CITY OF VINCENNES

STORMWATER TECHNICAL STANDARDS

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I. GENERAL

Best management practices can refer to structural measures (wetlands, ponds, sand filters, etc.) or non-structural measures (restrictive zoning, reduced impervious areas, etc.). BMPs are designed for the benefit of water quality and quantity. The following guidelines are intended to assist by outlining design criteria and recommending design methods for structural water quality BMPs.

Drainage design is an unique area of Civil Engineering because there are no definitive methods or rules that give absolute answers to engineering questions. The drainage designer must rely heavily on engineering judgment, experience, and common sense in order to achieve good solid drainage design. The many drainage design methods available to the engineering community are only tools to aid the engineer in making his or her judgments. It is crucial that the drainage designer fully understand each method that is employed, especially the limitations of each particular method. Only by having this understanding can the design be assured of coming up with a reasonable drainage design.

This guide provides design criteria and information for water quality best management practices, or BMPs as required by the City of Vincennes Municipal Separate Storm Sewer Program.

INFORMATION REQUIREMENTS

All of the following information and data, prepared and certified by an Indiana licensed professional engineer or land surveyor engaged in a storm drainage design shall be submitted to the Board for approval prior to application for a Building Permit for any development, redevelopment or new construction on real estate which lies within the jurisdiction of the Board.

The minimum sheet size of all maps and plats submitted in conjunction with the following shall be 8-1/2 inches by 11 inches; and the maximum sheet size shall 24 inches by 36 inches.

A. Topographic and Soils Map

A soils map of the proposed development and off-site contributing drainage areas, indicating soil names and their hydrologic classification, must be provided. In addition, a topographic map of the land to be developed and such adjoining land whose topography may affect the layout or drainage of the development must be provided. The contour intervals shall be one foot when slopes are less than four percent, and shall be two feet when the slope exceeds four percent. On this map the following shall be shown:

1. The location of streams and other flood water runoff channels, the extent of the floodplains at the established 100-year flood elevation where available (regulatory floodway), and limits of the floodway, all properly identified.
2. The normal shoreline of lakes, ponds, swamps and stormwater control facilities, their floodplains, and points of inflow and outflow if any.
3. The location and elevation of regulated drains, farm drains, inlets and outfalls, if any of record.
4. Storm, sanitary, and combined sewers and outfalls, if any of record.
5. The location of domestic and commercial waste systems and outlets, if any of record, or as otherwise known to applicant.
6. Seeps, wetlands, springs, and wells, that are visible or of record.

B. Drainage Plan

A comprehensive plan designed to handle safely the stormwater runoff and to detain the increased stormwater runoff must be provided. The plan shall provide or be accompanied by maps or other descriptive materials, illustrating pre-development and proposed development conditions, indicating the feasibility of the drainage plan and showing the following:

1. The extent and area of each watershed affecting the design of detention facilities as shown on USGS Quadrangle Maps or other more detailed maps as required by the Board. Also provide a vicinity map that geographically locates project area within the County.
2. The extent and area of each watershed tributary to the drainage channels in the development.
3. The street storm sewers and other storm drains to be built, the basis of their design, outfall and outlet locations and elevations, the receiving stream or channel and its 100-year water elevation, and the functioning of the drains during high water conditions.
4. The parts of the proposed street system where pavements are planned to be depressed sufficiently to convey or temporarily store overflow from storm sewers and over the curb runoff resulting from the heavier rainstorms and the outlets for such overflow.
5. Existing streams and floodplains to be maintained, and new channels to be constructed, their locations, cross sections and profiles.
6. Proposed culverts and bridges to be built, their materials, elevations, waterway openings and basis of their design.
7. Existing stormwater control facilities to be maintained, enlarged, or otherwise altered and new basins or ponds to be built and the basis of their design.
8. The estimated location and percentage of impervious surfaces existing and expected to be constructed when the development is completed.
9. The slope, type and size of all sewers and other waterways.
10. For all detention basins, a plot or tabulation of storage volumes with corresponding water surface elevations and a plot or tabulation of the basin outflow rates for those water surface elevations.
11. SWPPP.
12. Any existing and proposed easements and rights of access.
13. Party responsible for the permanent ownership and maintenance of the drainage system and a description of all maintenance requirements.

C. Valley Cross Section

One or more typical cross sections (if necessary and appropriate) must be provided showing all existing and proposed channels or other open drainage facilities carried to a point above the 100-year high water elevation; showing the elevation of the existing land and the proposed changes thereto, together with the high water elevations expected from the 100-year storm under the controlled conditions called for by this ordinance; and showing the relationship of structures, streets and other facilities.

D. Site Plan

A plan drawn to scale showing dimensions of the site with existing and proposed storm drainage facilities must be provided.

E. Stormwater Pollution Prevention Plan for Construction Sites

A stormwater pollution prevention plan associated with construction activities must be designed to, at least, meet the requirements of this Ordinance and must include the following:

Location, dimensions, detailed specifications, and construction details of all temporary and permanent stormwater quality measures.

Temporary stabilization plans and sequence of implementation.

Permanent stabilization plans and sequence of implementation.

Temporary and permanent stabilization plans shall include the following:

Specifications and application rates for soil amendments and seed mixtures.

The type and application rate for anchored mulch.

Construction sequence describing the relationship between implementation of stormwater quality measures and stages of construction activities.

A typical erosion and sediment control plan for individual lot development.

Self-monitoring program including plan and procedures.

A description of potential pollutant sources associated with the construction activities, which may reasonably be expected to add a significant amount of pollutants to stormwater discharges.

Material handling and storage associated with construction activity shall meet the spill prevention and spill response requirements in 327 IAC 2-6.1.

F. Post-Construction Storm Water Pollution Prevention Plan

The post-construction storm water pollution prevention plan must include the following information:

A description of potential pollutant sources from the proposed land use, which may reasonably be expected to add a significant amount of pollutants to stormwater discharges.

Location, dimensions, detailed specifications, and construction details of all post-construction stormwater quality measures.

A description of measures that will be installed to control pollutants in stormwater discharges that will occur after construction activities have been completed. Such practices include infiltration of run-off, flow reduction by use of open vegetated swales and natural depressions, buffer strip and riparian zone preservation, filter strip creation, minimization of land disturbance and surface imperviousness, maximization of open space, and stormwater retention and detention ponds.

A sequence describing when each post-construction stormwater quality measure will be installed.

Stormwater quality measures that will remove or minimize pollutants from stormwater run-off.

Stormwater quality measures that will be implemented to prevent or minimize adverse impacts to stream and riparian habitat.

A narrative description of the maintenance guidelines for all post-construction stormwater quality measures to facilitate their proper long term function. This Operation and Maintenance manual will be kept on file by the City of Vincennes for use during inspections. A copy will also be provided to the landowner for informational purposes.

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II. CONSTRUCTION BMPs

The City of Vincennes has adopted the *Indiana Stormwater Quality Manual* and *the Indiana Handbook for Erosion Control in Developing Areas* by reference. BMPs and methods described for designing, installing and managing erosion and sediment control practices are hereby accepted for use in the City of Vincennes. Please refer to those publications for further information and design standards.

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III. POST-CONSTRUCTION BMPs

The City of Vincennes has adopted a policy that the control of stormwater runoff quality will be based on the management of total suspended solids (TSS). The target TSS removal rate is eighty (80%) percent. In addition to TSS removal, BMPs must also be designed to treat the water quality volume (WQv) or the first flush of runoff. The water quality volume is the storage needed to capture and treat the runoff from the first inch of rainfall. In numerical terms, it is equivalent to an inch of rainfall multiplied by the volumetric runoff coefficient (Rv) and the site area.

The following equation is used to calculate WQv (in acre-feet):

$$WQv = \frac{(P)\,(Rv)\,(A)}{12}$$

where:

- WQv = water quality volume (acre-feet)
- P = 1 inch of rainfall
- Rv = 0.05 + 0.009(I) where I is percent of impervious cover
- A = area in acres

Pre-Approved BMPs

BMP Type	Description	Quantity Control	WQv and 80% TSS Removal
Stormwater Ponds	Stormwater ponds are constructed stormwater retention basins with a permanent water pool. Runoff from each rain event is captured & treated.	Yes	Yes
Stormwater Wetlands	Stormwater wetlands are constructed, artificial wetland systems used for stormwater management. They consist of a combination of shallow marsh areas, open water areas and semi-wet areas.	Yes	Yes
Bioretention Areas	Bioretention areas are shallow stormwater basins or landscaped areas that utilize engineered soils and vegetation to capture and treat stormwater runoff.	No	Yes
Water Quality Swales	Water Quality Swales are vegetated open channels that are designed and constructed to capture and treat stormwater runoff within dry cells.	No	Yes
Biofilters	Biofilters provide some filtering of stormwater runoff but by themselves they cannot remove 80% TSS. These can only be used as pre-treatment or part of a treatment train.	No	No
Catch Basin/Swirl Chamber	Catch Basins and Swirl Chambers are small filtering devices installed in line with the storm sewer systems to trap suspended solids and other pollutants. These must be approved on a case by case basis.	No	Yes

Stormwater Ponds

Wet retention ponds can be designed to meet both water quality and water quantity requirements. The wet pond or retention pond is a facility which removes sediment, Biochemical Oxygen Demand (BOD), organic nutrients, and trace metals from stormwater runoff. This is accomplished by slowing down stormwater using an in-line permanent pool or pond effecting settling of pollutants. The drainage area should be such that an adequate base flow is maintained in the pond.

A. Design Considerations
   1. The minimum length width ratio should be 3:1, preferably expanding outward toward the outlet.
   2. Maximize the distance between the inlet and outlet. This provides more time for mixing of the new runoff with the pond water and settling of pollutants.
   3. The stormwater pond must be constructed such that the water is not allowed to infiltrate from the permanent portion of the pool. Provide a geotextile or clay line if necessary.
   4. A forebay (or other pretreatment) shall be provided for each inlet to the pond.

B. Design Sequence
   1. Determine the watershed area and the areas to be treated. When designing the BMP for the effective area where the offsite areas bypass the BMP, the design shall only consider the drainage from the site (area to be treated).
   2. Determine the percentage of impervious area for the site.
   3. Determine the size of the forebay (or other pretreatment) for each inlet to the pond. The preferred method for each forebay is as follows:
      a. The depth is three (3’) feet below the normal pool.
      b. The berm, located one half (0.5’) foot below the normal pool, is five (5’) feet in width, semi-circular in shape with wetland plantings on top. (forebay effective depth is 2.5’)
      c. The bottom of the forebay must be a hard surface to facilitate cleanout.
      d. The forebay storage volume counts toward the water quality storage requirements.
      e. Size the forebay to contain 0.1 inches of runoff per impervious acre of contributing drainage.

   The following equation is used to calculate forebay volume FBv (in acre-feet):

$$FBv = (P)\,(A) / 12$$

where:

FBv = forebay volume (acre-feet)
P = 0.1 inch of rainfall
Aimp = Impervious area in acres

   4. Determine the Water Quality Volume – This volume shall be provided above the normal pool of the stormwater pond.

   The following equation is used to calculate WQv (in acre-feet):

$$WQv = \frac{(P)\,(Rv)\,(A)}{12}$$

where:

WQv = water quality volume (acre-feet)
P = 1 inch of rainfall
Rv = 0.05 + 0.009(I) where I is percent of impervious cover
A = area in acres

   5. Determine the size of the water quality orifice necessary to detain the water quality volume over a period of twenty-four (24) hours.
      a. Use the Orifice Equation to determine the size of the outlet necessary to provide a draw down time greater than twenty-four (24) hours.

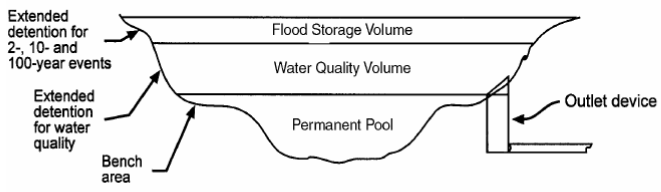
$$Q = CA(2gh)^{0.5}$$

where:

Q = Desired flow rate (cfs)
C = Inlet coefficient (Typically 0.6)
A = End area of pipe (sft)
G = Gravity 32.2 ft/s^2
H = Hydraulic Depth (ft) – (Total Depth minus half the pipe diameter)

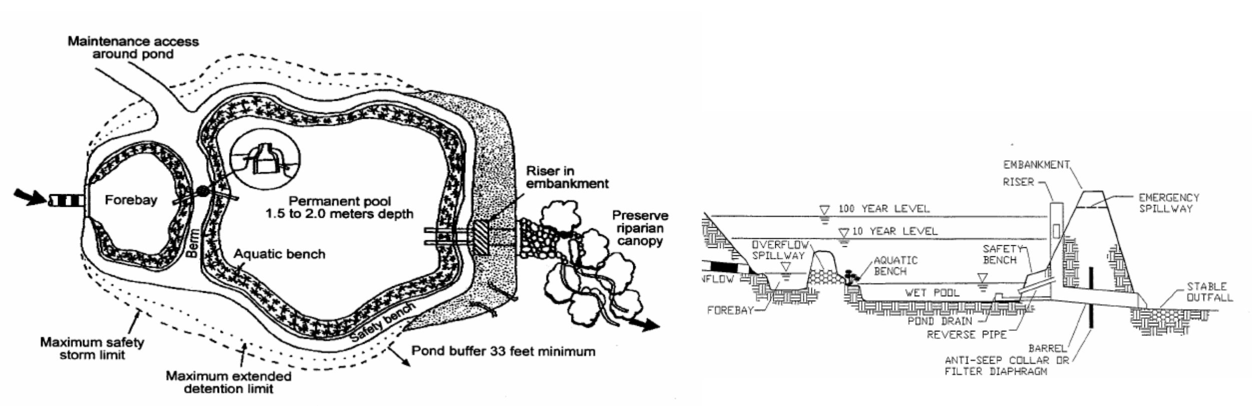
b. Use a computer model to show that at least twenty (20%) of the required Water Quality Volume is provide over a period of twenty-four (24) hours.
c. The minimum size of the orifice shall not less than four (4”) inches.

6. Design a multi-stage orifice to limit the stormwater runoff as required by the Stormwater Ordinance. A four (4”) inch diameter orifice is the smallest size acceptable, unless special accommodation is made to reduce the risk of plugging.



Source: Wet Detention Ponds, Pitt. 1998

C. Maintenance Considerations
1. Sediment removal in the forebay shall occur when 50% of the total capacity has been lost.
2. These shall be stated in the Operation and Maintenance Manual



Extended Storage Pond with a Sediment Forebay
Source: Schueler, 1992

SAMPLE STORMWATER POND PROJECT

Site Area: 27.68 acres
Common Area and Ponds: 9.29 acres

(The common area for this project is the grass area surrounding the ponds. This area will not have any paved or impervious areas other than the pond itself.)

69 Lots (55’ x 50’)
69 Drives (18’ x 40’)
3045’ Street (30’ + 4’ + 4’)

Impervious: 18.39 acres for house pads — 8.15 acres

Average Percent Impervious: 44.3% = ((8.15 acres)/(18.39 acres))*(100)

Forebay Volume: FBV = (Aimp)(P)/12 = (8.15)(0.1)/12 = 0.07 ac-ft = 2,958 cft

Forebay	Basin Area	Impervious Area	Forebay Volume	Forebay Top Radius
1	0.73 ac.	0.32 ac.	117.39 cft.	7.73 ft.
2	2.02 ac.	0.89 ac.	324.83 cft.	12.86 ft.
3	4.13 ac.	1.83 ac.	664.14 cft.	18.39 ft.
4	2.06 ac.	0.91 ac.	331.27 cft.	12.99 ft.
5	3.28 ac.	1.45 ac.	527.45 cft.	16.39 ft.
6	0.93 ac.	0.41 ac.	149.55 cft.	8.73 ft.
7	2.26 ac.	1.00 ac.	363.43 cft.	13.60 ft.
8	2.98 ac.	1.32 ac.	479.21 cft.	15.62 ft.
Total	18.39 ac.	8.15 ac.	2,958 cft	Average = 13.3 ft

Forebay Specifications:

- Depth: 2.5’ deep
- Shape: Half Circle
- Top Radius: 15 ft.
- Bottom Area: 0.0 sft.

Forebay volume = (2.5’/2)((3.14*15^2)/2) = 442 cft (8 Forebays)(442 cft) = 3536 cft > 2958 cft

Water Quality Volume

Rv = 0.05 + (0.009)(I) = 0.05 + (0.009)(44.3) = 0.45 where I is the percent impervious

WQv = (P)(Rv)(A)/12 = (1)(0.45)(18.39)/12 = 0.69 ac-ft

Pond Normal Pool (NP) = 2.55 acres ➔ (0.69 ac-ft)/(2.55 acres) = 0.27’ or 3.25” Above NP (Used 0.3’)

Depth of Extend Detention = 0.3 feet ➔ (0.3’)(2.55 ac) = 0.77 ac-ft > 0.69 ac-ft ➔ ok

Average Rate of Release over 24 hours = (0.77 acre-ft)(43,560 cft/ac)/(86,400 seconds) = 0.39 cfs

Head on 6” Diameter Pipe = (0.3’ – 0.25’) = 0.05’

Use the Orifice Equation to determine the size of the outlet necessary to detain the WQv for 24 hours.

Q = CA(2gh)^0.5 = (0.6)(0.196 sft)(2 x 32.2 x 0.05)^0.5 = 0.21 cfs ➔

(0.77 ac-ft)(43,560 cft/ac)/(0.22 cfs x 3600 seconds) = 42.35 hours
24 hour < 42.35 hours < 48 hours ➔ OK

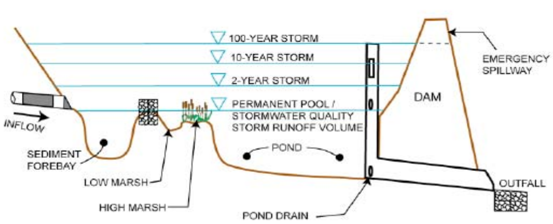
The detention pond is then sized per stormwater ordinance requirements using elevations above the Extended Detention Depth.

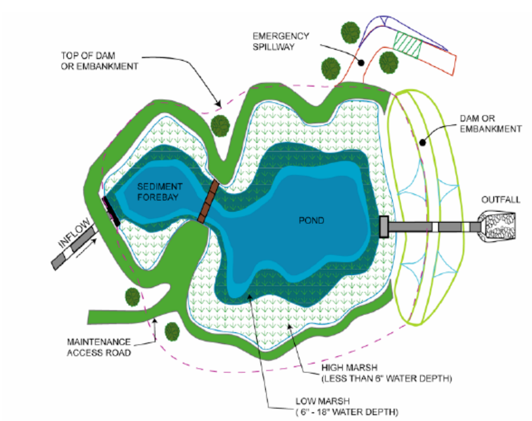
Stormwater Wetlands

Stormwater wetlands are artificial wetlands created for the purposes of stormwater pollutant removal and quantity control. Wetlands provide physical, chemical, and biological water quality treatment of stormwater runoff. The large surface area of the bottom of the wetland encourages higher levels of adsorption, absorption, filtration, microbial transformation, and biological utilization than might normally occur in more channelized water courses. Wetlands are characterized by the substrate being predominantly undrained hydric soil.

A. Design Considerations
1. The wetland should be designed such that a minimum amount of maintenance is required. This can be accomplished by approximating a natural situation as much as possible and avoiding unnatural attributes, such as a rectangular shape or rigid channels.
2. It is necessary to recognize that a fully functional wetland cannot be established spontaneously. Time is required for vegetation to establish and for nutrient retention and wildlife enhancement to function efficiently.
3. Both wetland ponds and channels require a near-zero longitudinal slope.
4. The minimum length width ratio should be 3:1 and incorporate long flow paths.
5. Forebays should be provided at the inlets for sediment concentration.
6. The outlet should be placed in an offbay at least 3 ft deep.
7. Soil types conducive to wetland vegetation should be used during construction.
8. Surrounding slopes must be stabilized, with the side slopes of the wetland being 4:1 or flatter.
9. The wetland pond should provide a minimum permanent storage equal to three-fourths of the water quality volume. The full water quality capture volume should be provided above the permanent pool.
10. Deepwater – 1.5’ to 6’ below the normal pool.
11. Low marsh – 6”-18” below normal pool, high marsh – 6” below normal pool - The high marsh area should have a greater surface area to volume ration than the low marsh area.
12. Semi-wet-zone – areas above normal pool – supports vegetation that can survive periodic flooding.
13. The depth of the water quality volume above the permanent pool should not exceed 2 ft. While, open-water areas may vary in depth between 2 and 4 ft and least 25 percent of the basin area.
14. Construction of the wetland shall not begin until the site work has been completed.
15. Professional assistance for the design, construction and maintenance of the wetland is highly recommended.
16. The current policy of the Indiana Department of Environmental Management prohibits the use of existing wetlands as a pollution control measure. However, using a site where nearby wetlands still exist is preferable.

Constructed Stormwater Wetland Components





B. Design Sequence

1. A water balance must be performed to demonstrate that a stormwater wetland could withstand a thirty (30) day drought at summer evaporation rates without completely drawing down. Also, inflow of water must be greater than that leaving the basin by infiltration or exfiltration. The following water balance equation should be used in calculations:

$$S = Qi + R + Inf – Qo – ET$$

   Where:
   S = net change in storage
   Qi = stormwater runoff inflow
   R = contribution from rainfall
   Inf = net infiltration (infiltration - exfiltration) Qo = surface outflow
   ET = evapotranspiration

2. Determine the size of the water quality orifice necessary to detain the water quality volume over a period of forth-eight (48) hours. The small orifices needed to provide the extended detention time will need to be protected.
3. Check if the surface area of the wetland is at least one (1%) percent of the area of the watershed draining into to it. Two or three percent is preferred.
4. Determine the wetland plantings:
   a. Two (2) aggressive wetland species of vegetation shall be established in quantity on the wetland.
   b. Three additional wetland species of vegetation shall be planted on the wetland, although in far less numbers
   c. 30 to 50 percent of the shallow (12 inches or less) area of the basin be planted with wetland vegetation.
   d. Approximately 50 individuals of each secondary species must be planted per acre; set out in 10 clumps of approximately 5 individuals and planted within 6 feet of the edge of the pond in the shallow area leading up to the ponds edge; spaced as far apart as possible, but no need to segregate species to different areas of the wetland.
   e. Wetland mulch, if used, shall be spread over the high marsh area and adjacent wet zones (-6 to +6 inches of depth) to depths of 3 to 6 inches. A minimum 25 foot buffer, for all but pocket wetlands, must be established and planted with riparian and upland vegetation (50 foot buffer if wildlife habitat value required in design).

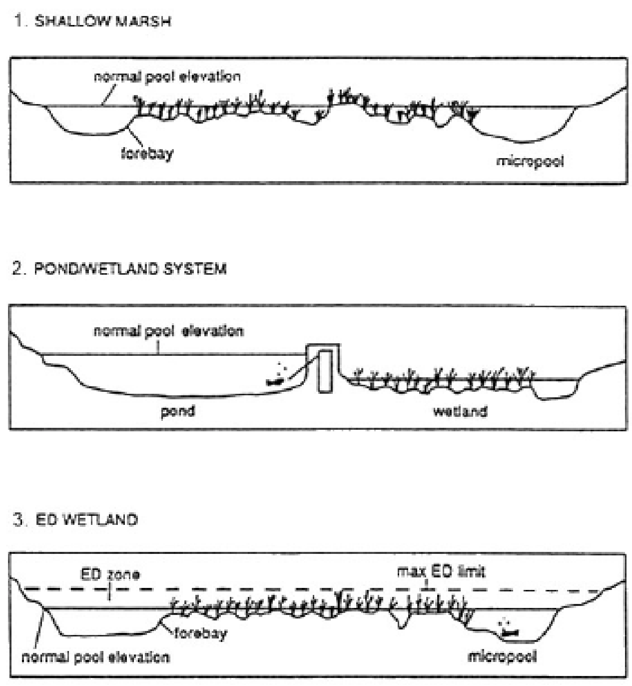
Design Criteria for Constructed Stormwater Wetlands

Design	Shallow Wetland	Pond/Wetland	Extended Detention
Length to Width	3:1	3:1	3:1

Allocation of WQv (pool/marsh/semi-wet) in %	25/75/0	70/30/0 (include pond volume)	20/30/50*
Allocation of surface area (deep water/ low marsh/ high marsh/ semi-wet) in %	20/35/40/5	45/25/25/5 (includes pond surface area)	20/20/10/50*
Forebay	Required	Required	Required
Micropool	Required	Required	Required
Outlet Configurations	Reverse-slope pipe, hooded weir	Reverse-slope pipe, hooded weir	
Cleanout Frequency (years)	2 to 5	10	2 to 5
Outlet Configuration	Reverse-Slope or Broad Crested Weir	Reverse-Slope or Broad Crested Weir	Reverse-Slope or Broad Crested Weir

*In an Extended Detention Wetland fifty (50%) percent of the Stormwater Quality Runoff Volume is temporarily stored in the semi-wet zone. Release of this volume must meet the requirements for Extended Detention Basins. (Schueler, 1992)

C. Maintenance Considerations
1. Sediment removal in the forebay shall occur when 50% of the total capacity has been lost.
2. These shall be stated in the Operation and Maintenance Manual



Comparative Profiles of the Three Stormwater Wetland Designs (Schueler, 1992)

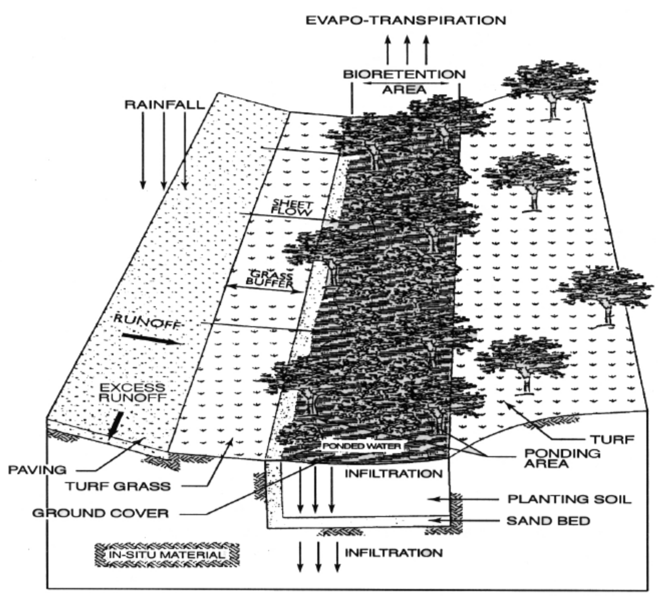
Bioretention

Bioretention areas, or rain gardens, are structural stormwater controls that capture and temporarily store the WQv using soils and vegetation in landscaped areas to remove pollutants from stormwater runoff.

Bioretention areas are engineered facilities in which runoff is conveyed as sheet flow to the "treatment area," consisting of a grass buffer strip, ponding area, organic or mulch layer, planting soil, and vegetation. An optional sand bed can be included in the design to provide aeration and drainage of the planting soil. The filtered runoff is typically collected and returned to the conveyance system, though it can be exfiltrated into the surrounding soil in areas with porous soils.

A. Design Considerations

1. Bioretention facilities are designed for intermittent flow and should drain and aerate between rainfall events. Sites with continuous flow from groundwater, sump pumps or other areas must be avoided. The ground surface must be two (2') feet above the water table.
2. Drainage provided by sheet flow only (less than 1ft/s)
3. Minimum area is 200 sft. (at least 15 feet wide and a minimum length of 40 feet long)
4. Planting soil four (4') deep minimum and a 1.5 to 3 percent organic content with a maximum 500-ppm concentration of soluble salts.
5. Planting soils must be sandy loam, loamy sand or loam texture with a clay content rating from 10 to 25 percent
6. Soils should have an infiltration rate of at least 0.5 inches per hour.
7. The soil pH should be between 5.5 and 6.5.
8. Maximum ponding depth 0.5'.



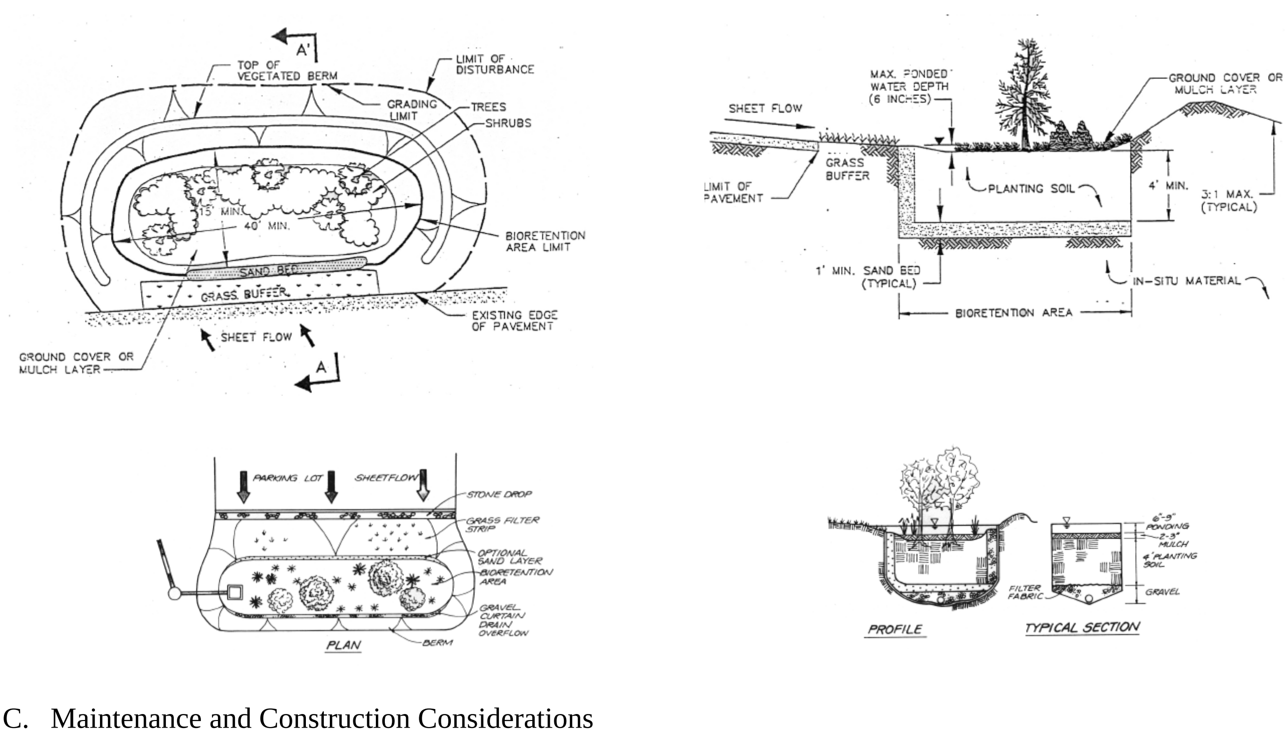
Bioretention Area Conceptual Layout
(Prince George's County Dept. of Environmental Protection, 1993)

B. Design Components

1. Darcy's law (Q = kiA) – drain time 48 hours – k of 0.5ft/day (minimum)

2. Provide a grass filter strip (6’ min.) between the contributing drainage area and the ponding area.
3. Provide a mulch layer must consist of 2-4 inches of commercially available finely shredded hardwood mulch or shredded hardwood chips.
4. Provide a sand bed 12-18 inches thick. Sand must be clean and have less than 15% silt or clay content.
5. Pea gravel for the diaphragm and curtain, where used, must be ASTM D 448 size No.6 (1/8 "to 1/4").
6. Provide an underdrain collection system must be equipped with a 6 inch perforated PVC pipe in an 8-inch gravel layer. The pipe must have 3/8-inch perforations, spaced on 6-inch centers with a minimum of 4 holes per row. The pipe is spaced at a maximum of 10 feet on center, and a minimum grade of 0.5% must be maintained. A permeable filter fabric is placed between the gravel layer and the planting soil bed. The filter fabric must be non-woven, non-heat bond and needle-punched.
7. Provide a minimum elevation difference from the inflow to the outflow of 5 feet.
8. Design an overflow structure and a non-erosive overflow channel must be provided to safely pass the flow from the bioretention area that exceeds the storage capacity to a stabilized downstream area. The high flow structure within the bioretention area can consist of a yard drain catch basin, with the throat of the catch basin inlet typically 6 inches above the elevation of the shallow ponding area.

Bioretention Areas: Parking Edge Without Curb
(Prince George’s County Dept. of Environmental Protection, 1993)



C. Maintenance and Construction Considerations

1. If the bioretention area is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the bioretention

area and elevations and grades have been established as noted in the approved stormwater management plan for post-construction runoff control.

2. Landscaping is critical to the performance and function of the bioretention area. A dense and vigorous groundcover must be established over the contributing pervious drainage area before runoff can be diverted into the facility.
   - The bioretention area should be vegetated like a terrestrial forest ecosystem, with a mature tree canopy, subcanopy of understory trees, scrub layer and herbaceous ground cover. Three species of each tree and shrub type should be planted.
   - The tree-to-shrub ration should be 2:1 to 3:1. On average, trees should be spaced 8 feet apart. Plants should be placed at regular intervals to replicate a natural forest. Woody vegetation should not be planted at inflow locations.
   - After the trees and shrubs are established, the ground cover and mulch should be established.
   - Use native plants, selected based upon hardiness and water tolerance.

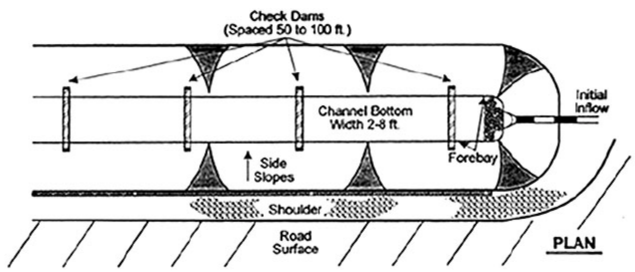
Water Quality Swales

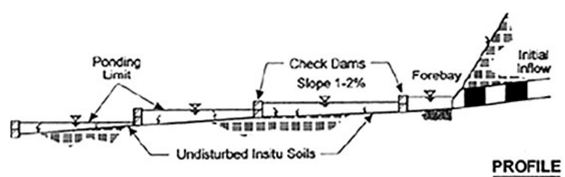
Water quality swales are shallow vegetated channels designed and constructed to capture and convey stormwater where pollutants are removed by filtration through grass and infiltration through soil. They are wider than a ditch that is sized only to transport flow, require shallow slopes and shallow flow and soils that drain well. Water quality swales are limited to areas with relatively low percentage of impervious acreage, such as residential and industrial developments.

A. Design Considerations

1. Vegetated swales are often used as a pretreatment measure for other downstream BMPs

2. Runoff waters are typically not detained long enough to effectively remove very fine suspended solids, and swales are generally unable to remove significant amounts of dissolved nutrients.
3. Water quality swales are channels designed with a filter bed and underdrain system. They are designed to filter and infiltrate the entire WQv through the bottom of the swale.
4. Runoff is collected by a perforated pipe and discharged at the outlet.
5. Max depth = 12 to 18 inches
6. Water quality swales perform best in high permeable soils (k of 0.5ft/day having a 30” minimum depth)
7. Seasonal highwater table three (3’) feet below the bottom of the swale.
8. Select swale location based on the design parameters. - If locations available cannot accommodate a linear swale, a wide-radius curved path can be used to gain length or the designer may need to investigate how the flow (Q) can be reduced.
9. A dense planting of grass provides the filtering mechanism responsible for water quality treatment in swale. In areas of poor drainage, wetlands species can be planted for increased vegetative cover. Use wetland species that are finely divided like grass and relatively resilient. Invasive species, such as cattails, should be avoided to limit proliferation in the swale





B. Design Sequencing

1. The design begins by providing a forebay for each inlet.
2. Verify the maximum ponding time is less than 48 hours
3. Verify the residence time is five (5) minutes
4. Determine the peak flow rate (100 year) and the Water Quality Volume (WQv) to the system.
5. If the peak flow rate exceeds one (1 ft/s) foot per second, the runoff from larger events should be designed to bypass the swale.
6. Determine the slope of the system – between one (1%) and six (6%) percent.
7. Select a swale shape - trapezoidal cross-sections are preferred because of relatively wider vegetative areas and ease of maintenance. A parabolic shape is also acceptable, provided the

width is equal to or grater than the design bottom width for a trapezoidal cross section.

8. Determine required channel width and depth using Manning equation. Typical bottom widths range from two (2') feet to eight (8') feet.
9. Calculate the cross-sectional area of flow for the channel.
10. Calculate the velocity of channel flow. V (ft/sec)=Q(cfs)/A(ft2) This velocity should be less than 1.0 ft/s, a velocity that was found to cause grasses to be flattened, reducing filtration.
11. Calculate swale length - (100' min)

    $$L=(60)(V)(5\text{ minutes})$$

    Where:
    L=length required to achieve residence time
    V=velocity of channel flow (ft/sec)

    For example, if V = 1.0 ft/s, then a 300-ft swale is needed for a 5-min residence time

    If the value of V suggests that a longer swale will be needed than space permits, investigate how the design flow Q can be reduced, or increase flow depth (y) and/or swale width (wt) up to the maximum allowable values and repeat the analysis.

C. Maintenance Considerations

1. The treatment of potential for mosquito breeding areas must be addressed in the Operation and Maintenance Manual.
2. These shall be stated in the Operation and Maintenance Manual

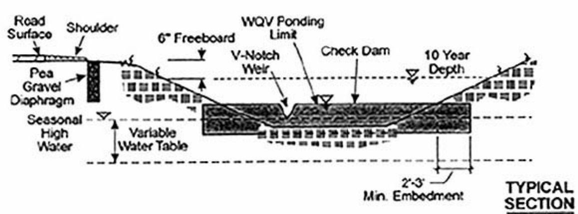


Figure 1. Wet Swale

Source: Center for Watershed Protection 1999

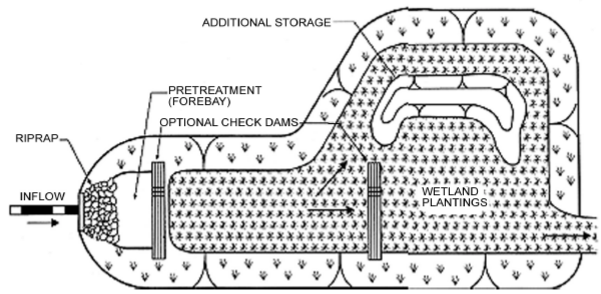


Figure 2. Wet Swale

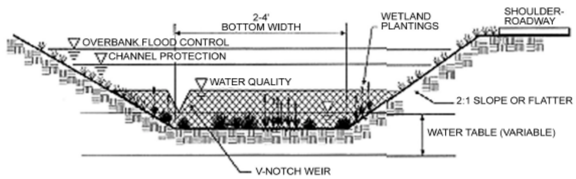


Figure 3. Wet Swale Cross Section

Source: Center for Watershed Protection. 2001

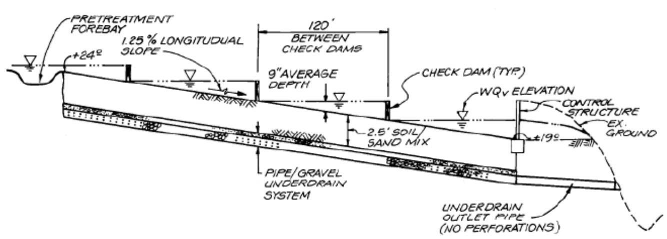
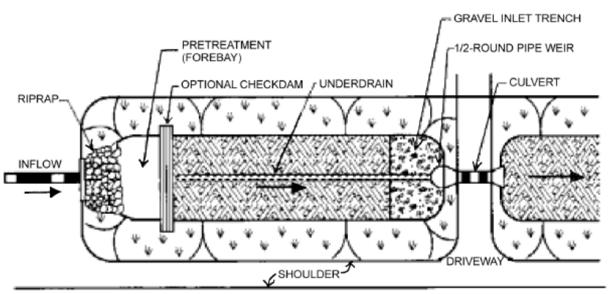


Figure 1: Dry Swale Longitudinal Section
Source: Maryland, 2000



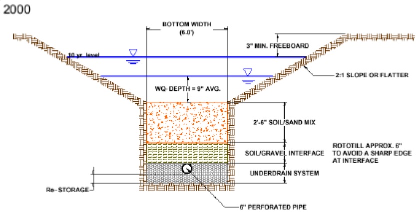


Figure 3: Dry Swale Trapezoidal Section
Source: Maryland, 2000.

Figure 2: Dry Swale Plan View
Source: CWP, 2000

Biofilters

Biofilters are densely vegetated sections of land, designed to treat runoff from and remove pollutants through vegetative filtering and infiltration. Biofilters must receive runoff from adjacent areas as sheet flow. The vegetation slows the runoff and filters out sediment and other pollutants. However, the TSS removal provided is less than 80 percent. Therefore, biofilters must be used in a treatment train in conjunction with other management practices to provide the 80 percent performance goal.

Biofilters are best suited to treating runoff from roadways, rooftops, small parking areas and pervious areas. They can be easily incorporated into residential development as land-use buffers and setbacks.

<u>Allowable Biofilter Variations</u>

Filter strip: A filter strip is a uniformly graded and densely vegetated strip of land. The vegetation can be grasses or a combination of grass and woody plants. Pollutant removal efficiencies are based upon a 50-foot wide strip. Uniform sheet flow must be maintained through the filter strip to provide pollutant -reduction and to reduce erosion.

Riparian buffer: A riparian buffer is a strip of land with natural, woody vegetation along a stream or other watercourse. Besides the undergrowth of grasses and herbaceous vegetation, the riparian buffer includes deep rooted trees. The 20 foot zone closest to the stream or watercourse contains the trees, while the outer 30 feet of the riparian buffer contains a dense stand of grasses. The overall width of the riparian buffer is 50 feet. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and to avoid erosion.

A. Site and Drainage Considerations

1. To ensure sheet flow into the filter strips and riparian buffers, flow spreaders or level spreaders must be designed and installed where concentrated runoff flows into filter strips or riparian buffers.
2. Level Spreader: The grade of a level spreader shall be 0%. The channel grade for the last 20 feet of the dike or diversion entering the level spreader must be less than or equal to 1 % and designed to provide a smooth transition into spreader. The depth of a level spreader as measured from the lip must be at least 6 inches. The level spreader lip must be constructed on undisturbed soil (not fill material) to uniform height and zero grade over length of the spreader. The maximum drainage area to the level spreader shall be 10 acres or less with the optimal size being less than 5 acres. The maximum flow into the level spreader must be 30 cfs or less.
3. Appropriate length, width, and depth of level spreaders shall be selected from the following table.

Design Flow (efs)	Entrance Width (ft)	Depth (ft)	End Width (ft)	Length (ft)
0-10	10	0.5	3	10
1 0-20	16	0.6	3	20
20-30	24	0.7	3	30

4. Capacity of the spreader, filter strip and riparian buffer length (perpendicular to flow) must be determined by estimating the volume of flow that is diverted to the spreader for water quality control.
5. The released runoff to the outlet must be on undisturbed stabilized areas in sheet flow and not allowed to re-concentrate below the structure.
6. Slope of the filter strip from a level spreader must not exceed 10 percent.
7. All disturbed areas must be vegetated immediately after construction.'
8. The minimum filter strip width is 20 feet.
9. Filter strips must be designed for slopes between 2 percent and 6 percent.
10. Ensure that flows in excess of design flow move across and around the filter strip without damaging it.
11. Filter strips can be used effectively as pretreatment measures. The minimum sizing criteria are as follows:

Source: Claytor and Schueler, 1996

Parameters	Impervious Area		Pervious Area (lawns, etc.)	
Maximum inflow		75		100

approach length.(ft)	35				75			
Filter strip slope(max = 6%)	<2%	>2%	<2%	>2%	<2%	>2%	<2%	>2%
Filter strip minimum Length	10	15	20	25	10	12	15	18

12. Riparian buffers: The use of buffers is limited to drainage areas of 10 acres or less with the optimal size being less than 5 acres.
13. Slope of the buffer from a level spreader cannot exceed 10 percent.
14. Top edge of buffer must directly abut the contributing impervious area and follow the same elevation contour line.
15. Biofilters and level spreaders must be located within a drainage easement. A copy of the easement should be included in the digital copy of the BMP operations and maintenance manual.

B. Performance Standards

Biofilters designed, constructed and maintained as noted in this manual provide the following pollutant reductions:

Pollutant	Percent Reduction (riparian buffer/filter strip)
BOD	40/10%
TSS	60/30%
Total P	35/10%
Total N	25/10%
Metals	70/30%

Catch Basins/Swirl Chambers

There are many catch basin inserts and swirl chamber designs readily available on the market today. Most storm drain inserts reduce oil and grease, debris, and suspended solids through gravity, centrifugal force, or other methods. Once trapped, sediments and floatable oils must be pumped out regularly to maintain the effectiveness of the units. Catch basin inserts or swirl chambers can be designed and installed in a storm drain system provided the following minimum criteria have been met:

- An overflow weir to pass storm events larger than the design storm has been provided.

- The catch basin inserts or swirl chamber has been sized to remove 80% TSS. This TSS removal rate must be provided by independent testing, not manufacturer testing.
- The specific maintenance needs or issues for each catch basin insert or swirl chamber has been addressed in the Operation and Maintenance Manual.
- The currently approved list of manufactures is available at the City Engineer's office.

CITY OF VINCENNES
BMP POLICY GUIDELINES

IV. SAMPLE O & M MANUAL

(SAMPLE ON THE FOLLOWING PAGE)

BMP OPERATION AND MAINTENANCE MANUAL

FOR

PROJECT NAME
ADDRESS
CITY, STATE ZIP

BMP Owner Name	
BMP Owner Address	
BMP Owner Phone Number	
BMP Owner Fax Number	
BMP Owner Email Address	

BMP Inspection and Maintenance Agreement:

City of Vincennes Fees (per BMP)

- Inspection fee for the first three years, paid lump sum in year one $150.00/BMP
- Annual BMP inspection fee after three years $50.00/BMP
- The annual BMP inspection fee may increase five ($5) every year thereafter.
- Additional inspections required due to maintenance issues: $50.00/Hour

o The BMP owner agrees to pay all the fees required by the City of Vincennes, including inspection fees, and/or any additional fees required.

o Routine inspections are the responsibility of the BMP owner. Maintenance is also the responsibility of the owner. The City of Vincennes must be notified of any changes in BMP ownership, major repairs or BMP failures in writing within 30 days. The letter should be addressed to:

Vincennes City Engineer
205 Vigo Street
Vincennes, IN 47591

o In the event that the City of Vincennes finds a BMP in need of maintenance or repair, the City of Vincennes will notify the BMP owner of the necessary maintenance or repairs and give the landowner a timeframe for completing the maintenance or repairs. If the maintenance or repairs is not completed within the timeframe, the maintenance or repairs will be completed by the City or its representative and the BMP owner will be invoiced.

o The City of Vincennes representatives has the right to enter the property to inspect, maintenance or repair the BMP.

BMP Owner Signature: ______________________________

BMP Owner Printed Name: ______________________________ Date: ___________________

State of Indiana)
) SS:
County of __________________)

Before me, the undersigned Notary Public in and for said County and State, personally appeared the above owner, who acknowledged the execution of the foregoing instrument as his voluntary act and deed, for the purpose therein expressed. Witness my hand and notarial seal this _______ day of ____________________, 20____.

____________________ ____________________ ________________ ________________
Signature Printed Name Expiration Date County of Residence

INSPECTION CHECKLIST FOR BMP OWNERS

FOR

PROJECT NAME
ADDRESS
CITY, STATE ZIP

BMP Owner Name	
BMP Owner Address	
BMP Owner Phone Number	

BMP Owner Fax Number	
BMP Owner Email Address	
Date	
Inspector(s)	

BMP Type		
Maintenance Item	Satisfactory/Unsatisfactory	Comments

BMP Type		
Maintenance Item	Satisfactory/Unsatisfactory	Comments

Additional Comments:

____

____

____

____

Action Taken:

________________________________Started:____________Completed:________

________________________________Started:____________Completed:________

________________________________Started:____________Completed:________

________________________________Started:____________Completed:________

V. Principles and Standards of Stormwater Drainage Design

Section 5.1 Determination of Runoff Quantities

Because topography and the availability and adequacy of outlets for storm runoff vary with almost every site, the requirements for storm drainage tend to be an individual matter for any project. It is required that each proposed project be discussed with the City of Vincennes Surveyor at the earliest practical time in the planning stage.

Runoff quantities shall be computed for the area of the parcel under development plus the area of the watershed flowing into or through the parcel under development. The quantity of runoff which is generated as the result of a given rainfall intensity must be calculated as outlined in this section.

Computations for areas up to and including 20 acres may be based on the Rational Method or NRCS TR-55 (Urban Hydrology for Small Watersheds). For areas larger than 20 acres, hydrograph techniques and/or computer drainage modeling methods must be used. Hydrograph techniques and computer modeling methods used to determine stormwater runoff shall be proven methods in the practice of hydrology, subject to approval of the Board.

Section 5.2 Rational Method

We decided to leave it in the ordinance, I think. That saves having to massage another document.

In the Rational Method, the peak rate of runoff, Q, in cubic feet per second is computed as:

$$Q = CIA$$

Where:

C = runoff coefficient, representing the characteristics of the drainage area and defined as the ratio of runoff to rainfall

I = average intensity of rainfall in inches per hour for a duration equal to the time of concentration (tc) for a selected rainfall frequency. The practical minimum time to be used is 5 minutes

A = tributary drainage area in acres

Guidance to selection of the runoff coefficient "C" is provided by Table 1 and Table 1A, which show values for different types of surface and local soil characteristics. The composite "C" value used for a given drainage area with various surface types shall be the weighted average for the total area calculated from a breakdown of individual areas having different surface types.

Table 2 provides runoff coefficients for different land use classifications. In the instance of undeveloped land situated in an upstream area, a coefficient or coefficients shall be used for this area in its present or existing state of development.

Rainfall intensity shall be determined from the rainfall frequency table shown in Table 5A. The time of concentration (tc) to be used shall be the sum of the inlet time and flow time, or travel time, in the drainage facility from the most hydraulically remote part of the drainage area to the point under consideration.

Inlet time is the combined time required for the runoff to reach the inlet of a storm sewer. It includes overland flow time and flow time through established surface drainage channels such as swales, ditches and sheet flow across such areas as lawns, fields, and other graded surfaces.

The flow time, or travel time, in the storm sewers may be estimated by the distance in feet divided by velocity of flow in feet per second. The velocity shall be determined by the Manning Formula.

TABLE 1

URBAN RUNOFF COEFFICIENTS

Type of Surface	Runoff Coefficient "C"
Asphalt	0.82
Concrete	0.85
Roof	0.85
Compacted Gravel / Crushed Stone	0.65
Lawns (Sandy)	
Flat (0-2%)	0.07
Rolling (2-7%)	0.12
Steep (greater than 7%)	0.17
Lawns (Clay)	
Flat (0-2%)	0.16
Rolling (2-7%)	0.21
Steep (greater than 7%)	0.30

TABLE 1A

RURAL RUNOFF COEFFICIENTS

Type of Surface	Runoff Coefficient "C"
Woodlands (Sandy)	
Flat (0-5% slope)	0.10
Rolling (5-10% slope)	0.25
Steep (greater than 10%)	0.30
Woodlands (Clay)	
Flat	0.30
Rolling	0.35
Steep	0.50
Pasture (Sandy)	
Flat	0.10
Rolling	0.16
Steep	0.22
Pasture (Clay)	
Flat	0.30
Rolling	0.36
Steep	0.42
Cultivated (Sandy)	
Flat	0.30
Rolling	0.40
Steep	0.52
Cultivated (Clay)	
Flat	0.50
Rolling	0.60
Steep	0.72
Farmsteads	
Fallow	

TABLE 2

Runoff Coefficients "C" by Land Use

LAND USE	RUNOFF COEFFICIENTS Flat	Rolling	Steep
Commercial	0.75	0.83	0.91
Commercial (Neighborhood)	0.54	0.60	0.66
Industrial	0.63	0.70	0.77
Garden Apartments	0.54	0.60	0.66
Churches	0.54	0.60	0.66
Schools	0.31	0.35	0.39
Semi Detached Residential	0.45	0.50	0.55
Detached Residential	0.40	0.45	0.50
Quarter Acre Lots	0.36	0.40	0.44
Half Acre Lots	0.31	0.35	0.39
Parkland	0.18	0.20	0.22

General Notes:

Flat terrain 0-2% Slopes.
Rolling terrain 2-7% slopes.
Steep terrain greater than 7% slopes.
Interpolation, extrapolation and adjustment for local conditions shall be based on engineering experience and judgment.

Time of Concentration of Rainfall on Small Drainage Basins

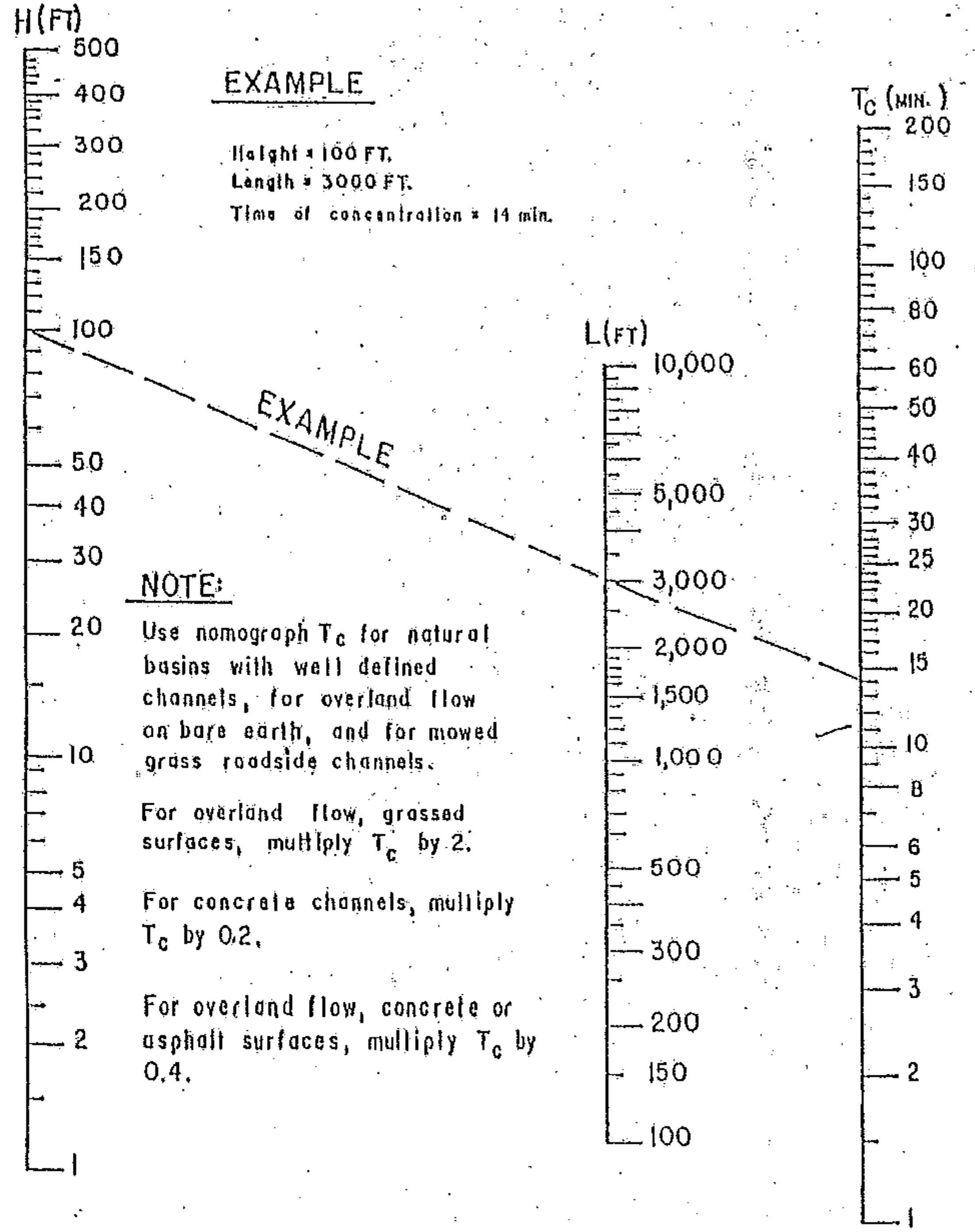


Figure 1. Nomograph for Determing Time of concentration
(Developed from the Kirpich Equation)

Section 5.3 Required Design Capacity of Stormwater Control Facilities

Various parts of a drainage facility must accommodate runoff water as follows:

A. The minor drainage system such as inlets, catch basins, steel gutters, swales, sewers and small channels, which collect stormwater, must accommodate peak runoff from a 10 year return period storm. Rainfall duration shall be equal to the time of concentration or ten minutes if the time of concentration is less than ten minutes. A Huff, first quartile storm distribution and 1 hour storm duration shall be used for computer modeling. These storm distribution coordinates are contained in Table 6. The following additional requirements must be satisfied:
   1. Open channels carrying peak flows greater than 30 cubic feet per second shall be capable of accommodating peak runoff for a 50 year return period storm within the drainage easement.
   2. Culverts shall be capable of accommodating peak runoff from a 50 year return period storm when crossing under a road which is part of the Indiana Department of Highways rural functional classification system and are classified as principal or minor arterial, major or minor collector roads. The minimum culvert size shall be 15 inches.
   3. Temporary water storage will not be permitted on any local street or road, except by special exception of the Board.

B. Major drainage systems are defined in Section 1.3 and shall be designed in accordance with Indiana Department of Natural Resources standards.

Section 5.4 Storm Sewer Design Standards

All storm sewers subject to this Ordinance whether private or public, and whether constructed on private or public property, shall conform to the design standards and other requirements contained herein. The hydraulic capacity of storm sewers shall be determined using Manning's Equation:

A. Manning's Equation

$$Q = (A)(V)$$

$$\text{Where; } V = \frac{1.486}{n} R^{(2/3)} S^{(1/2)}$$

A = Waterway area of conduit in square feet
Q = Discharge in cubic feet per second (cfs)
V = mean velocity of flow in feet per second
R = the hydraulic radius in feet
S = the slope of the energy grade line in feet per foot
n = roughness coefficient

The hydraulic radius, R, is defined as the cross sectional area of flow divided by the wetted flow surface or wetted perimeter. Typical "n" values and maximum permissible velocities for storm sewer, materials are listed in Table 3. (Roughness coefficient (n) values for other sewer materials can be found in standard hydraulics texts and references.)

B. Minimum Size

The minimum size of all storm sewers shall be 12 inches. Rate of release for detention storage shall be controlled by an orifice plate or other devices, subject to approval of the Board, where the 12 inch storm sewer will not limit rate of release as required.

C. Grade
Sewer grade shall be such that, in general, a minimum of two feet of cover is maintained over the top of the pipe. Pipe cover less than the minimum may be used only upon the approval of the Board. Uniform slopes shall be maintained between inlets, manholes and inlets to manholes. Final grade shall be set with full consideration of capacity required, sedimentation problems and other design parameters. Minimum and maximum allowable slopes shall be those capable of producing velocities of two and one-half and 15 feet per second, respectively when the sewer is flowing full. Velocity in excess of 7 feet per second shall require the use of water-tight joints to reduce soil infiltration potential.

D. Alignment
Storm sewers shall be straight between manholes insofar as possible. Where long radius curves are necessary to conform to street layout, the minimum radius of curvature shall be no less than 100 feet for sewers 42 inches and larger in diameter. Deflection of pipe sections shall not exceed the maximum deflection recommended by the pipe manufacturer. The deflection shall be uniform and finished installation shall follow a smooth curve. Storm sewers smaller than 42 inches in diameter shall not be curved.

E. Manholes
Manholes shall be installed to provide access to continuous underground storm sewers for the purpose of inspection and maintenance. Manholes shall be provided at the following locations:

1. Where two or more storm sewers converge.
2. At the point of beginning or at the end of a curve, and at the point of reverse curvature (PC, PT, PRC).
3. Where pipe size changes.
4. Where an abrupt change in alignment occurs.
5. Where a change in grade occurs.
6. At suitable intervals in straight sections of sewer (300' maximum distance).

F. Inlets
Storm inlets or drainage structures shall be utilized to collect surface water through grated openings and convey it to storm sewers, channels or culverts. Inlet design and spacing shall be in accordance with Section 7-400 of the Indiana Department of Highways Road Design Manual Volume 1 or other approved design procedure. The inlet grate openings provided must be adequate to pass the design 10 year flow with 50% of the sag inlet areas clogged. An overflow channel from sag inlets to a channel or basin shall be provided at sag inlets, so that the maximum depth of water that might be ponded in the street sag or gutter shall not exceed 12 inches above the gutter elevation.

TABLE 3

Typical Values of Manning's n

Material	Manning's n	Desirable Maximum Velocities*
Closed Conduits		
Concrete	0.013	15 f.p.s
Vitrified	0.013	15 f.p.s
Brick	0.015	15 f.p.s
Cast Iron	0.013	15 f.p.s
Circular Corrugated Metal Pipe, Annular Corrugations, 2 2/3 x ½ in.		
Unpaved	0.024	10 f.p.s.[1]
25% Paved	0.021	10 f.p.s.[1]
50% Paved	0.018	10 f.p.s.[1]
100% Paved	0.013	10 f.p.s.[1]
Circular Corrugated Metal Pipe, Helical, 2 2/3 x ½ in. Unpaved Corrugations		
12"	0.011	10 f.p.s.[1]
18"	0.013	10 f.p.s.[1]
24"	0.015	10 f.p.s.[1]
36"	0.018	10 f.p.s.[1]
48"	0.020	10 f.p.s.[1]
60" or larger	0.021	10 f.p.s.[1]
Corrugated Polyethylene Smooth Interior Pipe (HDPE)	0.012	15 f.p.s.[1]
Open Channels		
Concrete, Trowel Finish	0.013	
Concrete, Broom or Float Finish	0.013	
Gunite	0.018	
Riprap Hand Placed	0.030	
Riprap Dumped	0.035	
Gabion	0.028	
New Earth (Uniform, Sodded, Clay	0.025	
Existing Earth (Fairly Uniform, With Some Weeds)	0.030	
Dense Growth of Weeds	0.040	
Dense Weeds and Light Brush	0.040	
Dense Weeds and Heavy Brush	0.060	
Swale With Grass	0.035	

*Velocity in excess of 7 f.p.s. require the use of water tight joints.

Values shown are for materials in good condition.
Values may increase as materials age or are damaged.

Section 5.5 Workmanship and Materials for Storm Sewers, Manholes and Inlets

A. Workmanship
The Specifications for the construction of storm sewers shall not be less stringent than those set forth in the latest edition of the Indiana Department of Highways' "Standard Specifications"; additionally, ductile iron pipe shall be laid in accordance with American Society of Testing Materials (ASTM) C-12.8

B. Materials
Storm sewer manholes and inlets shall be constructed of masonry, cast in place concrete or precast reinforced concrete or other material approved by the Board. Material and construction shall conform to the current Indiana Department of Highways' "Standard Specifications" unless otherwise approved in advance of installation by the Board.

Pipe and fittings used in storm sewer construction shall be: 1) PVC meeting the requirements of ASTM D-3034 SDR 35 with joints meeting the requirements of ASTM D-3212; 2) High density polyethylene (HDPE) meeting the requirements of AASHTO 294 and ASTM D-1248 with joints meeting the requirements of ASTM D-3212, or 3) concrete pipe (ASTM C-76). Other pipe and fittings not specified herein may be used only when specifically authorized by the Board. Pipe joints shall be flexible, watertight and shall conform to the requirements of the Materials of the latest edition of the Indiana Department of Highways' "Standard Specifications". The Board reserves the right to select pipe/fitting materials for selected uses in all drainage projects involving public rights-of-way in City of Vincennes. Approval shall be subject to the review and concurrence of the municipal engineering heads of the cities and towns.

C. Special Hydraulic Structures
Special hydraulic structures required to control the flow of water in storm runoff drainage systems include junction chambers, drop manholes, inverted siphons, stilling basins, and other special structures. The use of these structures shall be limited to those locations justified by prudent planning and by careful and thorough hydraulic engineering analysis.

Section 5.6 Open Channel Design Standards

All open channels subject to this Ordinance whether private or public, and whether constructed on private or public land, shall conform to the design standards and other requirements contained herein. The waterway for channels shall be determined using Manning's Equation.

A. Manning Equation

$$Q = (A)(V)$$

$$\text{Where; } V = \frac{1.486}{n} R^{(2/3)} S^{(1/2)}$$

A = Waterway area of channel in square feet
Q = Discharge in cubic feet per second (cfs)
V = mean velocity of flow in feet per second
R = the hydraulic radius in feet
S = Slope of the Energy Grade Line in feet per foot
(approximated by channel bottom slope in most cases)
n = roughness coefficient

B. Channel Cross Section and Grade

The required channel cross section and grade are determined by the design capacity, site topographical conditions, the material in which the channel is to be constructed, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains, tributary / lateral ditches, or streams. The channel grade shall be such that the velocity in the channel is high enough to prevent siltation but low enough to prevent erosion. Velocities less than 1.5 feet per second should be avoided, where possible, because siltation will take place and ultimately reduce the channel cross section resulting in more frequent maintenance required. The maximum permissible velocities in vegetation-lined channels are shown in Table 4. Developments through which the channel is to be constructed must be considered in design of the channel section. The proposed channel may increase sediment load, peak discharge and velocity in downstream reaches.

C. Side Slopes

Earthen channel side slopes shall be no steeper than 2 to 1, and shall be dependent on existing soil conditions. Flatter slopes may be required to prevent sloughing or erosion and for ease of maintenance. It is desirable to have slopes that are easily mowed to control vegetation and the growth of brush. Where channels will be lined, side slopes shall be no steeper than 1-1/2 to 1 with adequate provision made for bank drainage. Side slopes steeper than 1-1/2 to 1 may be used for lined channels provided that the side lining and structural retaining wall are designed and constructed with provisions for live and dead load surcharge.

D. Channel Stability

1. Characteristics of a stable channel are
   a. It neither aggrades nor degrades beyond tolerable limits.
   b. The Channel banks do not erode to the extent that the channel cross section is changed appreciably.
   c. Excessive sediment bars do not develop.
   d. Excessive erosion does not occur around culverts, bridges or other channel structures.
   e. Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.

2. Channel stability shall be determined for an aged condition and the velocity shall be based on the design flow or the bank full flow, whichever is greater, using "n" values for various channel linings as shown in Table 3.

3. Channel stability must also be checked for conditions immediately after construction. For this stability analysis, the velocity shall be calculated for the expected flow from a ten-year return period storm from the watershed, or the bank full flow, whichever is smaller. The "n" value for newly constructed channels shall be as shown in Table 3. The allowable velocity in the

newly constructed channel may be increased by a maximum of 20 percent to reflect the effects of vegetation to be established under the following conditions:

a. The soil and site in which the channel is to be constructed are suitable for rapid establishment and support of erosion controlling vegetation;
b. Species of erosion controlling vegetation adapted to the area, and proven methods of establishment are shown
c. The channel design includes detailed plans for establishment of vegetation on the channel side slopes; and A maintenance plan is in place to ensure vegetation is established.

E. <u>Drainage of Waterways</u>

Vegetated waterways that are subject to low flows of long duration or where wet conditions prevail shall be drained with a tile system or by other means such as paved gutters. Tile lines should be a minimum of 6 inches in size, be offset from the centerline, and may be outlet through a drop structure at the end of the waterway or through a standard tile outlet.

F. <u>Appurtenant Structures</u>

The design of channels shall include all structures required for the proper functioning of the channel, the laterals thereto, and travel ways for operation and maintenance. Recessed inlets and related structures needed for entry of surface and subsurface flow into floodway channels, without significant erosion or degradation, shall be included in the design of channel improvements. The design is also to provide the necessary flood gates, water level control devices, structural grade control, and any other appurtenance affecting the functioning of the channels and the attainment of the purpose for which they are built.

The effect of channel improvements on existing culverts, bridges, buried cables, pipelines, other utilities and thereto shall be evaluated to determine the need for modification or replacement. Culverts and bridges which are modified or added as part of channel improvement projects shall meet design and construction practice standards for the type of structure, and shall have a minimum capacity equal to the design discharge or appropriate governmental agency design requirements, whichever is greater.

Utilities on or adjacent to a site being developed, or re-developed, are the sole responsibility of the developer. The Board will not be held responsible for the existence, location, modification or damage to any utilities encountered while performing any activities related to this ordinance.

G. <u>Disposition of Spoil</u>

Spoil material resulting from clearing, grubbing and channel excavation shall be disposed in such a manner which will:

1. Minimize overbank wash. Maintain a minimum 15-foot wide berm between the top of bank and beginning of spoil toe.
2. Provide for the free flow of water between the channel and floodplain unless the valley routing and water surface profile are based on continuous dikes being installed.
3. Do not limit the development of travel ways, along the ditch, for maintenance purposes.
4. Leave the right-of-way in the best condition feasible, consistent with the project purposes, for productive use by the owner; as good of condition, or better, than existed prior to construction.
5. Improve the aesthetic appearance of the site to the extent feasible.
6. Be approved by the IDNR or US Army Corps of Engineers (as applicable) if deposited in the floodway.

7. Comply with 327 IAC 15-5, “Rule 5”, and 327 IAC 15-13, “Rule 13”, erosion and sediment control requirements.

H. Brush and Trees

Brush and trees may be disposed of by removing from the site, burying, or burning in accordance with local and state regulations.

TABLE 4

Maximum Permissible Velocities in Vegetal-Lined Channels and Watercourses 6)

Cover	Slope Range (% percent)	Permissible Velocity (1) Erosion Resistant Soils (ft. per sec.)	Easily Eroded Soils (ft. per sec.)
Bermudagrass	0 – 5	8	6
	5 – 10	7	5
	over 10	6	4
Kentucky Bluegrass	0 – 5	7	5
Smooth Brome	5 – 10	6	4
Blue Grass (other turf grasses)	Over 10	5	3
Grass Mixtures	0-5 (2)	5	4
Lespediza Sericea	(3)		
Reed Canarygrass	5 - 10	4	3
Redtop	0 - 5	3.5	2.5
Alfalfa			
Red Fescue			
Common Lespedeza (4)	(5)		
Sudangrass (4)	0 - 5	3.5	2.5

(1) Use velocities exceeding 5 feet per second only where good cover and proper maintenance can be obtained.
(2) Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with stone, concrete, or highly resistant vegetative center section.
(3) Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with stone, concrete, or highly resistant vegetative center section.
(4) Annuals – use on mild slopes or as temporary protection until permanent covers are established.
(5) Use on slopes steeper than 5 percent is not recommended.
(6) Adapted from Natural Resources Conservation Service, SCS-TP-61, Handbook of Channel Design for Soil & Water Conservation, 1949

Section 5.7 Construction and Materials for Open Channels

A. Construction
Specifications shall be in keeping with the current standards of engineering and construction practice and shall describe the requirements for proper installation of the project to achieve its intended purpose without damage to either on or off-site facilities.

B. Materials
Materials acceptable for use as channel slope protection are:
1. Vegetation
2. Revetment Riprap
3. Concrete
4. Hand-laid Riprap
5. Precast Cement Concrete Riprap / Slope Paving Materials
6. Grouted Riprap
7. Gabions

Other lining materials shall receive special approval of the Board. Materials shall comply with the latest edition of the Indiana Department of Highways "Standard Specifications", and shall have no detrimental effects on stormwater flow, the environment, or fish and wildlife.

Section 5.8 Stormwater Detention Note: Detention is descriptive of both wet and dry (detention basins and retention ponds, respectively.

The following shall govern the design of any improvement with respect to the detention of stormwater runoff.

A. Acceptable Detention Methods
The increased stormwater runoff resulting from a proposed development shall be detained on-site by the provisions of appropriate detention or retention basins, underground storage, parking lots, streets, lawns, or other acceptable techniques. Measures, which further retard the rate of overland flow and the velocity in runoff channels may also be required to partially control the runoff rate.

Detention basins or underground storage shall be sized to store excess flows from storms with a one hundred (100) year return period. Control devices shall limit the maximum release to a rate no greater than that prescribed by this ordinance.

B. Design Storm
Design of stormwater detention facilities shall be based on a return period of once in 100 years, or a one percent chance of occurrence in any given year. The storage volume and outflow rate shall be sufficient to handle stormwater runoff from the most critical of a 1-hour or 6-hour storm. Rainfall depth-duration-frequency relationships and intensity-duration-frequency relationships used shall be those given in Tables 5 and 5A.

TABLE 5 Total Rainfall Depth (inches) for given recurrence interval
NOTE: Insert info from NOAA Atlas 14 that I forwarded separately.
Attached again.

Duration	2-year	10-year	100-year
6-hr	2.45	3.49	5.60
1-hr	.54	2.19	3.51

Reference: Midwest Bulletin No. 71, Rainfall Atlas of the Midwest, Huff and Angel, Midwest Climate Center, NOAA, and Illinois State Water Survey, IDENR, 1992.

TABLE 5A
Rainfall Intensity in Inches per Hour for a Given Recurrence Interval

T (hrs)	2-year	5-year	10-year	25-year	50-year	100-year
0.08	5.07	5.95	6.72	7.88	8.90	10.04
0.17	4.03	4.73	5.34	6.27	7.08	7.99
0.25	3.37	3.96	4.47	5.24	5.92	6.68
0.33	2.87	3.37	3.80	4.46	5.03	5.68
0.5	2.13	2.50	2.82	3.31	3.73	4.21
0.67	1.65	1.94	2.19	2.57	2.90	3.27
0.83	1.34	1.58	1.78	2.09	2.36	2.66
1	1.11	1.30	1.47	1.72	1.94	2.19
1.5	0.69	0.81	0.92	1.08	1.22	1.38
2	0.48	0.57	0.64	0.75	0.85	0.96
3	0.28	0.33	0.37	0.43	0.49	0.55
4	0.19	0.22	0.25	0.29	0.33	0.37

TABLE 6

Rainfall Distribution Ordinates for Hydrologic Modeling
Percent of Total Rainfall Depth Ref. NOAA, Atlas 14 [NOTE: Insert info from NOAA Atlas 14 that I forwarded separately. Attached again.]

% Storm Time	1^{st} Quartile
0	0.00
10	22.82
20	44.69
30	57.11
40	65.33
50	71.43
60	78.15
70	84.66
80	90.00
90	95.36
100	100.00

C. Allowable Release Rate

The allowable release rate of stormwater from development, redevelopment, and new construction shall not exceed the stormwater runoff rate from the land area in its pre-developed condition as described in Section 2.1.

Special cases may exist where the downstream drainage capacity may be limited in such a way that strict adherence to this policy may result in undue property damage. In these cases, the board may further restrict the peak runoff release rate. The allowable release rate shall be reduced so that additional detention, as determined by the Board shall be required to store that portion of the runoff exceeding the capacity of the receiving sewers or waterways.

If more than one detention basin is involved in the development of the area upstream of the limiting restriction, the allowable release rate from any one detention basin shall be in direct proportion to the ratio of its drainage area to the drainage area of the entire watershed upstream of the restriction.

D. Drainage System Overflow Design

The drainage system shall have adequate capacity to safely and adequately convey the stormwater runoff from all upstream tributary areas through the development under consideration for a storm of 100 year design return period calculated on the basis of the upstream land in its present state of development. This conveyance shall be accomplished without damage to structures and improvements. An allowance, equivalent to the reduction in flow rate provided, shall be made for existing detention basins in upstream tributary areas, provided evidence of its construction can be shown.

E. Determination of Storage Volume

1. For areas up to and including 20 acres, the Rational Method may be used to determine the required volume of stormwater storage. The procedure is described in the HERPICC Stormwater Design Manual. Other design methods as described below in subsection 2 may also be used.
2. For areas larger than 20 acres, methods other than the rational method for determining runoff and routing of stormwater shall be used to determine the storage volume required to control stormwater runoff. The procedures or methods used shall be proven methods in the practice of hydrology, subject to approval of the Board. The Advanced Interconnect Pond and Channel Routing, SWMM, NRCS TR-20 (Project Formulation, Hydrology), HEC-HMS and NRCS TR-55 (Urban Hydrology for Small Watersheds) models are approved by the Board for appropriate use in analysis of the runoff and routing of stormwater.

F. General Detention/Retention Basin Design Requirements

Basins shall be constructed to temporarily detain the stormwater runoff which exceeds the maximum peak flow rate authorized by this Ordinance. The volume of storage provided in these basins, together with such storage as may be contained in other on site facilities, shall be sufficient to control excess runoff from the one hundred (100) year storm.

The following design principles shall be observed:

1. The maximum volume of water stored and subsequently released at the design release rate shall not result in storage duration in excess of 48 hours unless additional storms occur within the period.
2. The maximum planned depth of stormwater stored should generally not exceed five feet.
3. All earthen stormwater detention facilities shall be separated by not less than 50 feet from any building or structure to be occupied.
4. Debris and safety screens having a maximum opening of 6 inches shall be provided for any pipe or opening to prevent children or large animals from crawling into the structures.
5. Earthen dams that are a component of stormwater facilities shall be designed and constructed according to sound engineering and construction principals. Dams shall not be designed to overtop in a 100-year storm, unless approved by the board.
6. Danger signs shall be mounted at appropriate locations to warn of deep water and possible flooding conditions during storm periods or other dangers that exist. Fencing shall be provided if deemed necessary by the Board.
7. Outlet control structures shall be designed to operate as simply as possible and shall require little or no maintenance and/or attention for proper operation. They shall limit discharges into existing or planned downstream channels or conduits so as not to exceed the predetermined maximum authorized peak flow rate at maximum storage levels.
8. Emergency overflow facilities such as a weir or emergency spillway shall be provided for the release of exceptional storm runoffs or in emergency conditions should the normal discharge devices become inoperative. The overflow facility shall be of such design that its operation is automatic and does not require manual attention. It shall be designed to be stable and resist erosion in exceptional storm runoffs. It shall direct all flows to the receiving outlet without passing through any off-site property.
9. Grass or other suitable vegetative cover shall be provided throughout the entire earthen basin area. Grass shall be maintained in healthy condition and should be cut regularly at approximately monthly intervals during the growing season or as required.
10. Debris and trash removal and other necessary maintenance shall be performed on a regular basis to assure continued operation in conformance to design.

11. A report shall be submitted to the Board describing (a) the proposed development; (b) the current land use conditions; (c) the method of hydraulic and hydrologic analysis used, including input and output files, shall be included as appendices to the report; (d) a maintenance plan describing the party responsible for the permanent ownership and maintenance of the drainage system and a description of all maintenance requirements.

G. Detention Basin Design Requirements

Provisions shall be incorporated to facilitate complete interior drainage of detention basins, to include the provisions of natural grades to outlet structures, longitudinal and transverse grades to perimeter drainage facilities, paved gutters, or, the installation of subsurface drains.

H. Retention Pond Design Requirements

The following additional design principals shall be observed:

1. Basins designed with permanent pools or containing permanent ponds shall have a water area of at least one-half acre. If fish are to be maintained in the pond, a minimum depth of approximately 10 feet shall be maintained over at least 25 percent of the pond area. The remaining pond area shall have no extensive shallow areas, except as required by subsection (3) below.
2. In excavated ponds, the underwater side slopes in the pond shall be stable with a maximum slope of 2 ½ to 1. In the case of valley storage, natural slopes may be considered to be stable.
3. A safety ledge four to six feet in width is required and must be installed in all ponds approximately 18 to 24 inches below the permanent water level. The slope above the safety ledge shall be stable, with a maximum slope of 3 to 1, and of a material such as stone or riprap which will prevent erosion due to wave action.
4. Periodic maintenance is required in ponds to control weed growth. The pond shall also be designed to provide for the easy removal of sediment, which will accumulate during periods of pond operation.
5. For emergency use, basin cleaning or shoreline maintenance, facilities shall be provided or consideration given for auxiliary equipment to permit emptying and drainage.
6. Dry fire hydrants and drafting basins for fire protection may be requested for installation in areas where fire protection water supplies are not available.

I. Parking Lot Storage

Paved parking lots may be designed to provide temporary detention storage of stormwaters on all or a portion of their surfaces. Depth of storage must be limited to a maximum depth of six (6) inches so as to prevent damage to parked vehicles and so that access to parked vehicles is not impaired. Ponding should, in general, be confined to those positions of the parking lots farthest from the area served.

J. Facility Financial Responsibilities

The construction and maintenance cost of stormwater control systems and facilities as required by this ordinance shall be accepted as part of the cost of land development. If general public use of the facility can be demonstrated, negotiations for public participation in the cost of such developments may be considered.

K. Facility Maintenance and Ownership Responsibilities

Facility maintenance responsibility and permanent ownership of detention/retention facilities during construction and thereafter shall be the responsibility of the land developer/owner, unless such responsibility and ownership is formally dedicated to and accepted by a public body. Assignment of responsibility for maintaining facilities serving more than one lot or holding shall be documented by appropriate covenants to property deeds, and shall be determined before the drainage plans are approved.

Stormwater detention and retention basins may be donated to the City or other unit of government for permanent ownership and maintenance providing:

1. The City or governmental unit is willing to accept responsibility.
2. The facility has been designed and constructed according to all applicable provisions of this ordinance.
3. All improvements have been constructed, approved and accepted by the City for the land area served by the drainage basin.
4. Dry detention basins shall have all slopes, bottom of the basin and area above the high water line seeded and stabilized; and shall have the high water line not closer than 50 feet to any development boundary.
5. The Board has accepted as-built documentation and all conditions of any permits have been met.

L. Inspections

All public and privately owned detention and retention storage facilities must be made available for inspection by representatives of the Board not less often than once every 2 years and as necessary following large storm events. If the Board determines that maintenance is needed or that the original objectives are not being realized, a certified inspection report covering the physical conditions, available storage capacity and operational condition of key facility elements will be provided to the owner.

M. Corrective Measures

If the Board finds deficiencies, the person, or entity, responsible for the stormwater control facilities will be required to take the necessary measures to correct such deficiencies. If the person, or entity, responsible fails to do so, the Board will undertake the work and collect from the responsible party, using lien rights, if necessary.

N. Joint Development of Control Systems

Stormwater control facilities may be planned and constructed jointly by two or more developers as long as compliance with this Ordinance is maintained and future operation and maintenance is assured.

O. Installation of Control Systems

Runoff and erosion control facilities shall be installed as soon as possible during the course of site development. Detention/retention basins shall be designed with an additional (six) percent of available capacity to allow for sediment accumulation resulting from development and to permit the basin to function for reasonable periods between cleanings. Basins should be designed to collect sediment and debris in specific locations so that removal costs are kept to a minimum.

P. Detention Facilities in Floodplains

If detention storage is provided within a floodplain, only the net increase in storage volume above that which naturally existed on the floodplain shall be credited to the development. No credit will be granted for volumes below the elevation of the regulatory flood at the location unless compensatory storage is also provided.

Q. Off-Site Drainage Provisions

When the allowable runoff is released into an area that is susceptible to flooding, the developer may be required to construct appropriate storm drains through such area to avert increased flood hazard. The requirement of off-site drains shall be at the discretion of the Board.