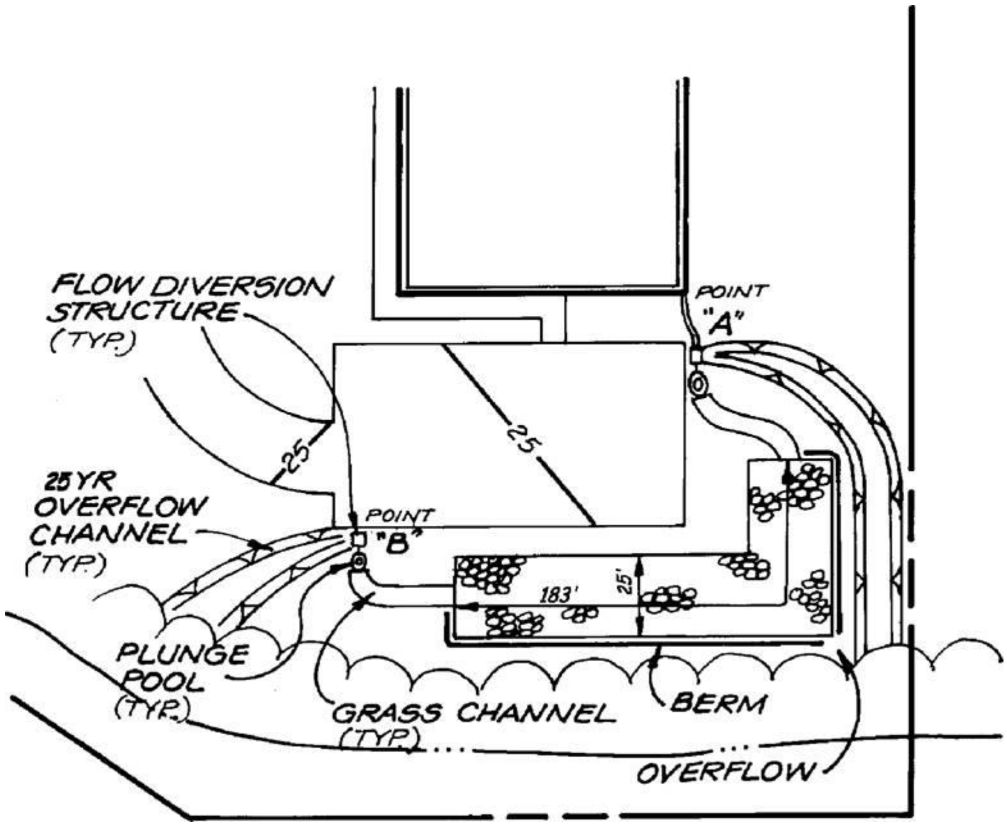


Figure 4. Infiltration Trench Site Plan

Step 6 -- Size the flow diversion structures.

Since two entrances are used, two flow diversions are needed.

For the entire site:

$Q_{25\text{-year}}$ = 17 cfs (See Figure 3)

Peak flow for WQ_v = 2.2 cfs. (Step 3).

For the first diversion (Point A)

Assume peak flow equals ⅓ of the value for the entire site.

Thus, $\mathbf{Q_{25-year} = 17 / 3 = 5.7\ cfs}$

Peak flow for $\mathbf{WQ_v = 2.2 / 3 = 0.73\ cfs}$

Size the low flow orifice to pass 0.73 cfs with 1.5' of head using the Orifice equation.

$$\mathbf{Q = CA\ (2gh)^{1/2};\quad 0.73\ cfs = 0.6A\ (2 * 32.2\ ft^2 / s * 1.5')^{1/2}}$$

$$\mathbf{A = 0.12\ sq\ ft = \pi d^2 / 4;\quad d = 0.4';}\ \text{use 6" pipe with 6" gate valve}$$

Size the 25-year overflow weir crest at 22.5'. Use a concrete weir to pass the 25-year flow $\mathbf{(5.7 - 0.73 = 5\ cfs)}$. Assume 1 foot of head to pass this event. Size using the weir equation.

$$\mathbf{Q = CLH^{1.5};\quad L = Q / (CH^{1.5})}$$

$$\mathbf{L = 5\ cfs / (3.1)(1)^{1.5} = 1.6';\ \underline{use\ 1.6'}}\ \text{(see Figure 5)}$$

Size the second diversion (Point B) using the same techniques. Peak flow equal 2/3 of the value for the entire site. Thus:

$\mathbf{Q_{25-year} = 17 * 0.67 = 11.4\ cfs}$

Peak flow for $\mathbf{WQ_v = 2.2 * 0.67 = 1.47\ cfs}$

Size the low flow orifice to pass 1.47 cfs with 1.5' of head using the Orifice equation.

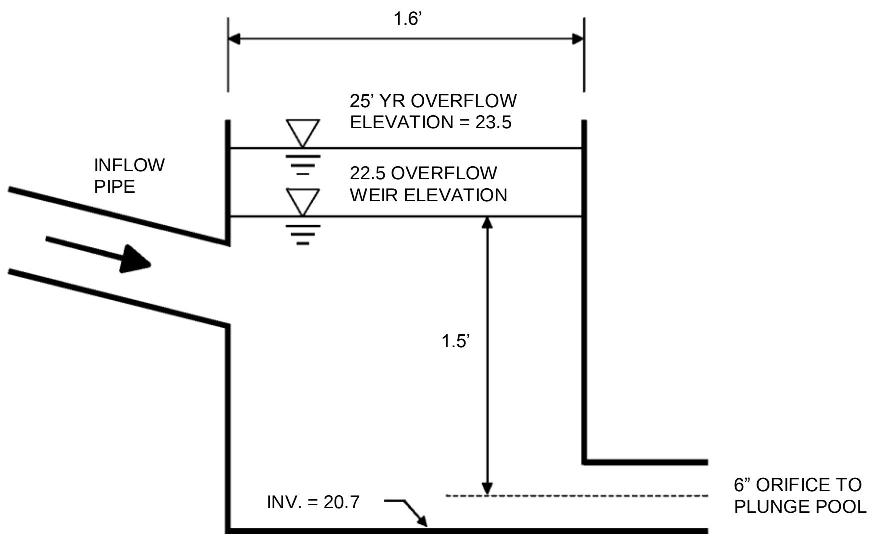
$$Q = CA\,(2gh)^{1/2}; \quad 1.47\ cfs = 0.6A\,(2 * 32.2\ ft^2 / s * 1.5')^{1/2}$$

$$A = 0.25\ sq\ ft = \pi d^2 / 4; \quad d = 0.56';$$ use 8" pipe with 8” gate valve

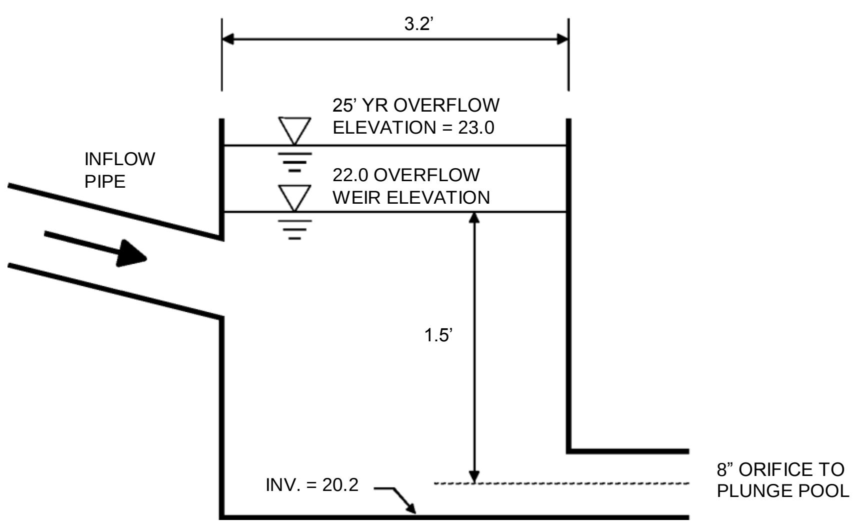
Size the 25-year overflow weir crest at 22.0'. Use a concrete weir to pass the 25-year flow $(11.4 - 1.47 = 9.9\ cfs)$. Assume 1 foot of head to pass this event. Size using the weir equation.

$$Q = CLH^{1.5}; \quad L = Q / (CH^{1.5})$$

$$L = 9.9\ cfs / (3.1)(1)^{1.5} = 3.2';\ \underline{use\ 3.2'}$$ (see Figure 5)



Point “A”



Point “B”

Figure 5. Flow Diversion Structures

Step 7 -- Size pretreatment volume and design pretreatment measures

As rule of thumb, size pretreatment to treat 25% of the WQ_v. Therefore, treat

$$\mathbf{8{,}102 * 0.25 = 2{,}026\ ft^3.}$$

For pretreatment, use a pea gravel filter layer with filter fabric, a plunge pool, and a grass channel.

Pea Gravel Filter

The pea gravel filter layer covers the entire trench with 2" (see Figure 6). Assuming a porosity of 0.32, the water quality treatment in the pea gravel filter layer is:

$$\mathbf{WQ_{filter} = (0.32)(2")(1\ ft / 12\ inches)(3{,}883\ ft^2) = 207\ ft^3}$$

Plunge Pools

Use a 5'X10' plunge pool at Point A and a 10'X10' plunge pool at Point B with average depths of 2'.

$$\mathbf{Total\ WQ_{pool} = (10\ ft)(10 + 5\ ft)(2\ ft) = 300\ ft^3}$$

Grass Channel

Thus, the grass channel needs to treat at least $\mathbf{(2{,}026 - 207 - 300)\ ft^3 = 1{,}519\ ft^3}$

Use a Manning's equation nomograph or software to size the swale.

The channel at point A should treat one third of 1,519 ft^3 or 501 ft^3

- Assume a trapezoidal channel with 4' channel bottom, 3H:1V side slopes, and a Manning's n value of 0.15. Use a nomograph to size the swale; assume a 1% slope.
- Use a peak discharge of 0.73 cfs (Peak flow for ⅓ of WQ_v, or 2,674 ft^3)
- Compute velocity: V = 0.5 ft/s
- To retain the ⅓ of the WQ_v (2,674 ft^3) for 10 minutes, the length would be 300'.
- Since the swale only needs to treat 25% of the water quality volume minus the treatment provided by the plunge pool and the gravel layer, or 501 ft^3, the length should be pro-rated to reflect this reduction.

  Therefore, adjust length:

  $$\mathbf{L = (300\ ft)(501\ ft^3 / 2{,}674\ ft^3) = 56'.\quad \underline{Use\ 60'.}}$$

The channel at point B should treat two thirds of 1,519 ft^3, or 1,018 ft^3

- Assume a trapezoidal channel with 5' channel bottom, 3H:1V side slopes, and a Manning's n value of 0.12. Use a nomograph to size the swale; assume a 0.5% slope.
- Use a peak discharge of 1.47 cfs (Peak flow for two thirds of WQ_v, or 5,428ft^3)
- Compute velocity: V=0.5 ft/s
- To retain the 2/3 of the WQ_v (5,428 ft^3) for 10 minutes, the length would be 300 feet.
- Since the swale only needs to treat 25% of the water quality volume minus the treatment provided by the plunge pool and the gravel layer, or 1,018 ft^3, the length should be prorated to reflect this reduction.

  Therefore, adjust length:

  $$\mathbf{L = (300\ ft)(1{,}018\ ft^3 / 5{,}428\ ft^3) = 56'.\quad \underline{Use\ 60'.}}$$

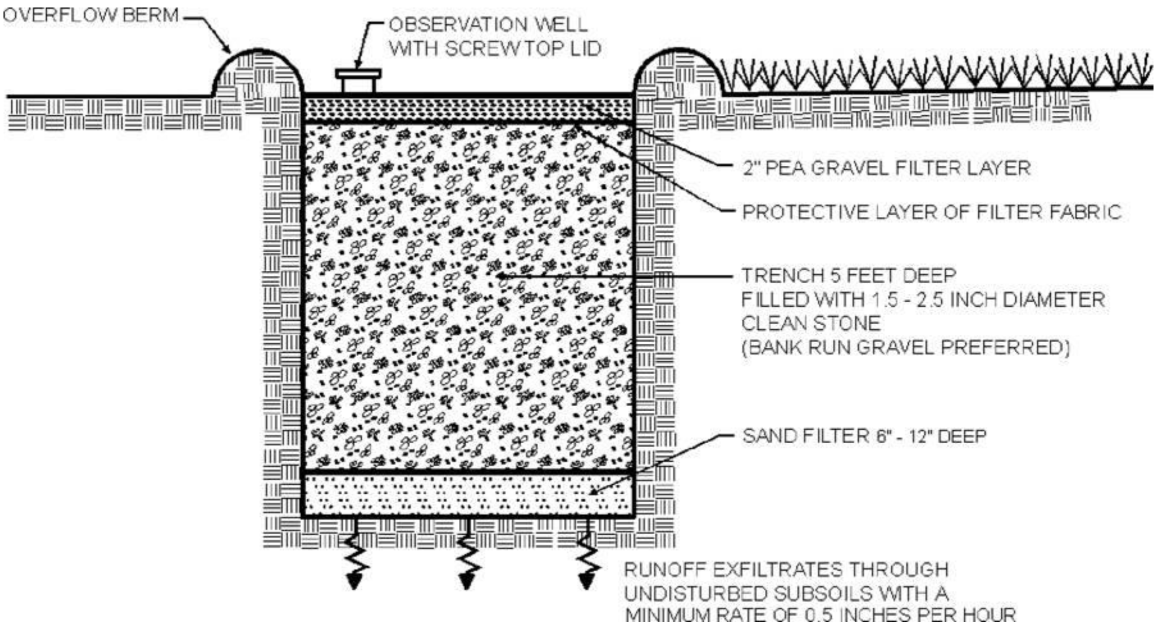


Figure 6. Infiltration Trench Cross Section

Step 8 -- Design Spillway(s)

Adequate stormwater outfalls should be provided for the overflow associated with the 25-year and larger design storm events, ensuring non-erosive velocities on the down slope.

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