Appendix B

STORM WATER DESIGN CRITERIA

STANDARD DESIGN CRITERIA

1 GENERAL

These technical specifications address the design criteria necessary for stormwater management. The purpose of stormwater management is to prevent flooding, minimize property damage, prevent erosion, eliminate nuisance conditions, lower overall costs, and improve overall water quality.

Stormwater management is required to provide protection from flooding by limiting the post-developed peak rate of discharge (volume, velocity, & concentration shall also be considered); recharge where possible by allowing for retention of runoff where soils are compatible; and pollution abatement by retention with percolation or detention without infiltration (wet detention).

2 DEVELOPMENT WITHIN AREAS OF THE 100-YEAR FLOODPLAIN

2.1 NATIONAL FLOOD INSURANCE PROGRAM

Projects located within the 100-year floodplain of a river or stream come under the jurisdiction of the Flood Hazard Regulatory Authority as found in Part 31, Water Resources Protection of the Natural Resource and Environmental Protection Act, Act 451 of the Public Acts of 1994. A permit needs to be filed with the Department of Environmental Quality (DEQ) for projects that involve construction, filling, and grading within a floodplain area.

The objectives of Part 31 are: a) to ensure that the flood carrying capabilities of the rivers and streams is maintained such that the floodways are not obstructed and that flood elevations are not increased or flow diverted, and b) to ensure that the floodway portion of floodplains are not inhabited.

Many communities in Kent County also participate in the National Flood Insurance Program (NFIP). The program makes flood insurance available in those communities agreeing to regulate future floodplain construction. Associated with the program are community floodplain mapping, building standards, federal lending restriction, and flood insurance rates supportive of local floodplain regulation. In order for a community to participate in the NFIP local regulations must be in force to:

1. Require that new construction and substantial improvements in flood prone areas be designed and anchored to prevent flotation, collapse, or lateral movement, be constructed with materials and utility equipment resistant to flood damage, and be constructed by methods and practices to minimize flood damages.

2. Require, where flood elevation data are available, that

a. All new construction and substantial improvements of residential structures located in flood hazard areas have the lowest floor (including basement) elevated to or above the 100-year flood level.

b. All new construction and substantial improvements of nonresidential structures in flood hazard areas have the lowest floor (including basement) elevated or dry floodproofed to or above the 100-year flood level. A registered professional engineer or architect must certify Floodproofing.

3. Require anchoring of mobile homes in flood prone areas.

4. Maintain a record of all lowest floor elevations to which new buildings have been constructed or existing buildings have been floodproofed when the structures are located in a flood hazard area.

Floodplains are mapped for most communities that participate in the FIPF. Floodplain maps are available for inspection in city, village, and township offices, or may be obtained from the Department of Environmental Quality (DEQ). The DEQ may also be able to provide estimates of flood elevations in many streams, and in communities where maps do not exist.

In Kent County, the following communities participate in the NFIP and may have a floodplain map:

Cities of: East Grand Rapids, Grand Rapids, Grandville, Kentwood, Lowell, Walker, and Wyoming.

Village of Sparta

Townships of: Ada, Algoma, Alpine (no map), Caledonia, Cannon, Cascade, Plainfield, and Sparta.

2.2 FLOODPLAIN MITIGATION

Natural floodway filling or alteration shall not be allowed without review and approval by the Kent County Drain Commission and compliance with the Floodplain Regulatory Authority found in Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA) on watercourses with contributing drainage area of 2 square miles or greater. If a floodway has not been mapped, the applicant's consultant shall provide the floodway delineation to the Kent County Drain Commission for approval.

Natural floodway fringe filling or alteration shall not be allowed without review and approval by the Kent County Drain Commission and compliance with the Floodplain Regulatory Authority found in Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA) on watercourses with contributing area of 2 square miles or greater. If a floodplain has not been mapped, the applicant's consultant shall provide the floodplain delineation including the floodway to the Kent County Drain Commission for approval.

To provide for streambank stability a buffer zone is to be established and called out on a recorded plat, an approved block grading plan, a site plan, or an improvement plan. This zone shall consist of existing natural tree and vegetation slope protection within a minimum of 25 feet from the ordinary high water mark. This buffer zone shall be maintained as is, that is, no earth change or disturbance is to take place.

Replacement of lost floodplain shall meet the following criteria.

1. Replacement of the loss of floodplain storage volume at a 1 to 1 ratio unless watershed conditions warrant a higher ratio. This applies to floodplain associated with rainfall events up to a 100-year frequency. The grading plan shall provide for an equivalent volume of storage for floodplains associated with more frequent events such as 10 and 25 year frequencies.

2. Storm water detention does not apply toward the replacement volume.

3. Floodplain storage volume shall be computed above the seasonal high ground water level only.

4. The inflow and outflow rates to the area shall be consistent with predevelopment rates.

5. Up to 50 percent of the floodplain mitigation storage volume may be used for snow storage.

6. The proximity of the floodplain mitigation area shall provide for an equivalent hydrologic impact to the receiving stream and adjacent parcels.

3 DESIGN CRITERIA

The basis of design for the stormwater management facilities are governed by the following criteria:

3.1 DESIGN STORM DURATION AND DISTRIBUTION

The design storm serves as the basis for design. The selection of the storm duration and distribution affects the resulting runoff volume and peak discharge rate. Total storm volume and distribution has been selected to produce total runoff volume and peak runoff rates that are independent of the tributary area. The following characteristics of the design storm have been selected:

- The duration of the rainfall event shall be dependent on the time of concentration for the individual site. Section 5.3.7 provides information for calculating the time of concentration.

- Rainfall distribution for the design storm used for any stormwater management facilities must be in accordance with the U.S. Department of Agriculture, Soil Conservation Service (SCS) Type II Rainfall Distribution. Total rainfall volume and the distribution of that rainfall per SCS Type II are provided in Table 1. The distribution is provided at one-half hour intervals for a variety of return intervals.

3.2 DESIGN STORM VOLUME

The design of all facilities must be based on the design storm return interval that is the probability that the storm will occur in any one year. For example, the 100-year storm has a 1 percent probability of being met or exceeded in any one year. The 25-year storm has a 4 percent probability of being met or exceeded in any one year. The following are the return interval design criteria for stormwater related facilities:

- Bridges for major roads
  - 100-year with no backwater for new crossings
  - 100-year with no greater than a 0.1 foot increase or reduction in backwater for existing crossings.

- Ditches and bridges/culverts for drainage external to a development
  - 100-year storm if no floodway channel is available
  - 10-year storm may be used otherwise

- Storm Sewers
  - 10-year storm flow capacity, using gravity flow, if floodway available
  - 100-year flow capacity required if no floodway channel available

- Floodways
  - 100-year flow capacity

- Roadside swales for drainage internal to the development
  - 10-year flow capacity

- Detention/retention basin primary discharge control volume
  - 25-year flow capacity

- Detention/retention basin emergency floodway capacity
  - Provisions shall be made to convey the 10-year storm flow over the emergency spillway without damaging the containment berm

3.3 BASIN DISCHARGE CONTROLS

- The peak release rate shall be 0.13 cfs/acre

- The first 0.5” of runoff shall be held for not less than 12 hours or more than 24 hours.

3.4 REQUIRED CALCULATION METHODS

A variety of methods can be used to calculate the peak runoff rate and to estimate runoff volume for a development. Three alternative methods are provided each with certain limits on their usage. Any of these three methods may be used subject to the development size limitations set forth. Alternative generally accepted engineering calculation methods are allowed, but will require additional review prior to acceptance. The permissible calculation methods are described as follows:

- Developments with tributary areas that are less than 40 acres:
  - The Rational Method – (Section 5)

- Developments with tributary areas that are between 40 and 200 acres:
  - The SCS TR55 method – (Section 6)

- Developments with tributary areas that are over 200 acres:
  - HEC-HMS AND HEC-RAS

- Other acceptable Hydrologic and Hydraulic Computer Models include:
  PondPack, SWMM, HSPF, and FEQ.

  Other computer models may be used in lieu of those mentioned above if the complete input data and output data sets are furnished. Also provided that the data fields, column headings, etc. are described in text format.

TABLE 1 -Design Storm Hyetographs – SCS Method						
Type II 24-Hour Distribution						
Frequency:	2year	5year	10year	25year	50year	100year
Duration :	24 Hour	24 Hour	24 Hour	24 Hour	24 Hour	24 Hour
Depth	2.37	3.00	3.52	4.45	5.27	6.15
0.0	0.000	0.000	0.000	0.000	0.000	0.000
0.5	0.013	0.016	0.019	0.024	0.028	0.033
1.0	0.013	0.017	0.019	0.024	0.029	0.034
1.5	0.013	0.017	0.020	0.025	0.030	0.034
2.0	0.014	0.018	0.021	0.026	0.031	0.036
2.5	0.014	0.018	0.021	0.027	0.032	0.038
3.0	0.015	0.019	0.022	0.028	0.033	0.039
3.5	0.016	0.020	0.024	0.030	0.035	0.041
4.0	0.016	0.021	0.024	0.031	0.036	0.042
4.5	0.017	0.022	0.025	0.032	0.038	0.044
5.0	0.018	0.023	0.027	0.034	0.041	0.047
5.5	0.019	0.024	0.028	0.036	0.042	0.049
6.0	0.020	0.026	0.030	0.038	0.045	0.052
6.5	0.021	0.027	0.032	0.040	0.047	0.055
7.0	0.023	0.029	0.034	0.043	0.051	0.060
7.5	0.025	0.032	0.037	0.047	0.055	0.065
8.0	0.027	0.034	0.040	0.051	0.060	0.070
8.5	0.030	0.038	0.044	0.056	0.066	0.077
9.0	0.033	0.042	0.049	0.062	0.073	0.085
9.5	0.037	0.047	0.056	0.070	0.083	0.097
10.0	0.043	0.055	0.064	0.081	0.096	0.113
10.5	0.055	0.070	0.082	0.104	0.123	0.144
11.0	0.071	0.090	0.105	0.133	0.158	0.184
11.5	0.117	0.148	0.173	0.219	0.259	0.303
12.0	0.900	1.140	1.337	1.691	2.002	2.336
12.5	0.170	0.216	0.253	0.320	0.379	0.442
13.0	0.088	0.112	0.131	0.166	0.197	0.229
13.5	0.063	0.080	0.093	0.118	0.140	0.163
14.0	0.045	0.057	0.067	0.085	0.100	0.117
14.5	0.048	0.060	0.071	0.089	0.106	0.124
15.0	0.037	0.047	0.056	0.070	0.083	0.097
15.5	0.033	0.041	0.049	0.061	0.073	0.085
16.0	0.030	0.037	0.044	0.056	0.066	0.077
16.5	0.027	0.034	0.040	0.050	0.060	0.069
17.0	0.025	0.032	0.037	0.047	0.055	0.065
17.5	0.023	0.029	0.034	0.043	0.051	0.059
18.0	0.022	0.027	0.032	0.040	0.048	0.056
18.5	0.020	0.026	0.030	0.038	0.045	0.052
19.0	0.019	0.024	0.028	0.036	0.042	0.049
19.5	0.018	0.022	0.026	0.033	0.040	0.046
20.0	0.017	0.022	0.026	0.032	0.038	0.045
20.5	0.016	0.021	0.024	0.031	0.036	0.042
21.0	0.015	0.020	0.023	0.029	0.034	0.040
21.5	0.016	0.020	0.023	0.029	0.035	0.041
22.0	0.014	0.017	0.020	0.026	0.031	0.036
22.5	0.014	0.018	0.021	0.026	0.031	0.036
23.0	0.013	0.017	0.020	0.025	0.030	0.034
23.5	0.013	0.017	0.019	0.024	0.029	0.034
24.0	0.013	0.016	0.019	0.024	0.028	0.033

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

4.1.2.1 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.

4.1.2.2 The tailwater elevation for the storm sewer design shall be computed at the spillway elevation when discharging into a detention facility. No surcharging of the system should occur for the 10-yr storm event.

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 Submergence

The KCDC Storage Table 5, assumes a free flowing release. To account for submergence of the outlet when discharging into a water course, the outlet and required storage volume shall be placed above the 10-yr flood elevation of the water course.

4.5.1.3 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:

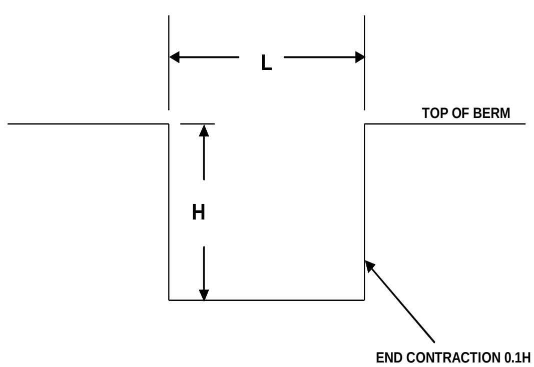
Design Equation for Rectangular Weir

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

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

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

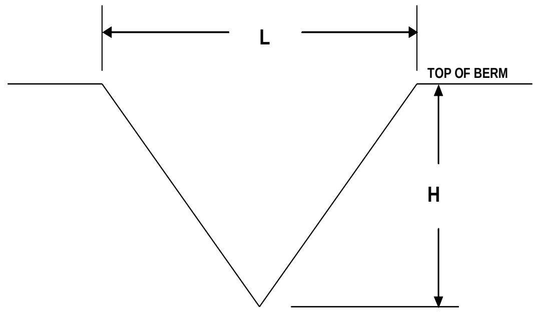
when vertical sidewalls are present (see illustration)



Design Equation for V-notch Weir

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

(see illustration)

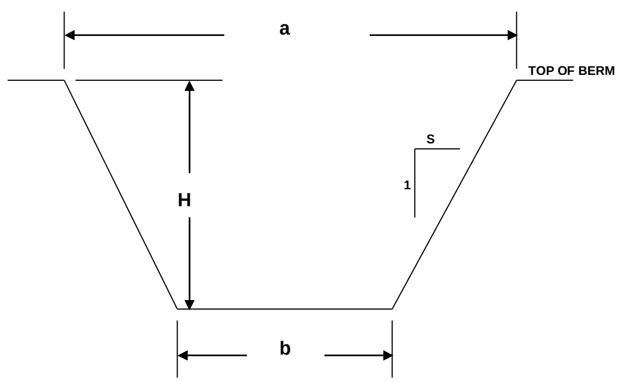


Design Equation for Trapezoidal Weir (normally used with earthen berms)

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

(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



4.5.1.4 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	8.01	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.

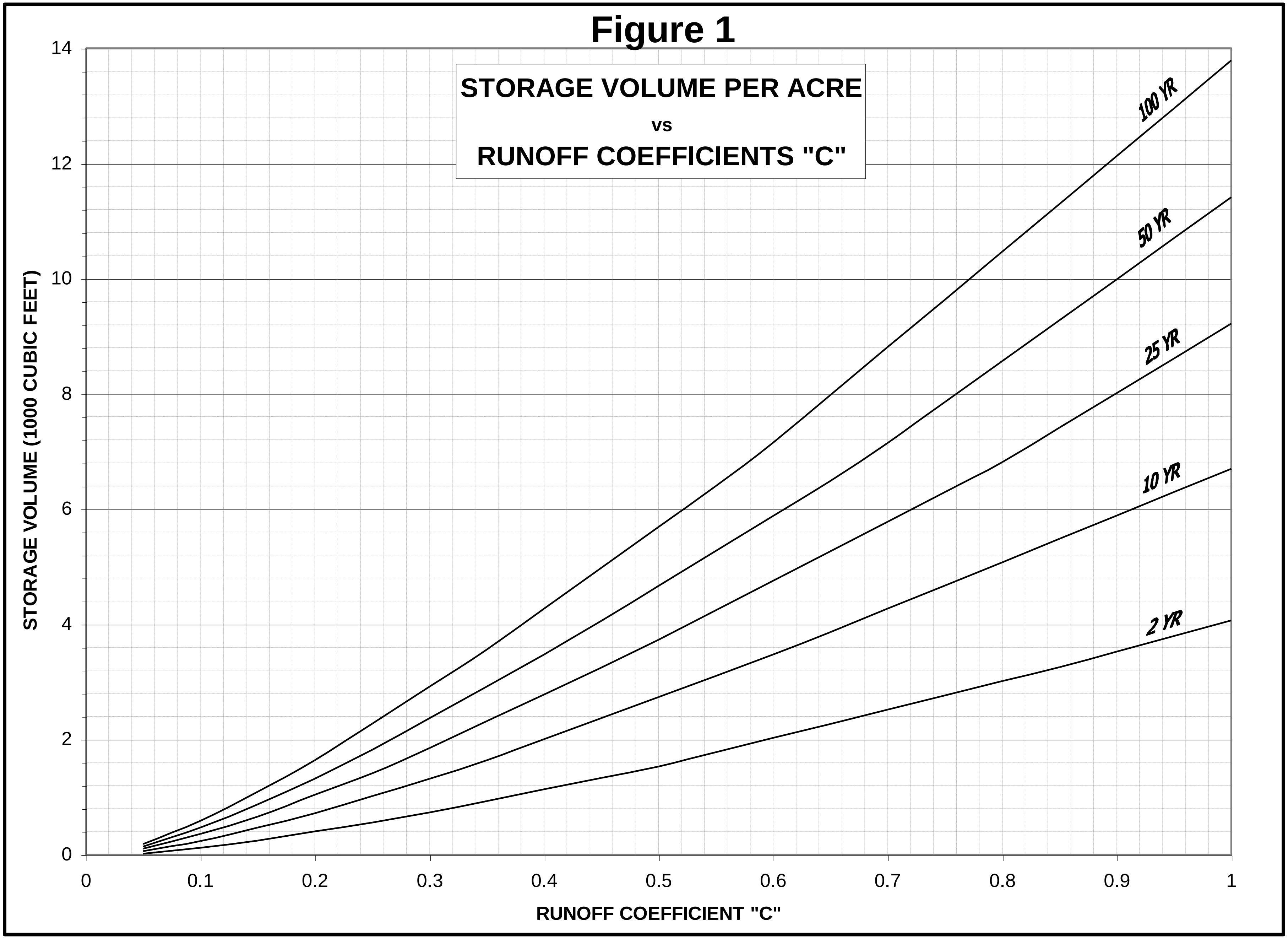


Figure 1
STORAGE VOLUME PER ACRE
vs
RUNOFF COEFFICIENTS "C"
100 YR
50 YR
25 YR
10 YR
2 YR
STORAGE VOLUME (1000 CUBIC FEET)
RUNOFF COEFFICIENT "C"
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Construction Standards

4.5.1.5 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)

4.5.1.6 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.)

4.5.1.7 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.

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

4.5.1.9 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.

4.5.1.10 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:

  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.
  A non-woven geotextile fabric shall be laid in the excavated trench first.
  The perforated drainpipe shall be covered with washed stone.
  Both stone and drain shall then be wrapped with the non-woven geotextile and backfilled with sandy porous material.
  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.

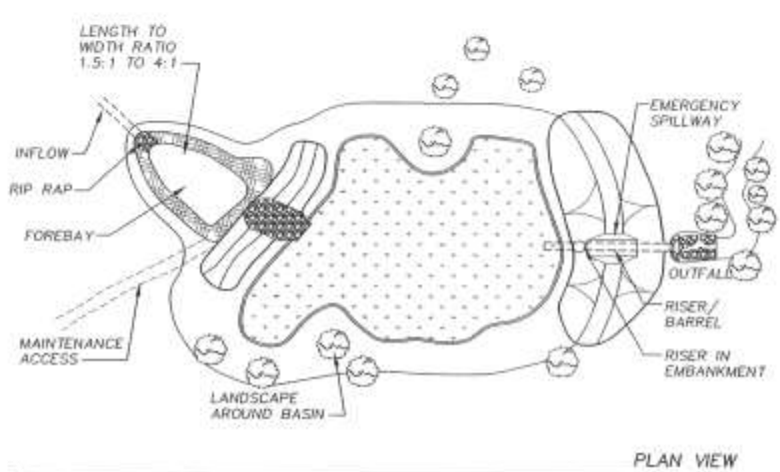
Natural or synthetic materials will be allowed for construction of emergency spillways if it can be demonstrated that the structures will not fail and will have significant longevity.

- 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

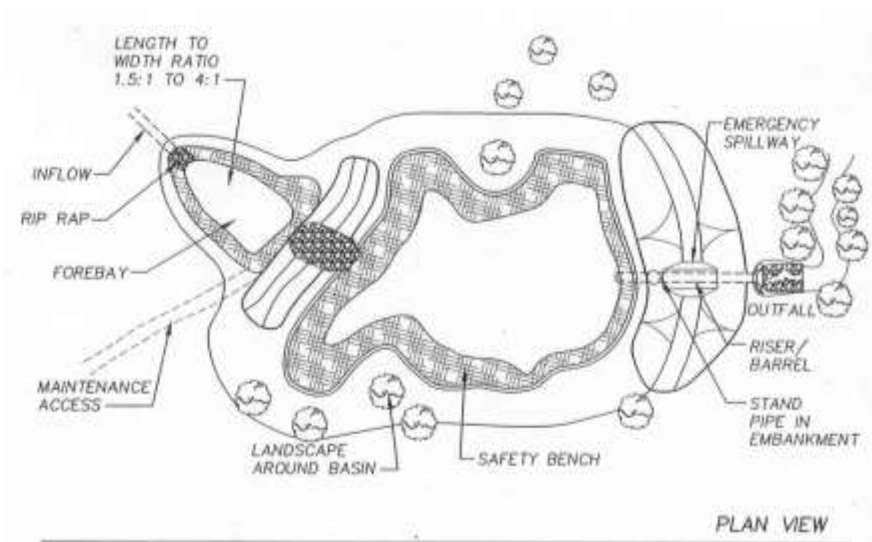
4.7.5 Receiving Stream

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)

- A Double-ring infiltrometer test is the recommended method to estimate the infiltration rate. At least one test should be conducted at the proposed bottom elevation of the basin.

- A maximum rate of 2 in/hr will be accepted as a design infiltration rate.

- 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 home site has been constructed 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.

- For further information in regards to Soil Infiltration Testing, visit the LID Manual for Michigan at http://www.swmpc.org/mi_lid_manual.asp.

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

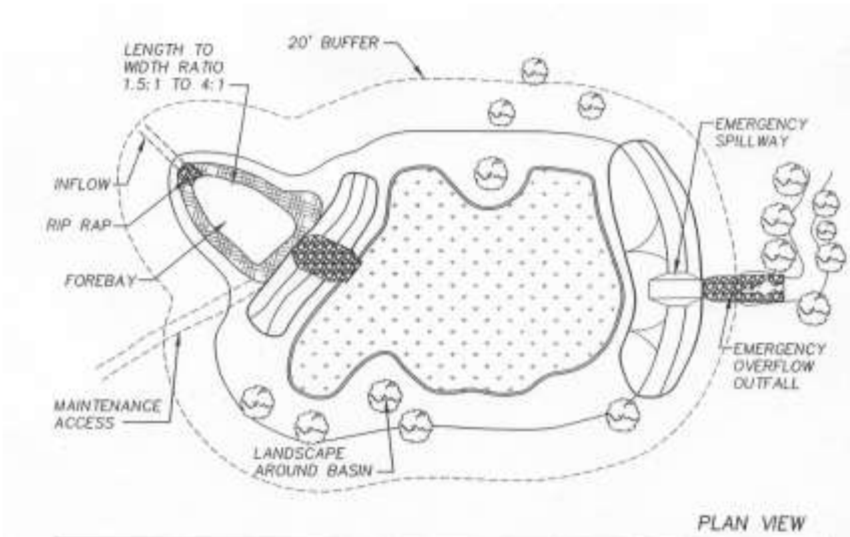
If a receiving stream is utilized, the criteria are the same as for dry ponds. See section 4.6.5

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
Filter Strips
Perforated Underdrain
Level Spreaders

INFILTRATION/RETENTION BASIN EXAMPLE



5 PEAK DISCHARGE RATE - RATIONAL METHOD

The Rational Method shall be used only in cases where the tributary area is 40 acres or less.

The Rational Method is a standard method for calculating the peak runoff rate for a parcel. The results of its use are very sensitive to the coefficients selected. As a result the method is best suited for use on small parcels where the additional time that may be required to use another method may not be justified. Larger parcels should utilize more accurate methods.

5.1 The Rational Method is based on three assumptions:

5.1.1 The peak runoff at any design location is a function of the average rainfall intensity during the time of concentration to that location.

5.1.2 The frequency of peak discharge is the same as the frequency of the average rainfall intensity.

5.1.3 The Time of Concentration is the time required for the runoff from the most remote part of the drainage area to become established and flow to the point under design.

5.2 The Rational Method is an empirical method based on the following equation: $Q = C \bullet i \bullet A$

C - Runoff coefficient, is a constant (dimensionless) which represent the fraction of rainfall which will result in the peak runoff rate from the land into a storm drainage system.

A - Area (acres) of the sub-basin upstream from the point of design, and must include upstream tributary areas not part of the development.

i - Rainfall intensity (in/hr) of the storm which represents the duration and frequency of rainfall which will create the maximum peak runoff. Typically, the intensity over the time of concentration for the sub-basin will result in the peak flow for a particular return period.

5.3 Procedure for Determining Peak Discharge

5.3.1 Delineate and determine the drainage area, (A), in acres, of the watershed upstream of the point of the storm drainage system in question. If the watershed drainage area is less then 1 acre or greater than 40 acres this method should not be used. The upstream area must be considered completely developed.

5.3.4 Determine the appropriate Runoff Coefficient, "C", for each land use in the drainage area from Table 6. A composite "C" shall be computed based on the respective percentages of each classification or land use within the drainage area.

Determine the overland time flow, t_o, from the following equation:

$$t_o = \left[\frac{2 \bullet L \bullet n}{3 \bullet \sqrt{S}}\right]^{(1/2.14)}$$

L - Distance of the overland flow path with the longest overland flow time for that sub-basin. The path follows a direction parallel to the slope of the sub-basin. Several flow times will have to be calculated for various paths to determine which path actually has the maximum flow time.

n - Friction coefficient (Manning's n) can be taken from Table 7.

S - Slope is the difference in elevation between the extreme edge of the flow path to the point of entry into the defined channel divided by the length of the flow path.

TABLE 6
Runoff Coefficients
Rational Method

Type of Land Use	2-year Storm	10-year Storm	25-year Storm	100-year Storm
Residential 1-2	0.29	0.43	0.45	0.47
Multi-family residential	0.35	0.46	0.47	0.47
Mobile home	0.37	0.53	0.55	0.56
CBD/Shopping	0.43	0.57	0.58	0.58
Comm/Business	0.39	0.51	0.51	0.52
Industrial	0.45	0.58	0.59	0.60
Industrial Park	0.37	0.53	0.55	0.56
Forest	0.1	0.24	0.27	0.32
Agriculture	0.16	0.3	0.33	0.37
Water	1.0	1.0	1.0	1.0
Extractive	0.12	0.27	0.3	0.34
Airport	0.22	0.31	0.32	0.34
Rural Residential	0.15	0.3	0.33	0.37

TABLE 7
Manning's n
Overland Flow

Ground cover	Manning’s n
Smooth asphalt or concrete	0.012
Rough asphalt or concrete	0.014
Packed clay	0.03
Light turf	0.2
Dense turf	0.35
Dense shrubbery	0.5

5.3.8 Determine the stream (channel) flow time, t_s, if stream flow is achieved within the sub-basin.

$$t_s = L \div V$$

and

$$V = 1.49 \bullet R^{2/3} \bullet s^{1/2} \div n$$

Where:

L = Channel Length (ft)
V = Velocity (ft/s)
R = Hydraulic Radius (ft)
s = Channel Slope (ft/ft)
n = Composite Manning's n for channel

For an open channel the hydraulic radius can be approximated as:

R = 0.6 for small streams (less than 100 Ac drained)
R = 1.5 for medium streams (100 Ac to 1 sq. mile)
R = 2.5 for large streams (more than 1 sq. mile)

For flow in a closed conduit (storm sewer) the conduit can be assumed to be flowing full and R = A ÷ P, where A is the flow area and P is the wetted perimeter.

5.3.9 Determine the pipe flow time;

$$t_p = L \div V$$

Where L is the pipe length, and V is the average pipe velocity.

5.3.10 The time of concentration, tc, is the sum of the overland flow time, the stream flow time, and the pipe flow time.

$$t_c = t_o + t_s + t_p$$

5.3.11 The time of concentration indicates the duration of a storm that will cause the maximum peak runoff rate to be reached. Using the return period from step 5 and the time of concentration as duration, the average intensity of the storm can be found using Figure 2.

5.3.12 The Peak Runoff Rate, Q, is then calculated using:

$$Q = C \bullet i \bullet A$$

Where:

Q = Peak Runoff Rate (cfs)
C = Composite Runoff Coefficient
i = Average Rainfall Intensity (in/hr)
A = Drainage Area (acres)

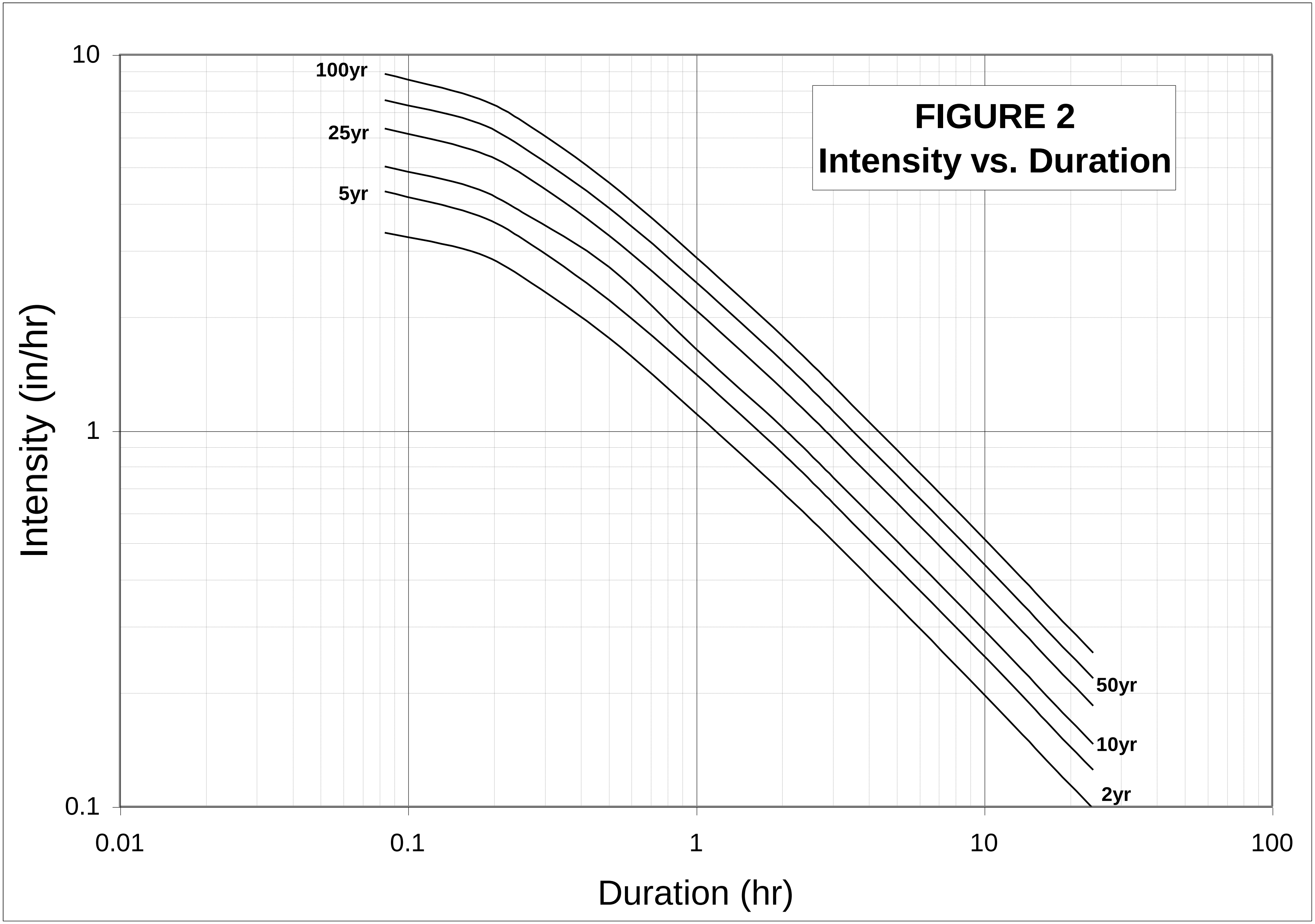


FIGURE 2
Intensity vs. Duration
Intensity (in/hr)
Duration (hr)
10
1
0.1
0.01
0.1
1
10
100
100yr
25yr
5yr
50yr
10yr
2yr

6 PEAK DISCHARGE RATE - SCS METHOD

The SCS Method can be used for calculation of peak discharge for tributary areas between 40 and 200 acres.

The SCS Method is based on use of TR-20 for calculation of the peak runoff from urban areas. The method uses composite land use types within a sub-basin. Land use is used as an indicator within this method of the percent impervious. Because of this, the method has been modified so that the land uses provided are specific to the percent impervious for these land uses in Kent County.

6.1 Following are the steps that need to be followed to use this method:

6.1.1 Delineate and determine the drainage area (A), in acres, of the sub-basin upstream of the point of the storm drainage system in question. If the watershed drainage area is less than 5 acres or greater than 200 acres this method should not be used.

6.1.2 List the future land uses and zoning classifications for the entire drainage area. Determine the percentages of each land use classification for the drainage area.

6.1.3 Determine the appropriate runoff curve number (CN) from Table 8 for each land use classification in the drainage area. Calculate the area-weighed CN ($A \bullet CN$) for the watershed. Round off the weighted CN to the nearest CN divisible by 5.

6.1.4 Select a 24 hour duration rainfall depth, P, with the appropriate return period from Table 9. The return period depends on the highest value zoning classification in the watershed and should be as follows:

10 years for residential areas;
25 years for commercial or industrial and other high value areas; and
100 years for flood protection works.

TABLE 8
% Impervious and Runoff Curve Numbers for Zoning Districts

Zoning District	Average Percent of Impervious Area	Runoff Curve Number by Hydrologic Soil Group			
		A	B	C	D
Residential 1-2	25%	54	70	80	85
Residential Multi-Family	50%	69	80	86	89
Mobile Homes	35%	60	74	82	86
CBD / Shopping	45%	66	78	85	88
Commercial / Business	55%	71	81	87	90
Industrial Park	35%	60	74	86	89
Forest	1%	25	55	70	77
Agricultural	14%	51	66	76	81
Water	100%	98	98	98	98
Extractive	14%	51	66	76	81
Airport	20%	51	68	79	84
Rural Residential	20%	51	68	79	84
Parks and Idle Land	5%	33	60	72	79

TABLE 9
SCS Rainfall Depth
24 Hour Storm Duration

Return Period (Years)	Rainfall Depth (Inches)
2	2.37
5	3.00
10	3.52
25	4.45
50	5.27
100	6.15

6.1.5 Using Figure 3 and the rainfall depth, P (inches), from Step 4, determine the runoff depth, Q (inches), for the watershed using the curve number (CN) determined from step 3.

6.1.6 Determine the unit peak discharge, q_u (cfs/inch), for the watershed drainage area, A, Figure 4.

6.1.7 Calculate the peak discharge (design flow), q, in cfs as follows:

$$q = P \bullet q_u$$

FIGURE 3
RUNOFF (Q) VS: RAINFALL (P)

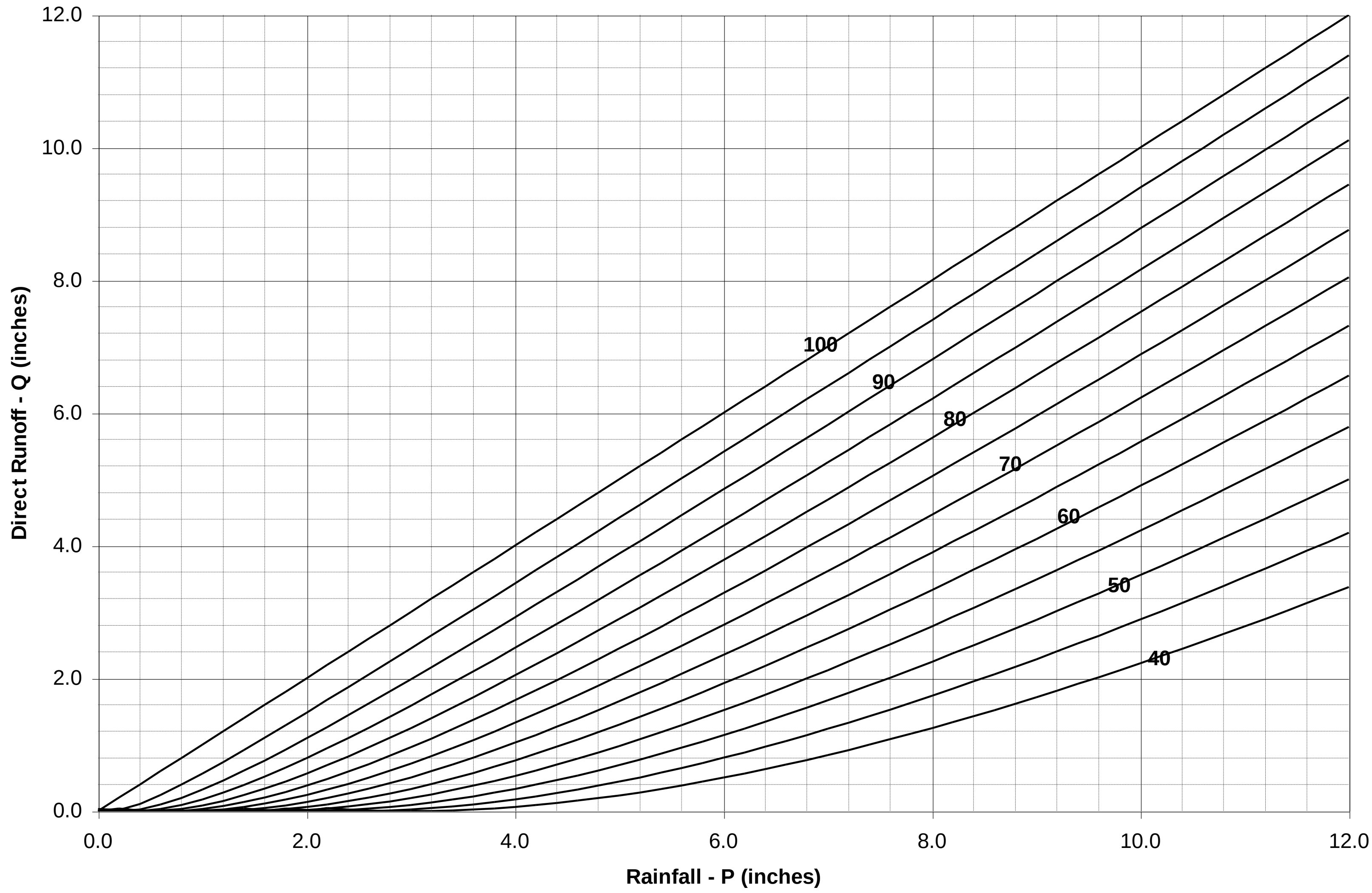


Exhibit 4-I: Unit peak discharge (q_u) for SCS type I rainfall distribution

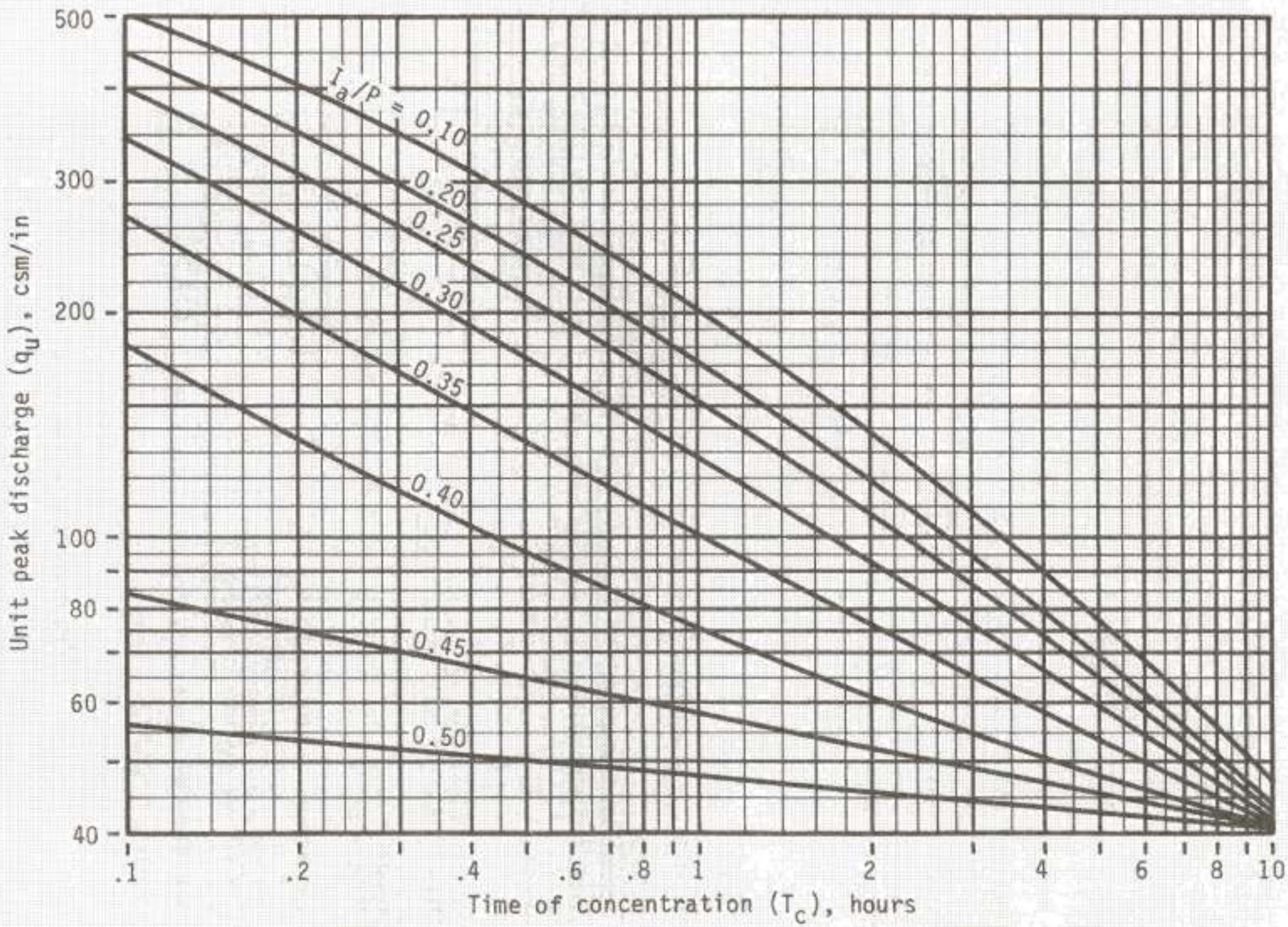


Exhibit 4-IA: Unit peak discharge (q_u) for SCS type IA rainfall distribution

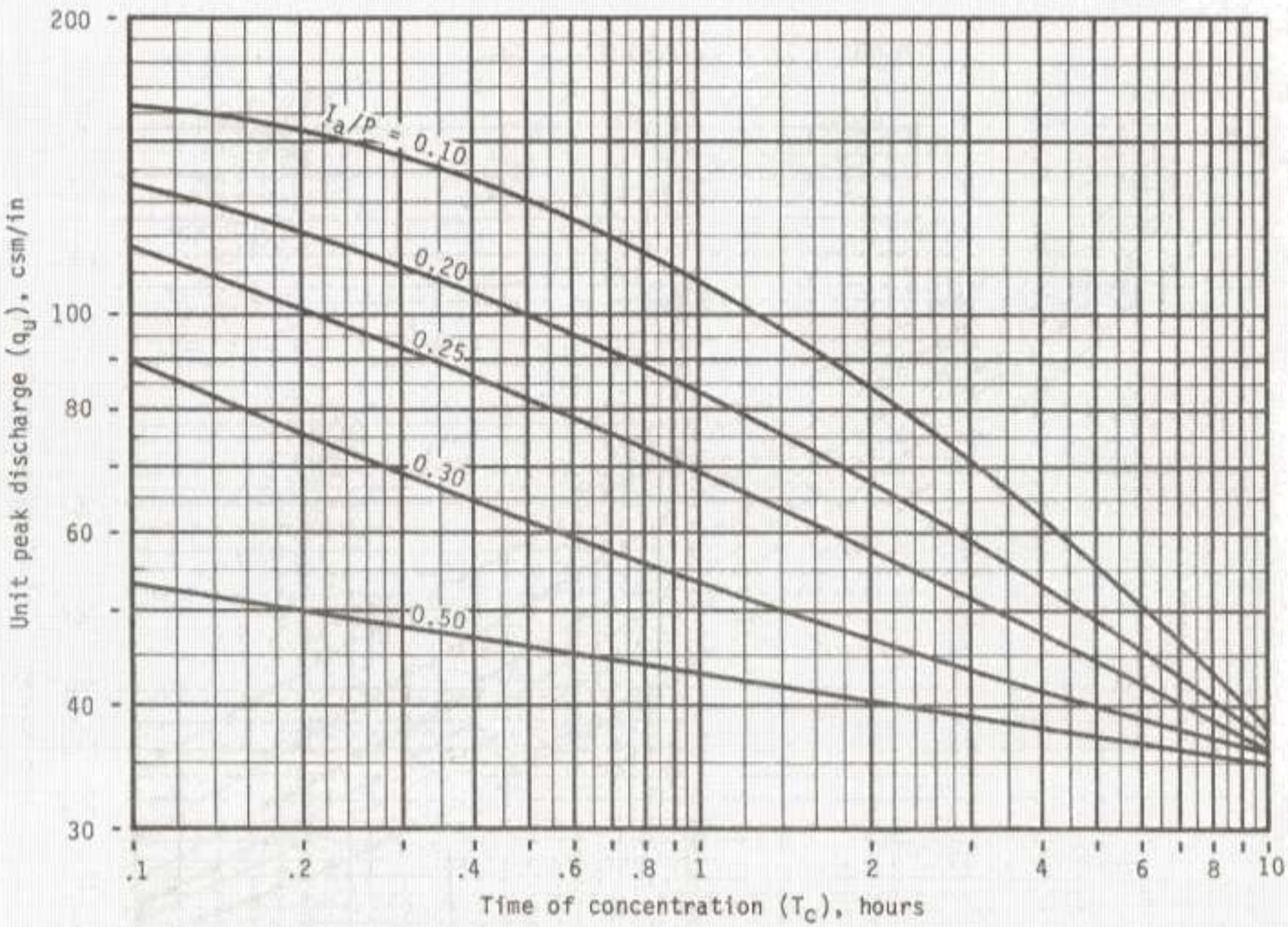


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Exhibit 4-II: Unit peak discharge (q_u) for SCS type II rainfall distribution

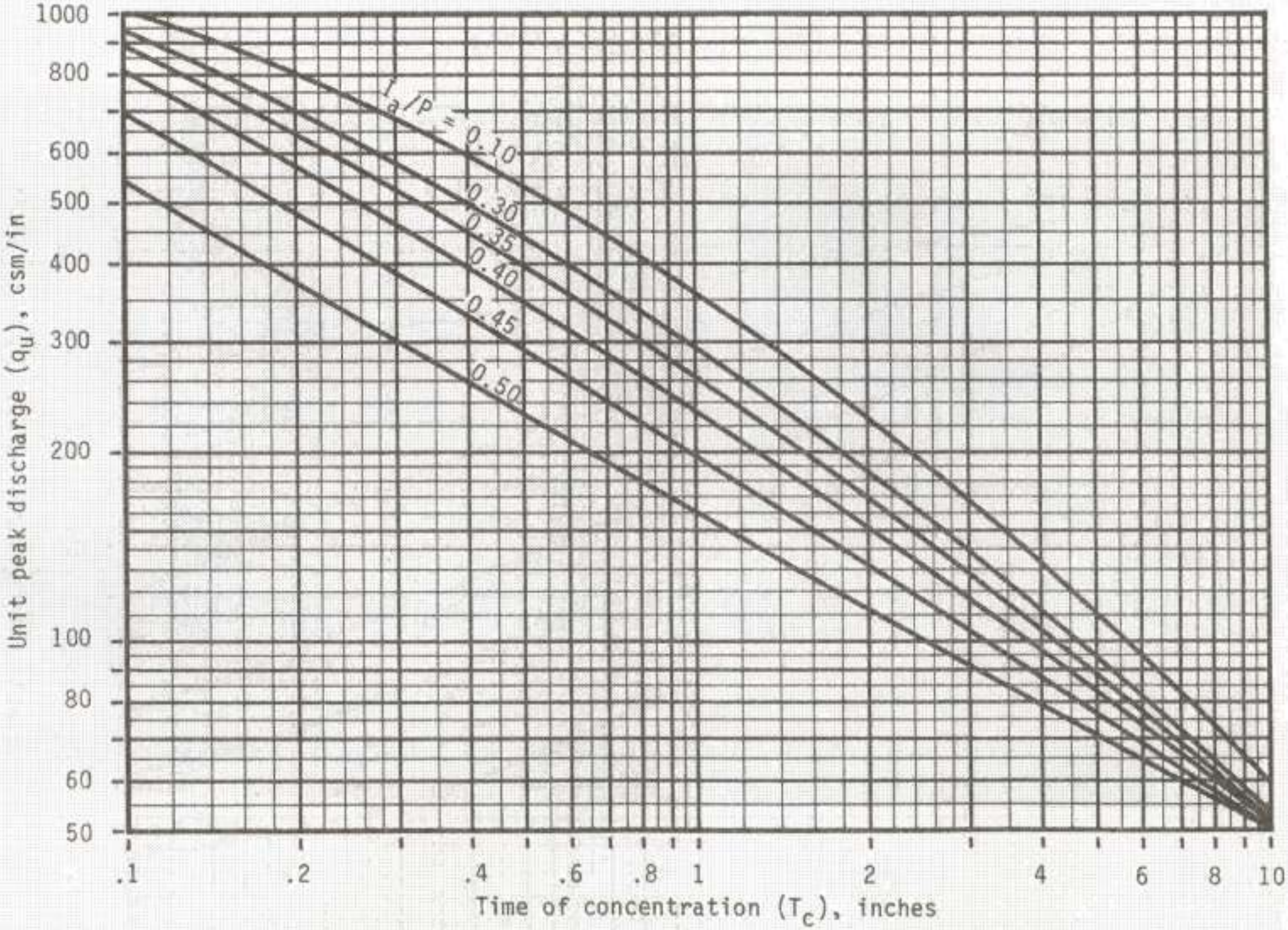
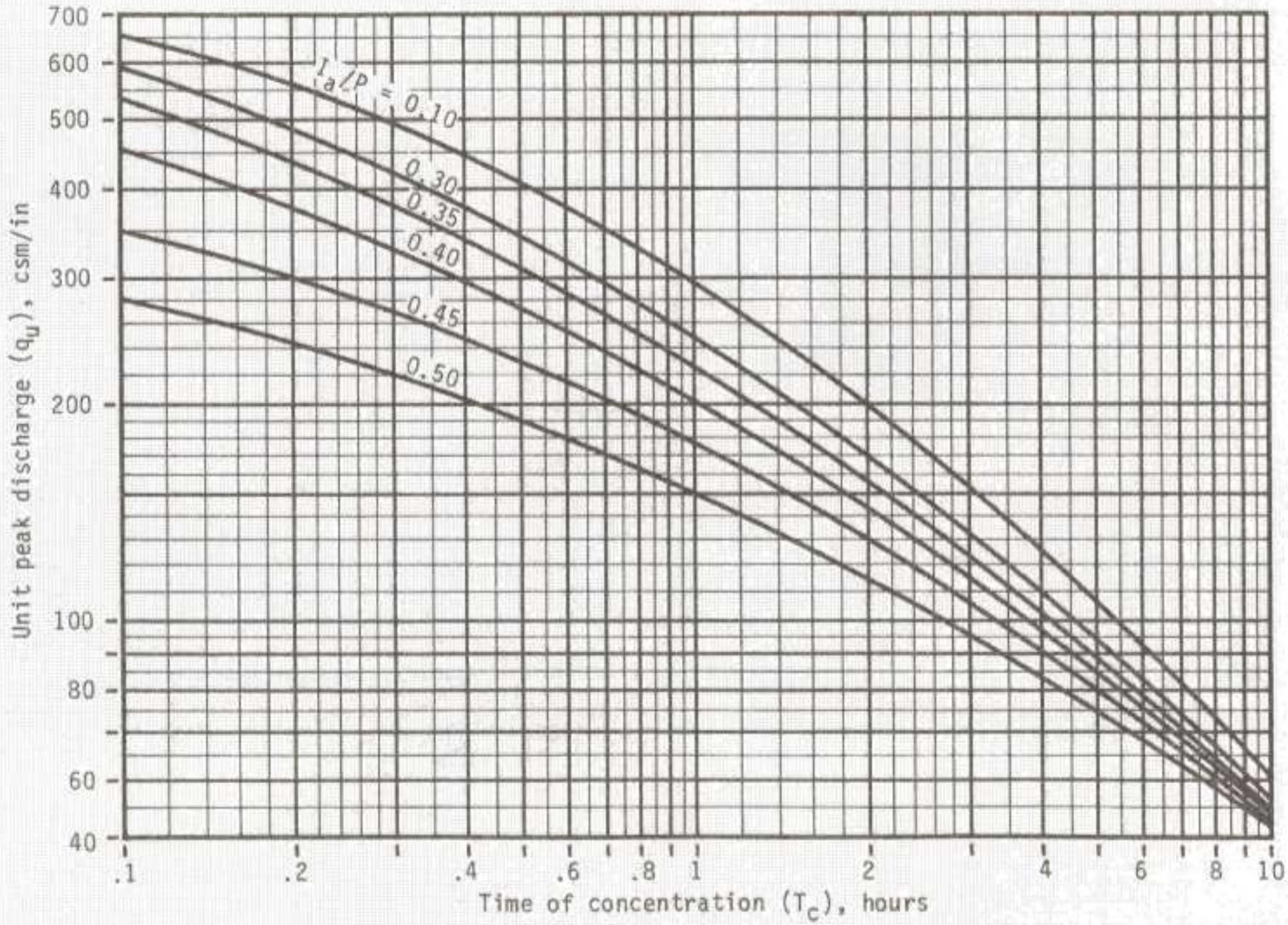


Exhibit 4-III: Unit peak discharge (q_u) for SCS type III rainfall distribution



(210-VI-TR-55, Second Ed., June 1986)

7 PEAK DISCHARGE – HEC-HMS & HEC-RAS

For drainage areas greater than 200 acres, use HEC-HMS AND HEC-RAS for modeling the watershed. These programs can be downloaded for free at:

HEC-HMS:

http://www.hec.usace.army.mil/software/hec-hms/hechms-hechms.html

HEC-RAS:

http://www.hec.usace.army.mil/software/hec-ras/hecras-hecras.html