Chapter 4 Engineering Calculations

4.0 Introduction

This chapter outlines the necessary calculations for stormwater management within the City of Charleston.

4.1 Acceptable Methods for Calculations

The owner/designer must include all soil testing results, assumptions, calculations, and computer program results. This section outlines calculation methods that the City of Charleston considers acceptable. Other methods of calculations may be considered by the City of Charleston, on a case-by-case basis.

4.1.1 On-site Storage requirements

The current standard for the EPA mid-Atlantic region, and as required by the WVDEP MS4 General Permit, is to keep and manage onsite the first 1-inch of rainfall from an average 24-hour storm preceded by 48 hours of no measurable precipitation. Extended filtration practices that are designed to manage one inch of rainfall may discharge through an underdrain. For projects that cannot meet the requirement of 100% capture by infiltration, evapotranspiration, and/or reuse, an alternative is available: off-site mitigation in lieu of. Policies regarding an alternative is discussed in Chapter 2 of this document.

4.1.2 Storage Volume Estimation

General Types of Storage:

- **Surface Storage:** A rough estimate of surface storage can be obtained by averaging the surface area and bottom area of a basin or depression and multiplying this area by the average depth. For irregular shapes, the volume can be estimated by finding the area inside each contour, multiplying each area by the contour interval, and adding the results. This is often referred to as the average end area method.
- **Stone Storage:** Storage in stone pores is equal to the volume of the crushed stone bed times the porosity. A design porosity of 40% (0.40) can be assumed for clean drainage stone. Well graded and densely graded stone will have less porosity.
- **Porous Media Storage:** This is also called an Engineered Soil, and is the storage available in porous media equal to the initial moisture deficit (i.e. the portion of total porosity that is not already occupied by moisture). This portion varies at the beginning of every storm. Acceptable design values are 30% (0.30) for sand and 20% (0.20) for growing soil. Engineered soils are designed as a growing media and storage media and typically have a porosity of 25% (0.25).
- **Active Storage:** Active or engineered storage (i.e. vaults, tanks, chambers) is storage that fills for a relatively short period of time (i.e. typically no more than 48 hours) and drains under gravity or pumped conditions. The maximum elevation that should be considered as active storage is the overflow elevation.

Hand, computer or spreadsheet storage volume calculations clearly showing assumptions must be provided for all permanent structures requiring a specific storage volume. Temporary sediment traps and basins shall also require appropriate storage calculations.

4.1.3 Hydrologic Runoff Calculation Methods

The two most common methods for calculating stormwater runoff are the Rational Method and the National Resources Conservation Service (NRCS) TR-55.

4.1.3.1 Rational Method

The Rational Method is one of the most common methods for determining peak runoff rates for urban and rural watersheds and may be used on small sites that are less than 200 acres in size. It is most effective in the design of ditches and urban drainage.

The Rational Method estimates peak runoff for a given watershed as a function of the drainage area, runoff coefficient, and the mean rainfall intensity. The Rational Method formula is expressed as follows:

$$Q=CiA$$

Q = maximum rate of runoff in cubic feet per second (cfs)

C = runoff coefficient representing a ratio of runoff to rainfall (see Table 4-1)

i = average rainfall intensity for a duration equal to the time of concentration (Tc) for a selected return period in inches per hour (in/hr) (see Chart 4-1, page 4-3)

A = drainage area to a given outlet point in acres (ac)

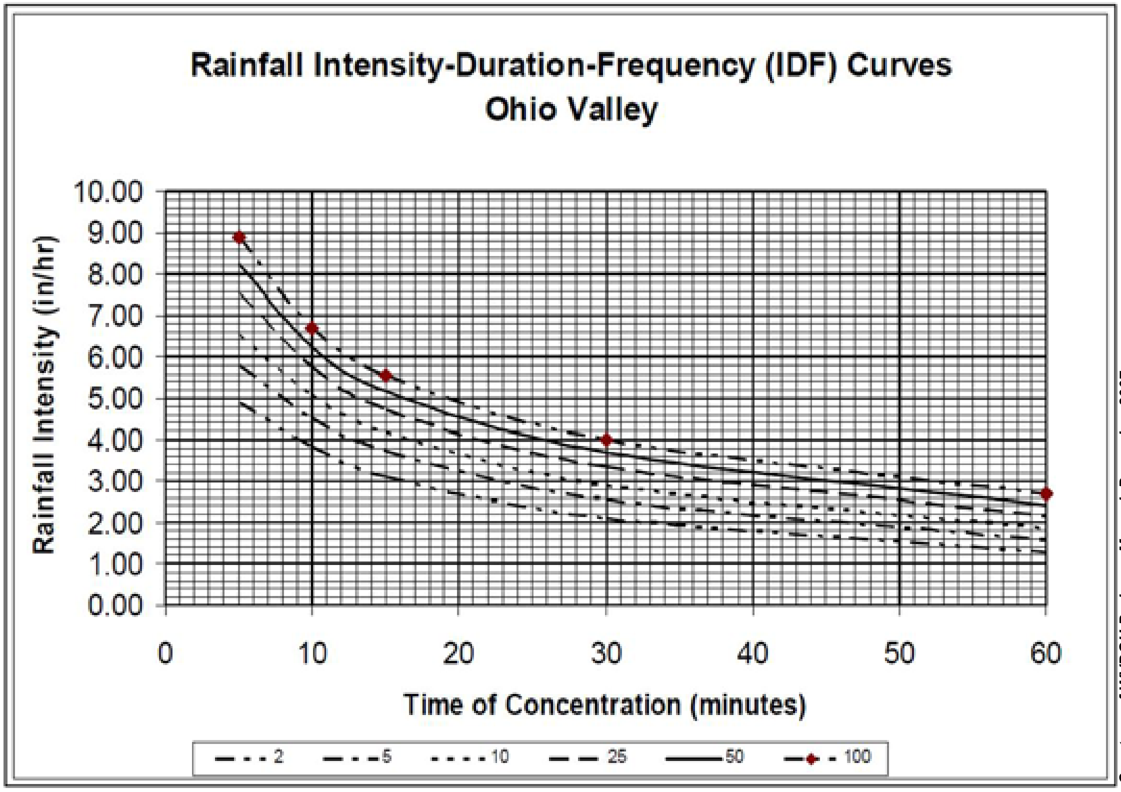
Runoff Coefficients

The runoff coefficient illustrated in Table 4-1 is represented by a range of C-Values. These values represent the soil or cover types that the rainfall will come in contact with when it first reaches the ground within a given drainage area.

Table 4-1: Recommended Runoff Coefficient (C) Values

Description of Area	Runoff Coefficient (C)		
	Slope 0% to 2%	**Slope 2% to 10%**	**Slope Over 10%**
Pavement, Roof, etc.	0.85	0.90	0.95
Earth Shoulders	0.55	0.60	0.70
Gravel or Stone	0.45	0.50	0.60
Grass Shoulders	0.30	0.35	0.40
Dense Residential Areas	0.60	0.65	0.80
Suburban Areas with Small Yards	0.40	0.50	0.60
Cultivated Land			
Clay Loam	0.35	0.50	0.60
Sand and Gravel (Infiltration)	0.25	0.30	0.35
Woods, Parks, Meadows, and Pasture Land	0.20	0.25	0.35
Urban			
Lawn	0.17	0.22	0.35
Playgrounds	0.30	0.35	0.40
Infiltration Area	0.10	0.15	0.20

Courtesy of WVDOH Drainage Manual, December 2007



Courtesy of WVDOH Drainage Manual, December 2007

Chart 4-1
Rainfall Intensity

Rainfall intensity, illustrated in Chart 4-1 by the Intensity-Duration-Frequency (IDF) Curve, is estimated based on the Time of Concentration (originally discussed in Section 3.4.4). The time of concentration (Tc) is the time required for water to flow from the most hydraulically remote point of the drainage area to the discharge point of the drainage area. There are several ways to calculate Tc. This manual discusses the Section Flow Method, where each section is broken down into three (3) types: sheet flow, shallow concentrated flow, and channel flow. The City will consider alternative methods as long as the method is clearly defined and all assumptions are explained in detail.

4.1.3.2 Time of Concentration Section Flow Method

Time of Concentration (Tc) is defined as the sum of the travel time within consecutive flow segments in the drainage basin consisting of overland flow, subdivided into the sheet flow and shallow concentrated flow, and channel or pipe flow signal.

$Tc = T_t$sheet flow + $T_t$shallow flow + $T_t$channel flow

Tc = Time of Concentration in minutes (min)
$T_t$sheet flow = sheet flow travel time in minutes (min)
$T_t$shallow flow = shallow concentrated flow travel time in minutes (min)
$T_t$channel flow = channel flow travel time in minutes (min)

The Section Flow Method is the City of Charleston’s preferred method for calculating Time of Concentration when using the Rational Method in developed areas.

Sheet Flow

Sheet Flow is described as shallow runoff on a plane surface with the depth remaining uniform across the sloping surface. Flow depths typically do not exceed two (2) inches and flow lengths should not exceed 100 feet. Flows beyond 100 feet usually become shallow concentrated flow.

Sheet flow is calculated using the following equation (also known as the Kinemetic Formula):

$$T_{tsheet} = \frac{0.93}{i^{0.4}} \left(\frac{nL}{\sqrt{S}} \right)^{0.6}$$

Where:

T = sheet flow travel time in minutes
n = Mannings roughness coefficient (see Table 4-2)
L = flow length in feet (ft)
i = rainfall intensity for the storm return period in inches per hour (in/hr) (see Chart 4-1, page 4-3)
S = slope of the surface in feet per foot (ft/ft)

Intensity depends on the Time of Concentration which is not immediately known. An initial estimate must be used for the Time of Concentration. For example, assume five (5) minutes for initial runoff time and use Chart 4-1 (page 4-3) for the initial rainfall intensity. Using the calculated Time of Concentration, repeat the calculation until the assumed and actual Time of Concentration numbers are the same (within +/- 1 minute).

Table 4-2: Mannings Roughness Coefficient for Sheet Flow

Surface Description	**n**
Smooth Concrete Surface	0.012
Smooth Asphalt Surface	0.011
Concrete Lined or Overlaid Surface	0.013
Gravel Surface	0.024
Rough / Uneven Bare Soil with Sparse Vegetation	0.050
Short Grass Surface	0.150
Dense Grass Surface	0.240
Lawn Grass Surface, such as Bermuda Grass	0.410
Forested Surface with Light Underbrush	0.400
Forested Surface with Dense Underbrush	0.800

Courtesy of WVDOH Drainage Manual, December 2007

Shallow Concentrated Flow

Flow that has not yet been concentrated into a channel or pipe, but has flowed farther than 100 feet as sheet flow, is considered shallow concentrated flow. To calculate the Time of Concentration for shallow concentrated flow, first estimate the velocity from the following equations:

$$V = k\sqrt{S}$$

Where:

V = velocity in feet per second (ft/sec)
k = surface cover coefficient (see Table 4-3)
S = slope of the surface (ft/ft)

Table 4-3: Surface Cover Coefficients Shallow Concentrated Flow

Cover Type	**k**
Forested Surface with dense underbrush, Lawn Grass Surface, such as Bermuda grass	2.5
Forested Surface with light underbrush, Rough / Uneven Bare Soil Surface with sparse vegetation	5.0
Dense Grass (i.e. Fescue) on an even soil surface	7.0
Short Grass Surface	9.0
Smooth Bare Soil Surface before vegetation establishment	10.1
Vegetated Channel	15.1
Gravel or Soil and Gravel Surface	16.2
Asphalt or Concrete Paved Surface	20.4

Courtesy of WVDOH Drainage Manual, December 2007

Source: WVDOH Drainage Manual December, 2007

The Time of Concentration for shallow concentrated flow is then found by the following equation:

$$T_t = \left(\frac{L}{V*60}\right)$$

Where:

T = shallow concentrated flow in minutes (min)
L = flow length in feet (ft)
V = velocity in feet per second (ft/sec)

Channel Flow

Channel flow occurs when flows are concentrated into natural or man-made channels. Areas of concentrated flow appear on aerial photos or topographic maps and can be used to determine flow lengths if detailed plans are unavailable. Calculate the time of concentration for channel flow by first estimating the velocity from the following equations. The area of the channel must be known or estimated and is assumed to be full for the purposes of estimation.

$$V = \left(\frac{1.49}{n}\right) R^{2/3} \sqrt{S}$$

Where:
V = velocity in feet per second (ft/sec)
n = roughness coefficient (see Table 4-4)
R = Hydraulic Radius in feet (flow area/wetted perimeter)
S = slope of the surface (ft/ft)

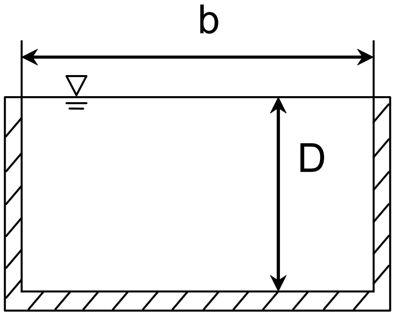
Table 4-4: Roughness Coefficient - Channel Flow

Surface Description	**n**		
CHANNEL FLOW	**Recommended**	**Range**	
Existing Vegetative Lining			
Nearly Bare, Light Grass	0.032	0.030 – 0.035	
Grass, Weeds, and Light Brush	0.040	0.030 – 0.050	
Thick Grass, Thick Brush, Small Trees	0.075	0.050 – 0.100	
Planned DOH Vegetative Lining			
Type B Seed Mixture (mowed)	0.042	0.036 – 0.050	
Type C-1 Seed Mixture (mowed)	0.036	0.030 – 0.040	
Type C-2 Seed Mixture (mowed)	0.027	0.022 – 0.033	
Type B Seed Mixture (unmowed)	0.090	0.050 – 0.140	
Type C-1 Seed Mixture (unmowed)	0.080	0.050 – 0.120	
Type C-2 Seed Mixture (unmowed	0.030	0.050 – 0.140	
Non Vegetative Lining	**Based on Depth of Flow**		
	0 - 0.5’	0.5 - 2.0’	> 2.0’
Concrete Lined Ditch or Channel	0.015	0.013	0.013
Grouted Rock Line Ditch or Channel	0.040	0.030	0.028
Bare Soil with little or no vegetation	0.023	0.020	0.020
Bare Rock or Rock Cut Ditch	0.045	0.035	0.025
Rocked Lined Ditch or Channel D_{50} = 4 inches	0.090	0.058	0.035
Rock Lined Ditch or Channel D_{50} = 6 inches	0.104	0.069	0.035
Rock Lined Ditch or Channel D_{50} = 12 inches	-	0.078	0.040

Courtesy of WVDOH Drainage Manual, December 2007

The Hydraulic Radius of a pipe or channel is calculated by dividing the flow area by the wetted perimeter. Wetted perimeter (wp) just as the name implies is the total cross sectional perimeter length where water is in contact with the channel bottom or sides or the pipe wall.

For example, to calculate the Hydraulic Radius for a rectangular channel the following formula would be used:



Rectangular Channel

Flow Area = b x D in square feet (sf)
Wetted Perimeter (wp) = b + D + D in feet (ft)
Hydraulic Radius = Flow Area / wp

Finally, the Time of Concentration for channel flow is determined by the following equation:

$$T_t = \left(\frac{L}{V*60}\right)$$

T = channel or pipe flown in minutes (min)
L = flow length in feet (ft)
V = velocity in feet/second

Please note: Channel configurations and pipes have widely varied dimensions and area and wetted perimeter calculations will vary. However, the Hydraulic Radius will always be Area / wp.

By adding all three flow equations together the total Time of Concentration (Tc) can be calculated for the drainage area.

Rainfall Intensity

Rainfall intensity (i) is the average rainfall in inches per hour for a duration equal to time of concentration for the selected time return period. To determine rainfall intesity use Chart 4-1 (page 4-3).

After the rainfall intensity is finalized, the rational formula is used to determine the maximum rate of runoff.

TR-55 Method

The TR-55 Method is widely used to produce estimates of runoff for both pervious and impervious cover. This method is recommended for estimating the peak discharge from sites that are 5 acres to 16,000 acres in size. It empirically accounts for the fact that soils become saturated and gradually yield more runoff during the course of a storm. For a detailed description of this method, see Urban Hydrology for Small Watersheds (NRCS Technical Release 55). This method is also available in electronic form from the NRCS website.

TR-55 utilizes curve numbers (CN) to account for land use and soils. Curve numbers should not be confused with the C-values used in the rational method. The appropriate curve number should be selected for each sub area within the selected drainage area, because this calculation method is very sensitive to changes in these values. These areas can be averaged to obtain a weighted curve number. See Table 4-6 (page 4-9) for approved CN values for each Hydrologic Soil Group.

The rainfall depths that must be used for calculating storm events in the City of Charleston are listed in Table 4-5. These values are from the West Virginia Department of Transportation Drainage Manual.

Table 4-5: City of Charleston 24 Hour Rainfall Depth

Rainfall Event	24 hour Rainfall Depth Range (inches)
1 year	2.35
2 year	2.66
5 year	3.44
10 year	3.93
25 year	4.60
50 year	4.96
100 year	5.40

WVDOH Drainage Manual, Dec. 2007

Table 4-6: Hydrologic Soil Group

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	**Hydrologic Condition**	**A**	**B**	**C**	**D**
URBAN AREAS					
Fully Developed Urban Areas with Established Vegetation. Open areas such as lawns, parks, golf courses, etc. equivalent to pasture. For other combinations determine a composite curve number.					
	Poor condition (grass cover <50%)	68	79	86	89
	Fair condition (grass cover 50% - 75%)	49	69	79	84
	Good Condition (grass cover <75%)	39	61	74	80
Impervious Areas					
	Paved parking lots, roofs, driveways, etc.	98	98	98	98
	Paved roads, curb and gutter	98	98	98	98
	Concrete open ditches	83	89	92	93
	Gravel roadway	76	85	89	91
	Soil roadway	72	82	87	89
Urban Districts					
	Average % Impervious Area				
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	83
Residential Districts by Average Lot Size					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	64	70	80	85
1 acre	20	51	68	79	84
2 acre	12	46	65	77	82
RURAL AREAS					
Brush-weed grass mixture with brush as the major element.					
	Poor condition (<50% cover)	48	67	77	83
	Fair condition (50% – 75% cover)	35	56	70	77
	Good condition (<75% cover)	30	48	65	73
Woods 50% cover – grass 50% cover (such as an orchard or tree farm)					
	Poor condition	57	73	82	86
	Fair condition	43	65	76	82
	Good condition	32	58	72	79
Woods Only					
	Poor condition (small trees, brush, forest litter)	45	66	77	83
	Fair condition (medium trees, heavy brush, forest litter)	36	60	73	79
	Good condition (large trees, thick undergrowth, undisturbed forest area)	30	55	70	77

Courtesy of WVDOH Drainage Manual, December 2007

Urban Area Modification

If the assumptions in Table 4-6 (page 4-9) are not applicable the CN may be adjusted with the following equations:

Connected Impervious area: An impervious area is considered connected if runoff from it flows directly into a drainage system or if runoff from it occurs as shallow concentrated flow that runs over a pervious area and then into the drainage system

Composite CN (connected impervious area)

$$CN_c = CN_c + \left(\frac{P_{imp}}{100}\right)\left(98\text{-}CN_p\right)$$

where:
CN_c = composite runoff curve number
CN_p = pervious runoff curve number
P_{im} = percent imperviousness

Example: Table 4-6 (page 4-9) gives a CN of 70 for a ½ acre lot in HSG B, w/ assumed impervious area of 25 percent. If the lot has 20 percent impervious and a pervious area CN of 61 the composite CN would be adjusted to 68 with the preceding equation.

Unconnected Impervious area: An impervious area is considered unconnected if the runoff from it is spread over a pervious area as sheet flow. Use the connected impervious area equation if the area is equal to or greater than 30 percent.

Composite CN (unconnected w/<30% impervious)

$$CN_c = CN_c + \left(\frac{P_{imp}}{100}\right)\left(98\text{-}CN_p\right)\left(1\text{-}0.5R\right)$$

where:
R = ratio of unconnected impervious area to total impervious area

Example: a ½ acre lot with 20 % total impervious area (75 percent which is unconnected) and a pervious CN of 61. Using the equation the composite CN would be 66.

The hydraulic soil groups (see Table 4-7) are defined as:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist predominantly of deep, well to excessively drained sand or gravel and have a high rate of water transmission. There are very few soils of this category in Charleston.

Group B soils have moderate infiltration rates when thoroughly wetted and consist predominantly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission. These soils are typically present in the flatter areas of Charleston.

Group C soils have low infiltration rates when thoroughly wetted and consist predominantly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission. These are the most common soils within Charleston.

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist predominantly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission. These soils are frequently found on the steep hillsides and ridge tops within Charleston.

Table 4-7: Hydraulic Soil Groups

HSG	Soil Textures
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

WVDOH Drainage Manual

The TR-55 method estimates the peak runoff for a given watershed as a function of the unit peak discharge, drainage area, runoff depth, and a pond or swamp adjustment factor. The TR-55 Method formula is expressed as follows:

$$qp = qu \times Am \times Q \times Fp$$

Where:

qp = peak discharge in cubic feet per second (cfs)

qu = unit peak discharge in cfs per square mile per inch (mi^2/in)

Am = drainage area in square miles (sq mi)

Q = runoff in inches (in)

Fp = pond and swamp adjustment factor (see Table 4-8, page 4-12)

The 24 rainfall depth for the City of Charleston is given in Table 4-5, (page 4-8) in inches (in) for a selected rainfall return period.

The pond and swamp adjustment factors are as follows:

Table 4-8: Pond and Swamp Adjustment Factor

Percentage of Pond and Swamp Area	Fp
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

WVDOH Drainage Manual, Dec. 2007

Time of Concentrated Flow

Calculating the time of concentration (Tc) for TR-55 method is similar to that of the rational method. Sheet flow, shallow concentrated flow and open channel flow must be determined.

Sheet Flow

Runoff that is of a uniform depth across the slope of the surface is known as Sheet Flow (T_t). Sheet flow typically does not exceed 2 inches in depth or 100 ft in length. A rainfall intensity of 2 year 24 hour depth is used to determine the T_t regardless of the storm frequency being used to determine the total site runoff. It is found using the following equation:

$$T_t = \frac{0.007\,(nL)^{0.8}}{\sqrt{P_{2\text{-}24}}\,S^{0.4}}$$

Where:

T_t = Sheet flow travel time in hours (hr)

n = (Table 4-2, page 4-4) Mannings Roughness Coefficient

L = Flow length in feet (ft)

P2-24 = The 2 year 24 hour rainfall depth in inches (2.66 in. from Table 4-5, page 4-8)

S = Slope of the surface (ft/ft)

Shallow Concentrated Flow

Once the flow has traveled farther than 100 ft, it is considered to be shallow concentrated. The T_t is found by determining the average velocity. The average velocity can be found using the equations below or see Chart 4-2, page 4-12.

Unpaved Surfaces	$V = 16.1345 \times S^{0.5}$
Paved Surfaces	$V = 20.3282 \times S^{0.5}$

Where:

V = Average Velocity in foot per second (ft/sec)
S = Slope of the surface (ft/ft))

Travel time is then calculated with:

$$T_t = \left(\frac{L}{V*3600}\right)$$

Where:

T_t = Shallow Concentrated flow travel time in hours (hr)

L = Flow Length in feet (ft)

V = Velocity in feet per second (ft/sec)

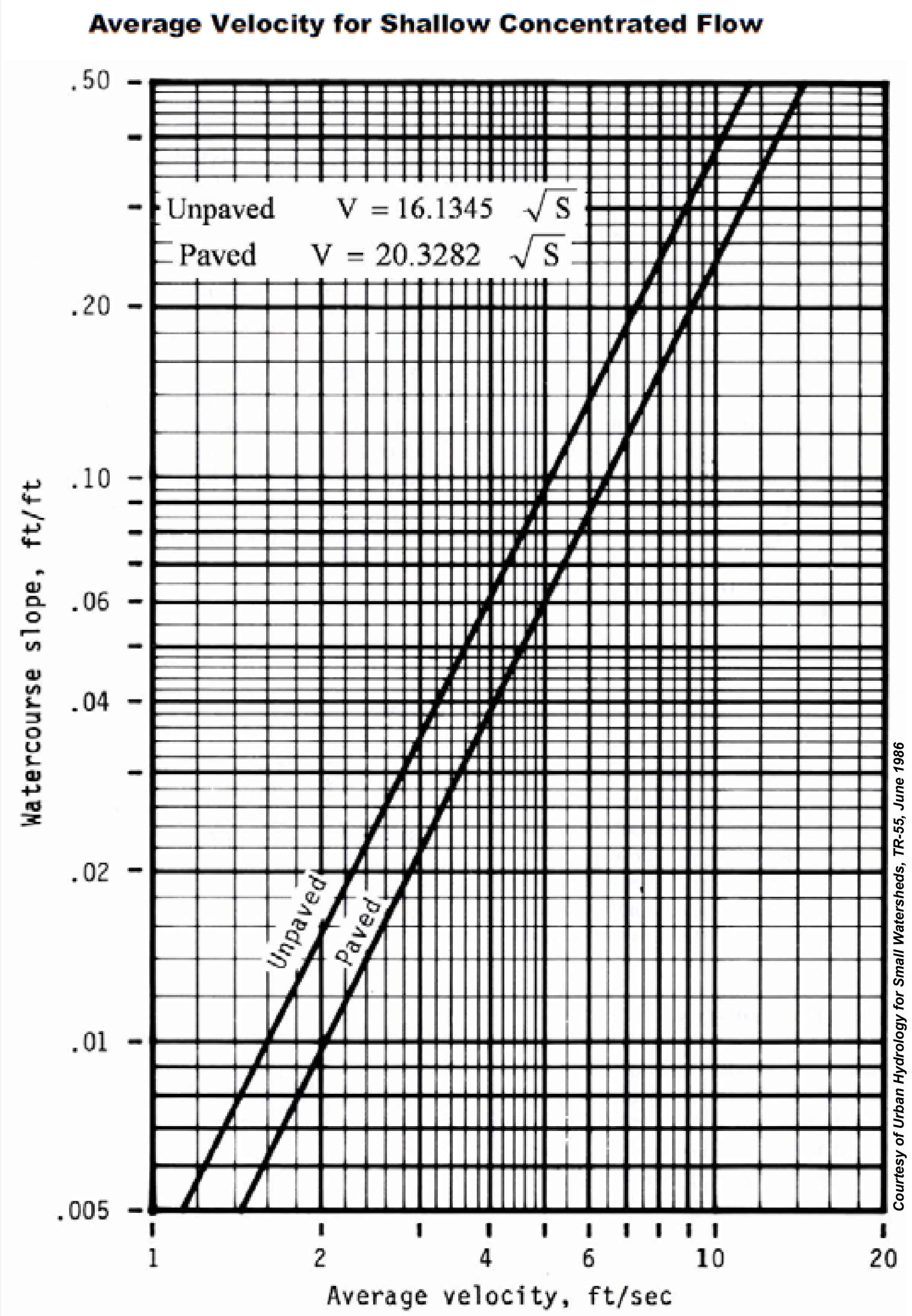


Chart 4-2
Average Velocities for Estimating Travel Time for Shallow Concentrated Flow

Open Channel Flow

Open channel flow is flow that is in either a channel or pipe. In this case, Tt is found by first determining the velocity using Manning's equation:

$$V = \left(\frac{1.49}{n}\right) R^{2/3} \sqrt{S}$$

Where:

V = velocity in feet per second (ft/sec)

n = Mannings Roughness Coefficient (see table 4-2, page 4-4)

R = hydraulic radius in feet (flow area/wetted perimeter) (see calculation example in Channel Flow Section)

S = Slope of the surface (ft/ft)

Travel time is then calculated: $$T_t = \left(\frac{L}{V*3600}\right)$$

Where:

Tt = shallow concentrated flow travel time in hours (hr)

L = flow length in feet (ft)

V = velocity in feet per second (ft/sec)

The CN is determined by weighting the different surface CNs with the associated areas. Once the CN and rainfall depth are determined the runoff (Q) is expressed in inches.

The runoff (Q) can be determined from the following Chart 4-3:

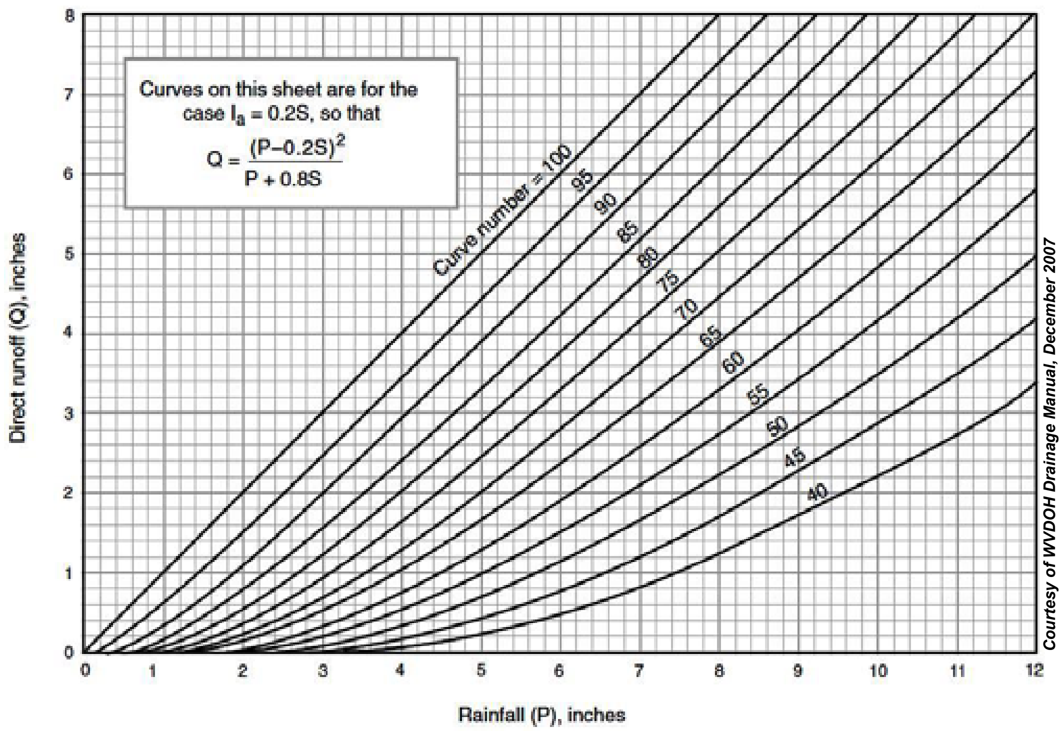


Chart 4-3
Runoff Depths for selected CN & 24 Hr Rainfall Depth

Table 4-9 is used to find the initial abstraction (Ia) in inches according to the CN and compute Ia/P. P equals the rainfall depth in inches for the given storm event, while initial abstraction (Ia) includes all stormwater losses before runoff begins (water retained in surface depressions, water taken up by vegetation, evaporation, and infiltration).

Initial Abstraction Values (I_a) for Curve Numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Courtesy of Urban Hydrology for Small Watersheds, TR-55, June 1986

Table 4-9
Initial Abstract Values (I_a) for Curve Numbers

The unit peak discharge (qu) is determined by using the Tc and the Ia/P value see Chart 4-5 (page 4-16). If Ia/P is greater than the values charted, then the smallest value would be used. If the value falls between the charted values, use interpolation to determine the peak discharge (qu) value.

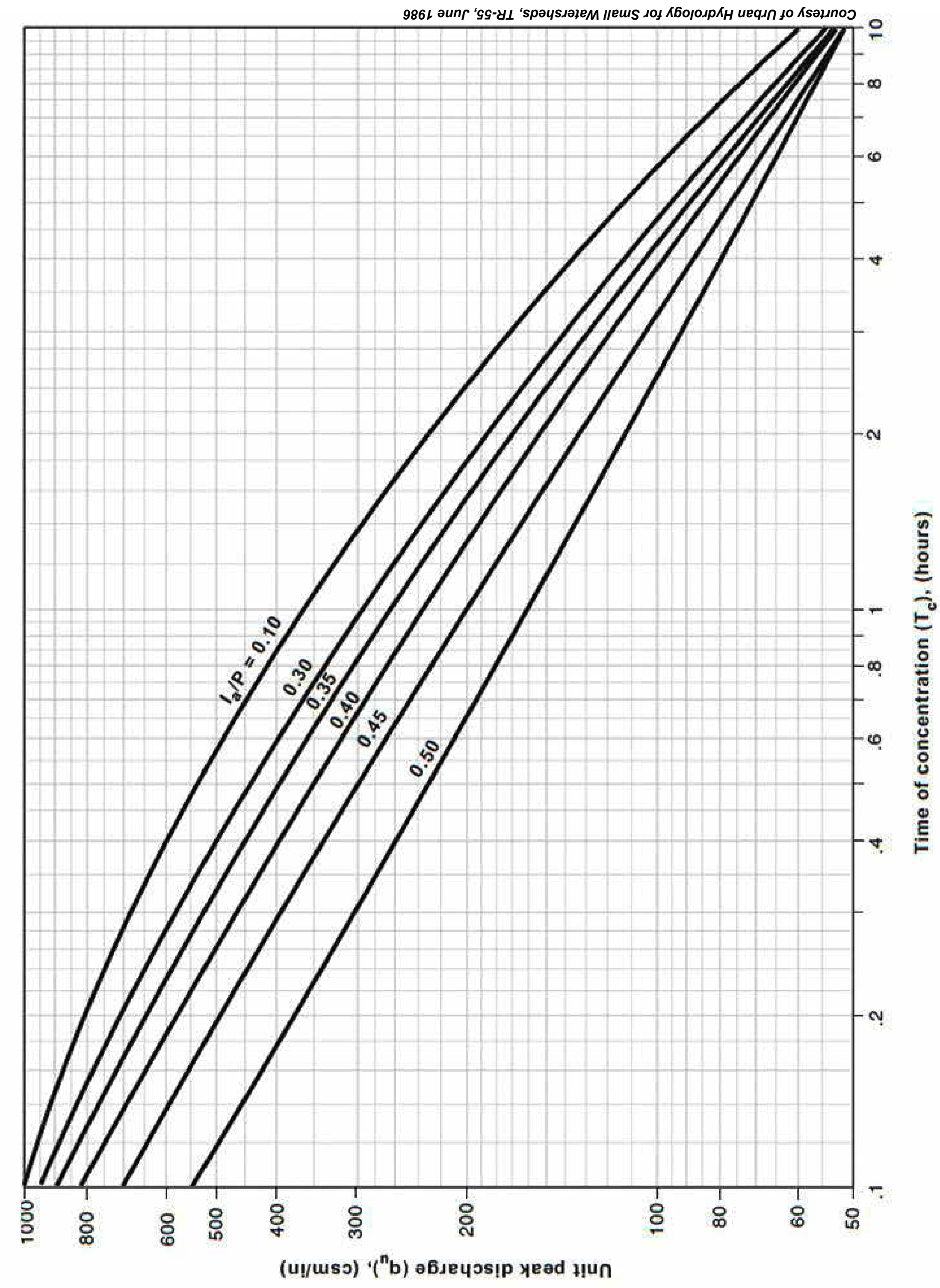


Chart 4-5
Unit Peak Discharge for Type II Rainfall Distribution

In Summary

Calculate the peak discharge (qu) for the desired rainfall event by using the TR-55 formula.

The following steps outline the computation procedure for this method:

- Determine the Drainage Area (Am) in square miles from a topographic map.
- Determine the Runoff Curve Number (CN) using weighted values for multiple conditions.
- Obtain the 24-hour Rainfall Depth (P) in inches for a selected frequency or return period from Table 4-5 (page 4-8).
- Determine the Runoff depth (Q) in inches (rounded to the nearest hundredth of an inch) using Chart 4-3, (page 4-14) by solving the runoff equation.
- Determine the Time of Concentration (Tc in hours).
- Use Table 4-9, (page 4-15), page to determine the initial abstraction (Ia) in inches according to the CN and compute Ia/P.
- Use Chart 4-5 (page 4-16) for Type II rainfall distribution to obtain the Unit Peak Discharge (qu) in cfs per square mile per inch of runoff using Tc and Ia/P. If the computed Ia/P ratio is outside the range of the chart, then the limiting value shall be used. If the ratio falls between the limiting values use linear interpolation to determine the unit peak discharge.
- Obtain the Pond and Swamp Adjustment Factor (Fp) from Table 4-8 (page 4-12).
- Calculate the peak discharge (qp) for the selected rainfall frequency by multiplying the values of qu, Am, Q, and Fp.

4.1.4 Storm Sewer Design

The storm sewer must be designed to safely convey the 10 year storm without surcharging inlets. If Flood Control is required, runoff from larger storms must be safely conveyed off the site, either through overland flow or a storm sewer. Runoff conveyed to neighboring property must not have any adverse impacts. The rational method may be utilized when designing storm sewers.

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