4 HYDRAULIC DESIGN

A variety of design criteria are provided for the design of stormwater control facilities. These govern the basis of design for each type of facility.

4.1 STORM SEWER DESIGN

(For design storm volume of storm sewer see section 3.2 on page 22)

4.1.1 Peak Runoff Rate Determination

The peak runoff rates for which the system must be designed will be determined from one of the appropriate methods provided above, depending on the tributary area served by the facility.

4.1.2 Capacity Calculations

The Manning's equation must be used for calculating the pipe capacity unless the conduit is backwater affected or surcharges. In this case, the appropriate calculation techniques must be used to account for backwater and pressure flow. The Manning's equations is defined as:

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$$

Q	=	Flow capacity of open channel
n	=	Manning friction coefficient
A	=	Cross sectional area of open channel
R	=	Hydraulic Radius (area/wetted perimeter)
S	=	Average slope of drainage channel

The following Manning's n friction coefficients provided in Table 2 must be used for calculations of conduit capacity.

4.1.3 Construction Standards for Storm Sewer

4.1.3.1 All backyard yard basins and manholes shall be 4' in diameter, if the depth is equal to or greater than 4 feet; otherwise a 2' diameter is acceptable.

4.1.3.2 Storm sewer placed between houses shall have sealed (O-Ring) joints.

4.1.3.3 A minimum easement width of 30 feet is required for all underground storm sewer and a 20 feet width for all overland drainage swales.

4.1.4 Floodways

An overland floodway shall be constructed to serve all trapped yard basins and low areas in the road to prevent flooding should the storm sewer fail or be inadequate to handle runoff from a severe storm.

4.1.4.1 The floodway shall be sized to convey the 100-yr storm.

4.1.4.2 Provide a profile of the floodway, and establish a critical elevation. Establish all affected Lots minimum building openings so that they are at least 1 foot above the critical elevation of the floodway.

4.1.4.3 Establish the easements as floodways to regulate the floodway elevations. These easements shall be dedicated to a drainage district. A minimum easement width of 20 feet will be required.

TABLE 2
Conduit Manning's n Values

Manning's n	Conduit Material
0.012	Smooth PVC & PE Plastic Pipe
0.013	Concrete Pipe
0.024	Corrugated Metal & Plastic Pipe

4.2 OPEN CHANNELS

4.2.1 Peak Runoff Rate Determination

The peak runoff rates for which the system must be designed will be determined from one of the appropriate methods provided above, depending on the tributary area served by the facility.

4.2.2 Capacity Calculations

The capacity shall be calculated for the design condition (e.g. bare earth bottom with dense grass 6" to 12" on banks)

The normal depth and velocity shall be determined for the 1-year storm under the fresh cut or bare earth conditions. Temporary controls are to be installed to reduce the velocity so that it is non-erosive. The Manning equation, as defined above, will be used to determine the discharge capacity for an open channel.

The following Manning's n friction coefficients provided in Table 3 must be used for calculation of open channel capacity.

TABLE 3
Open Channel Manning's n Values

Manning's n	Channel Material
0.02	Grouted cobble or rough concrete lined ditches
0.02	Artificial channels in earth of regular form free from weeds and other growth
0.02	Smooth rubble
0.03	Sandy soils and gravel
0.04	Jagged rock and rough rubble
0.04	Well maintained grass, depth of flow over 4 inches
0.04	Fairly regular channels in earth with average growth of weeds and aquatic plants
0.05	Natural streams of irregular form badly grown up with willows, weeds, and brush
0.05	Well maintained grass, depth of flow under 4 inches
0.06	Heavy grass not maintained

4.3 ALLOWABLE VELOCITIES

The peak allowable velocities are necessary to prevent soil erosion and siltation of drainage channels and retention ponds. The allowable velocities for a variety of open channel materials are provided in Table 4.

TABLE 4
Allowable Open Channel Velocities

Type of Lining	Allowable Velocity
Ordinary earth	1 to 2 fps
Clay and gravel	4 fps
Coarse gravel	4 fps
Good sod	5 to 6 fps
Riprap & reinforced turf	10 fps
Concrete or grouted riprap	no limit

4.4 CHANNEL SPECIFICATIONS

An established ground cover over the side slopes is required

The steepest permissible side slope shall be 3 to 1 (horizontal to vertical) if vegetation cover requires no maintenance. If regular mowing is required, the side slope shall be 4 to 1.

A minimum of 1 foot of freeboard is required above the design water level.

Bank heights greater than 6 feet shall be benched to provide for equipment access and/or erosion control.

4.5 DETENTION POND – GENERAL

4.5.1 Design Criteria

4.5.1.1 Peak Discharge Rate – The peak discharge rate is 0.13 cfs/acre for all areas where stormwater ordinance zoning does not apply. Release pipe size shall be calculated using the orifice equation.

$$Q = 0.6 * A_{pipe} * (2gh)^{0.5}$$ - Orifice Equation

A_{pipe} = cross sectional area of pipe (4" minimum diameter)
g = 32.2 ft/sec^2 – gravitational constant
h = depth of water at design volume (difference between water surface and pipe centerline)

In areas where a city, township, or village stormwater ordinance has been established, the guidelines and zoning established in the ordinance will supercede the standards in this document and will be applied when reviewing developments. The following matrix provides general guidance regarding the requirements for zones A, B, and C. In additional, the Drain Commissioner reserves the right to modify the release rate in sensitive watersheds.

	Zone A	**Zone B**	**Zone C**
Storm Water Management Standards	Use infiltration basins, infiltration trenches, extended detention basins, and/or constructed wetlands. Maintain and enhance buffer strips.	Use detention ponds: maintain and enhance buffer strips, and reduce directly connected impervious area	Use sediment basins, maintain and enhance buffer strips, and reduce directly connected impervious area
Water Quality Control	Detain the first 0.5" of runoff from the contributing watershed, with detention per Zone B and infiltration where conditions permit, or provide equivalent treatment	Detain the first 0.5" of runoff from the contributing watershed for 24 hours or provide equivalent treatment	Provide sedimentation control within the drainage system
Bank Erosion Control	Rate of release shall be limited to 0.05 cfs/acre for a 2-year storm event	None	Storm water runoff shall not exceed the capacity of the downstream conveyance system
Flood Control	Detention with infiltration when conditions permit. Release rate of 0.13 cfs/acre.	Release rate of 0.13 cfs/acre.	Direct conveyance of storm water runoff within the capacity of the downstream system

4.5.1.2 Emergency Spillway Design

An emergency spillway shall be designed for every detention basin. It shall be sized

to safely pass the peak runoff from the 10-year storm recurrence interval (10% annual chance) from the total contributing drainage area, as ultimately developed. Spillway design shall extend from the berm crest to the outfall channel.

The following equations and details provide guidance for designing emergency spillways:

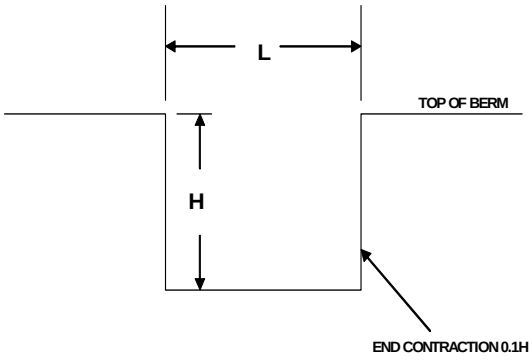
Design Equation for Rectangular Weir

$$Q = CLH^{3/2}$$

where C = 3.3 for sharp crested weirs (e.g. sheet piling)
C = 3.0 for broad crested weirs (e.g. earth berm)

$$Q = C(L - 0.2H)H^{3/2}$$

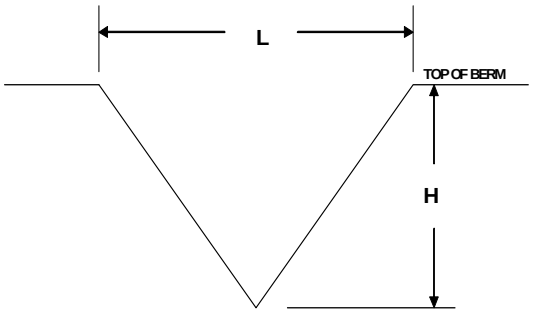
when vertical sidewalls are present (see illustration)



Design Equation for V-notch Weir

$$Q = 1.28LH^{3/2}$$

(see illustration)

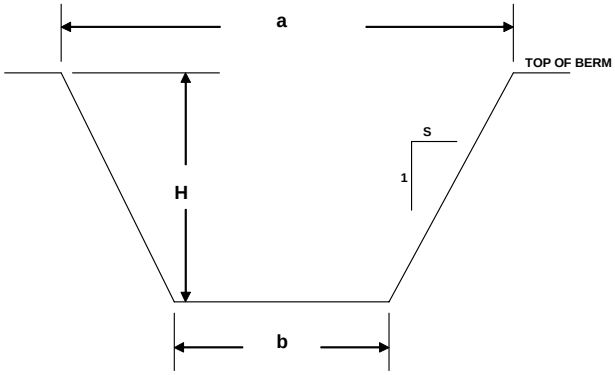


Design Equation for Trapezoidal Weir (normally used with earthen berms)

$$Q = C\left(\frac{(a+b)}{2} - 0.2H\right)H^{3/2}$$

(see illustration)

where C = 3.0 for broad crested (earth berm)
a = width of weir at design high water elevation
b = width of weir at base
s = minimum of 4 for grass weirs



4.5.1.3 Detention Storage

The requirement for detention volume may be determined from Figure 1, Table 5, or by routing the inflow required recurrence interval hydrograph through the basin. Note the requirements in Section 3.4 for acceptable calculation methods. Table 5 assumes 0.13cfs/acre release rate and a free (unsubmerged) outfall.

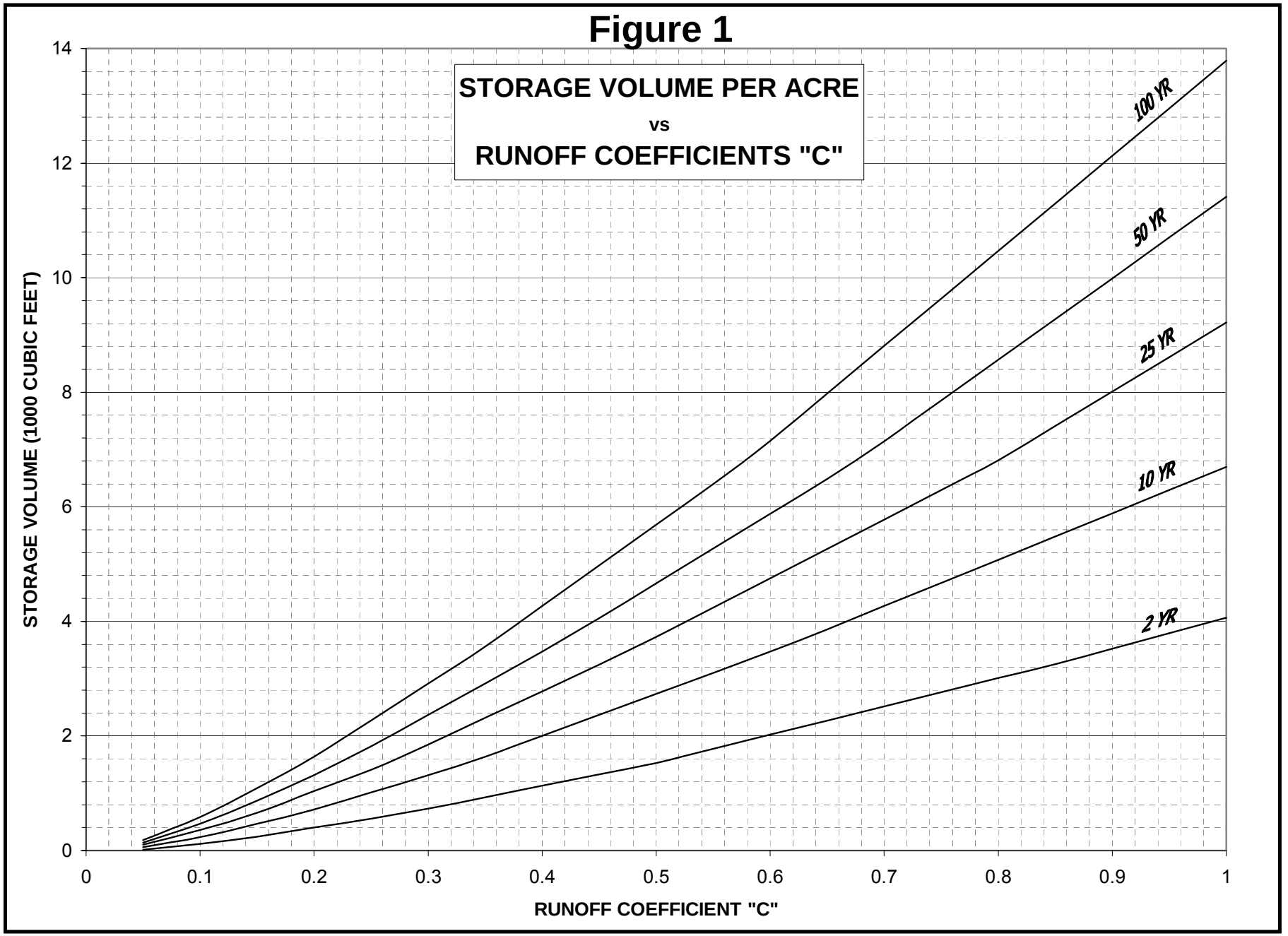
The area of the detention pond must be included in any calculations of impervious area.

TABLE 5[(1)]
STORAGE VOLUME PER ACRE

RUNOFF COEFFICIENT "C"	100 YR	50 YR	25 YR	10 YR	2 YR
	1000 CUBIC FEET[(2)]				
0.05	0.18	0.14	0.10	0.06	0.01
0.10	0.59	0.47	0.36	0.23	0.11
0.15	1.09	0.87	0.66	0.47	0.24
0.20	1.63	1.32	1.04	0.72	0.40
0.25	2.28	1.82	1.41	1.02	0.56
0.30	2.92	2.37	1.85	1.31	0.73
0.35	3.56	2.92	2.31	1.63	0.93
0.40	4.27	3.47	2.78	2.00	1.13
0.45	4.98	4.06	3.24	2.37	1.33
0.50	5.69	4.66	3.73	2.74	1.53
0.55	6.40	5.27	4.24	3.10	1.78
0.60	7.15	5.88	4.75	3.47	2.02
0.65	7.98	6.48	5.27	3.86	2.27
0.70	8.81	7.15	5.78	4.27	2.52
0.75	9.64	7.86	6.29	4.67	2.76
0.80	10.47	8.57	6.81	5.08	3.01
0.85	11.30	9.28	7.41	5.48	3.26
0.90	12.13	9.99	8.73	5.89	3.52
0.95	12.96	10.70	8.61	6.29	3.79
1.00	13.79	11.41	9.22	6.70	4.07

NOTES
(1) TABLE TO BE USED FOR WATERSHED AREAS SMALLER THAN 40 ACRES.
(2) EACH UNIT IN THE STORAGE TABLE REPRESENTS 1000 CUBIC FEET.
(3) STORAGE TABLE ALREADY TAKES INTO ACCOUNT 0.13 CFS/ACRE RELEASE RATE, THEREFORE THE TABLE SHALL NOT BE USED TO CALCULATE THE REQUIRED VOLUME FOR ANY INFILTRATION SYSTEMS OR BASINS UNTILIZING A RELEASE RATE THAT IS NOT 0.13 CFS/ACRE
(4) IN A SITUATION WHERE THE DETENTION FACILITY OUTFALL WILL BE SUBMERGED, REDUCING THE RELEASE RATE, THIS TABLE SHALL NOT BE USED.

Figure 1


STORAGE VOLUME PER ACRE
vs
RUNOFF COEFFICIENTS "C"
STORAGE VOLUME (1000 CUBIC FEET)
RUNOFF COEFFICIENT "C"
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100 YR
50 YR
25 YR
10 YR
2 YR

Construction Standards

4.5.1.4 Only one detention basin is allowed per development or original parcel, unless field considerations dictate otherwise. (e.g. the site is divided by a ridge line)

4.5.1.5 Configurations include wet detention basins, dry detention basins, infiltration basins, underground storage, roof top storage, porous pavement, and parking lot storage (12" maximum depth on lot) with a restricted outlet. (Subsequent sections of this document provide design criteria for the methods listed above.)

4.5.1.6 It is imperative that during the construction phase of development the detention storage facility is constructed first. The pond shall be graded, topsoiled, seeded, and stabilized before any final approval is granted.

4.5.1.7 Erosion blanket shall be placed on all detention basin slopes and pond bottom before final approval.

4.5.1.8 Detention storage must be provided during the construction phase. If the permanent detention facility cannot be built during the start of construction (e.g. roof top storage), then an approved temporary facility shall be constructed and maintained.

4.5.1.9 Integration of detention storage for the site in question with the drainage from upland areas must satisfy the NO INCREASE IN FLOOD ELEVATION requirement for the developed watershed. Hydrographs for the existing and future conditions shall be determined.

4.6 DETENTION PONDS – DRY DETENTION CRITERIA

4.6.1 Construction Standards

Dry detention basins must be built to minimize operation and maintenance efforts after the basin has been constructed. To ensure that the detention basins are designed and built properly, the following general guidelines must be used.

- The pond must be designed to contain runoff from the 25 – year rainfall event. (4% annual chance).

- Provide a flat maintenance shelf with a minimum width of 15-ft shall be provided around the perimeter of the basin. The pond must provide load bearing capability for maintenance vehicles.

- Adequate underdrainage must be provided to allow normal turf maintenance.

- The pond slopes must be sufficiently gradual to allow accessibility. The maximum allowable slope shall be 1 Vertical : 4 Horizontal

- Minimum buffer/setback for the detention basin shall be 25 feet from the basin easement to any dwelling.

- The channels to and from the basin must have appropriate transitions into and out of the original channel.

- Paved or permeable material may be used.

4.6.2 Detention Basin Grades

- Banks – 25% maximum allowed anywhere.

- Bottom Cross Slopes - 4% minimum allowed anywhere.

- Bottom Longitudinal Slopes - 4% minimum allowed anywhere.

- An acceptable alternative to the required grading is to install an underdrain. With the installation on an underdrain, a required minimum bottom grade of 2% shall be constructed. The underdrain shall be constructed in the following manner:

    1. The underdrain shall be one of the last items to be installed to eliminate any sediment build-up that would cause the underdrain to not function properly.
    2. A non-woven geotextile fabric shall be laid in the excavated trench first.
    3. The perforated drainpipe shall be covered with washed stone.
    4. Both stone and drain shall then be wrapped with the non-woven geotextile and backfilled with sandy porous material.
    5. See detail in Appendix G.

4.6.3 Low Flow/Extended Release

- A low flow channel or subsurface underdrain is required when the pond bottom may be subject to non-storm flow from groundwater, footing drainage, storm sewer acting as underdrain, and sump discharge such that vegetation will not grow across the bottom of the pond.

- An infiltration trench, or similar device, shall be used to limit the time of inundation to 24 hours.

4.6.4 Outlet Structure and Emergency Spillway

- Emergency spillways must be constructed of hot rolled plant mix asphalt or

concrete with geotextile fabric underneath. The spillway must extend down the back slope of the dike to form an inlet section and outward from the toe of the fore slope to form an apron with the outfall channel. Where desirable, turf reinforced with a three-dimensional root mat or geogrids may be used in lieu of paving in non-traffic areas.

Natural or synthetic materials will be allowed for construction of emergency spillways if it can be demonstrated that the structures will not fail and will have significant longevity.

- All edges of concrete or asphalt paving must be toed in a minimum of 12 inches.

- Energy dissipaters designed in accordance with the procedures used in FHWA publication HEC No. 14 shall be provided at all pipe outfalls.

- Erosion protection shall be provided for changes in cross section of the outlet channel and for transition from turbulent to laminar flow.

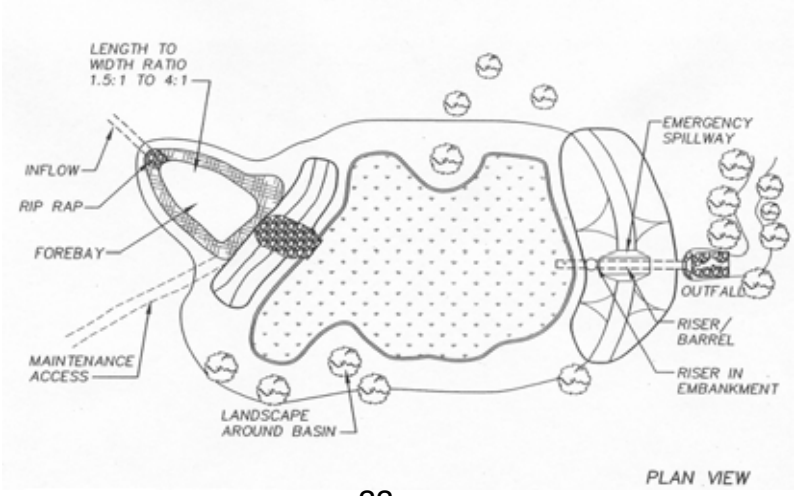
4.6.5 Receiving Stream

- In general, the receiving stream is to be left in its natural state, except that drain checks or similar erosion control measures may be required if the frequency of the 2-year storm runoff, under present conditions, is materially affected. Normal depth and velocity shall be checked for a distance of 660 feet downstream.

- Should the existing drainage onto adjacent land consist of sheet runoff, concentrated flows shall be diffused. A level area of reinforced turf sufficient for spreading the flow shall be provided.

- The Drain Commissioner may require the receiving stream to be cleaned of debris to ensure an adequate stormwater outlet for a proposed development.

DRY DETENTION BASIN EXAMPLE



4.7 DETENTION PONDS – WET DETENTION CRITERIA

4.7.1 Construction Standards

Wet detention facilities must be built to optimize the filtration and nutrient uptake of marsh type wetland plants. To insure that the detention basin is designed and built properly, the following general guidelines must be used.

- The pond must be designed to contain runoff from the 25 – year rainfall event. (4% annual chance).
- Minimum buffer/setback for the wet detention basin shall be 50 feet from the basin easement to any dwelling.
- Adequate access must be provided for the removal of sediment.
- Baffles may be required to prevent short circuiting the hold time of the basin.

4.7.2 Detention Basin Grades

- Banks – 25% maximum allowed anywhere
- Near normal waterline – 7% maximum from 10.0" above to 24.0" below the normal waterline. Below this point, slopes must be no steeper than 1 vertical to 4 horizontal.

  NOTE: PERMANENT IMPOUNDMENTS OR OPEN PIT PONDS DESIGNED AS SITE AMENITIES HAVE AN INHERENT RISK, WHICH MUST BE ASSUMED BY THE LANDOWNER. THE LANDOWNER IS THE PARTY RESPONSIBLE FOR POLICING HIS PROPERTY. THESE TYPES OF SITE AMENITIES WILL ONLY BE ALLOWED IF THE DISTRICT IS HELD HARMLESS BY THE LANDOWNER.

- Bottom Grades
  - The bottom may be undulated to better promote the establishment of wetland vegetation. Pockets or depressions shall be varied in size from 100 sq. ft. to 1000 sq. ft. and shall not be more than 12 inches deep.
  - Dikes may be used as baffles to lengthen the flow line through the basin. The height of the dikes shall not exceed ¼ of the design depth.

4.7.3 Low Flow/Extended Release

The criteria are the same as for dry ponds. See section 4.6.3

4.7.4 Outlet Structure and Emergency Spillway

The criteria are the same as for dry ponds. See section 4.6.4

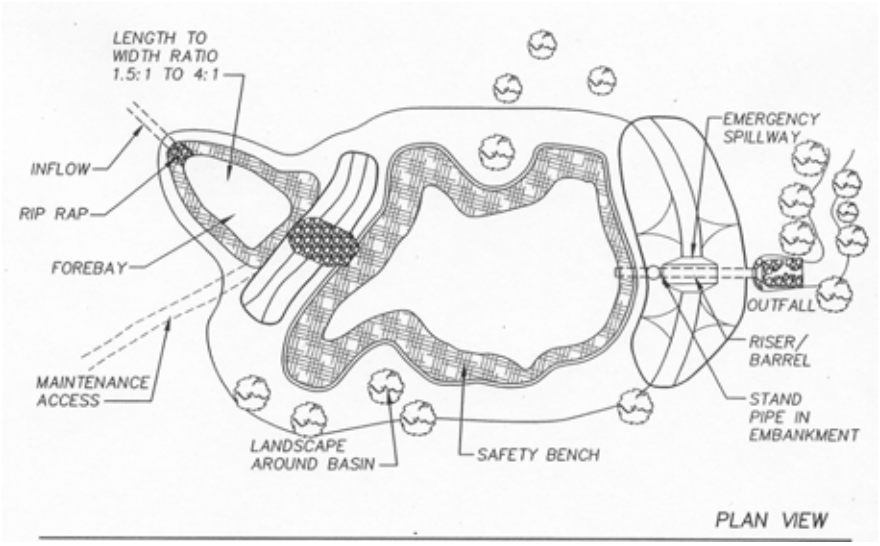
4.7.5 Receiving Stream

The criteria are the same as for dry ponds. See section 4.6.5

4.7.6 Planting Plan

A landscape plan shall be submitted identifying the wetland plants to be established, the limits of turf maintenance and the placement of shrubs and bushes between the maintenance and non-maintenance areas.

WET DETENTION BASIN EXAMPLE



4.8 RETENTION PONDS – INFILTRATION BASIN CRITERIA

4.8.1 Construction Standards

- The infiltration basin shall be designed to store runoff from back-to-back 100-yr rainfall events (1% annual chance) if no positive outlet is available. If a positive outlet is available for an emergency spillway, the pond shall be sized to store runoff for a single 100-yr event (1% annual chance).

- Construction of the infiltration basin shall be within a remote location to provide easy maintenance access as well as eliminate a potential nuisance

for future home owners.

- When sizing the basin, infiltration cannot be accounted for to reduce the required volume.

- The bottom of the infiltration system shall be a minimum of 4 feet above the highest known water table elevation.

- Minimum buffer/setback for the infiltration basin shall be 25 feet from the basin easement to any dwelling.

- The infiltration system shall be designed to drain completely within 72 hours. Soil borings and infiltration rates shall be submitted as backup for the proposed infiltration facility.

- A design infiltration rate of 0.5 times the infiltration rate determined by geotechnical investigation, or an infiltration rate of 0.52 in/hr, shall be used to estimate the maximum time to drain by the equation:

$$72 \geq 12D / I$$

Where:	72	= Maximum allowable drain time (hours)
	12	= Factor to convert inches to feet
	D	= Basin depth (feet)
	I	= Design infiltration rate (in/hr)

- The contractor shall avoid compaction the soil in the infiltration basin area during excavation and grading. The final 2 feet of depth shall be removed by excavating to finish grade.

- A treatment forebay or equivalent storm water filter shall be included with any infiltration basin design. This forebay shall store the “first flush” of pollutants and sediment found in stormwater runoff. This forebay should be sized to store the first 0.5” of runoff for the site for 12 to 24 hours. This volume can be included in the overall required storage volume.

- The outlet structure from the treatment forebay shall be designed as a spillway to release water when the treatment forebay volume has been reached.

- All accumulated sediment shall be removed from the infiltration basin and the bottom scarified 4” to 6” prior to final approval.

- A flat maintenance shelf with a minimum width of 15-ft shall be provided around the perimeter of the basin.

- The Developer/Owner shall sign a maintenance agreement that requires that the retention basin be monitored for 3-years or until the last homesite has been construed and the lawn is established. The basin shall be inspected every two weeks or within 24 hours after a significant storm event during the growing season or while the soil in the basin is exposed. Any accumulation of sediment on the bottom of the basin shall be clean out and disk the soil in the bottom if necessary. A performance bond shall be submitted to ensure the work will be completed.

4.8.2 Detention Basin Grades

- Banks – 25% maximum allowed anywhere

- Bottom Grades – The bottom of the basin shall be as flat as possible to encourage uniform ponding and infiltration.

  NOTE: PERMANENT IMPOUNDMENTS OR OPEN PIT PONDS DESIGNED AS SITE AMENITIES HAVE AN INHERENT RISK, WHICH MUST BE ASSUMED BY THE LANDOWNER. THE LANDOWNER IS THE PARTY RESPONSIBLE FOR POLICING HIS PROPERTY. THESE TYPES OF SITE AMENITIES WILL ONLY BE ALLOWED IF THE DISTRICT IS HELD HARMLESS BY THE LANDOWNER.

4.8.3 Outlet Structure and Emergency Spillway

The criteria are the same as for dry ponds. See section 4.6.4

4.8.4 Receiving Stream

If a receiving stream is utilized, the criteria are the same as for dry ponds. See section 4.6.5

4.8.5 Additional Items

The Drain Commission may require the following items in some instances where infiltration basins are to be used:

Leaching Basins	Perforated Underdrain
Filter Strips	Level Spreaders

INFILTRATION/RETENTION BASIN EXAMPLE