CHAPTER 200 HYDROLOGY

SECTION 201 BASIC POLICIES AND REQUIREMENTS

201.01 Introduction

The following section provides a list of design policies which must be applied during a hydrologic analysis performed within the City of Carmel.

Following are discussions of concepts which will be important in a hydrologic analysis. These concepts will be used throughout the remainder of this chapter in dealing with different aspects of hydrologic studies.

201.02 Abbreviations and Definitions

Abbreviations

COE:	United States Army Corps of Engineers
IDEM:	Indiana Department of Environmental Management
IDNR:	Indiana Department of Natural Resources
INDOT:	Indiana Department of Transportation
NRCS:	USDA-Natural Resources Conservation Service
USDA:	United States Department of Agriculture

Definitions

Channel:	A portion of a natural or artificial watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a defined bed and banks which serve to confine the water.
Curve Number:	The NRCS index that represents the combined hydrologic effect of soil, land use, land cover, hydrologic condition and antecedent runoff condition.
Design Storm:	A selected storm event, described in terms of the probability of occurring once within a given number of years, for which drainage or flood control improvements are designed and built.
Drainage Area:	The area draining into a stream at a given point. It may be of different sizes for surface runoff, subsurface flow and base flow, but generally the surface runoff area is considered as the drainage area.

Duration:	The time period of a rainfall event.
Hydrograph:	For a given point on a stream, drainage basin, or a lake, a graph showing either the discharge, stage (depth), velocity, or volume of water with respect to time.
Inlet:	An opening into a storm drain system for the entrance of surface storm water runoff, more completely described as a storm drain inlet.
Major Drainage System:	Drainage system carrying runoff from an area of one or more square miles.
Minor Drainage System:	Drainage system carrying runoff from an area of less than one square mile.
Rainfall Intensity:	The rate at which rain is falling at any given instant, usually expressed in inches per hour.
Runoff:	That portion of precipitation that flows from a drainage area on the land surface, in open channels, or in stormwater conveyance systems.
Storm Frequency:	The time interval between major storms of predetermined intensity and volumes of runoff (e.g. a 5-yr., 10-yr., or 20-yr. storm).
Storm Sewer:	A closed conduit for conveying collected storm water, while excluding sewage and industrial wastes. Also called a storm drain.
Swale:	An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and may provide some groundwater recharge.
Time of Concentration:	The travel time of a particle of water from the most hydraulically remote point in the contributing area to the point under study. This can be considered the sum of an overland flow time and times of travel in street gutters, storm sewers, drainage channels, and all other drainage ways.
Watershed:	The region drained by or contributing water to a specific point that could be along a stream, lake or other stormwater facilities. Watersheds are often broken down into subareas for the purpose of hydrologic modeling.
Symbol Table:	To provide consistency within this chapter as well as throughout this manual the following symbols will be used. These symbols were selected because of their

wide use in hydrologic publications. In some cases the same symbol is used in existing publications for more than one definition. Where this occurs in this chapter, the symbol will be defined where it occurs in the text or equations.

Symbols	Definition	Units
A	Drainage Area	acres
C	Runoff Coefficient	-
CN	NRCS-runoff curve number	-
D	Duration	hours
I	Rainfall intensity	in/hr
n	Manning roughness coefficient	-
Q	Rate of runoff	cfs
q_p	Peak rate of discharge	cfs
t_c or T_c	Time of concentration	min
V	Velocity	ft/s

201.03 Hydrologic Methods

Runoff rates shall be computed for the area of the parcel under development plus the area of the watershed flowing into the parcel under development. The rate of runoff which is generated as the result of a given rainfall intensity may be calculated as follows:

A. Development Sites Less than or Equal to 5 Acres in Size, With a Contributing Drainage Area Less than or Equal to 50 Acres and No Depressional Storage

The Rational Method may be used. A computer model, such as TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE), that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies may also be used along with a 24-hour duration NRCS Type 2 storm. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D). In the Rational Method, the peak rate of runoff, Q, in cubic feet per second (cfs) is computed as:

$$\mathbf{Q = CIA}$$

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 (t_c) for a selected rainfall frequency.

A = Tributary drainage area in acres.

Values for the runoff coefficient "C" are provided in Table 201-1, which shows values for different types of surfaces and local soil characteristics. The composite "C" value used for a given drainage area with various surface types shall be the weighted average value for the total area calculated from a breakdown of individual areas having different surface types.

Rainfall intensity shall be determined from the rainfall frequency data shown in Table 201-2.

In general, the time of concentration (t_c) methodology to be used for all stormwater management projects within the City of Carmel shall be as outlined in the U.S. Department of Agriculture (USDA) - NRCS TR-55 Manual. In urban or developed areas, the methodology to be used shall be the sum of the inlet time and flow time in the stormwater facility from the most remote part of

the drainage area to the point under consideration. The flow 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's Equation (see Chapter 300). Inlet time is the combined time required for the runoff to reach the inlet of the 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.

B. Development Sites Greater Than 5 Acres in Size or Contributing Drainage Area Greater than 50 Acres or With Significant Depressional Storage

The runoff rate for these development sites and contributing drainage areas shall be determined by a computer model that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies and the 24-hour NRCS Type 2 Rainfall Distribution. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D). 24-hour Rainfall depth for various frequencies shall be taken from Table 201-3. The NRCS Type 2 distribution ordinates are found in Table 201-4. Examples of computer models that can generate such hydrographs include TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE). These programs may be downloaded free of charge from the associated agencies' web sites. The computer models ICPR and Pond Pack may also be used. However, the latter computer software are proprietary. If interconnected ponds are utilized, the use of ICPR or Pond Pack may be required to appropriately model the more complex hydrologic and hydraulic relationships associated with such system. Other models may be acceptable and should be accepted by the City of Carmel prior to their utilization.

C. Development Sites with Drainage Areas Greater than or Equal to One Square Mile

For the design of any major drainage system, as defined in Section 201.01, the discharge must be obtained from, or be accepted by, the IDNR. Other portions of the site must use the discharge methodology in the applicable section of this Chapter.

201.04
Design Storm
Frequencies

The design storm frequency is the basis for all runoff computations and stormwater facility designs. All stormwater facilities, whether private or public, and whether constructed on private or public property, shall conform to the design standards and other requirements contained herein.

Stormwater facilities functioning as a major drainage system as defined in Section 201.01 must also meet IDNR design standards in addition to the City of Carmel's standards. In case of discrepancy, the most restrictive requirements shall apply.

TABLE 201-1: Runoff Coefficients © for Use in the Rational Method

TYPE OF SURFACE	RUNOFF COEFFICIENT ©
Non-Urban Areas	
Bare earth	0.55
Steep grassed areas (slope 2:1)	0.60
Turf meadows	0.25
Forested areas	0.20
Cultivated fields	0.30
Urban Areas	
All watertight roof surfaces	0.90
Pavement	0.85
Gravel	0.85
Impervious soils (heavy)	0.55
Impervious soils (with turf)	0.45
Slightly pervious soil	0.25
Slightly pervious soil (with turf)	0.20
Moderately pervious soil	0.15
Moderately pervious soil (with turf)	0.10
Business, Commercial & Industrial	0.85
Apartments & Townhouses	0.70
Schools & Churches	0.55
Single Family Lots < 10,000 SF	0.45
Lots < 12,000 SF	0.45
Lots < 17,000 SF	0.40
Lots > ½ acre	0.35
Park, Cemetery or Unimproved Area	0.30

TABLE 201-2: Rainfall Intensities for Various Return Periods and Storm Durations

Rainfall Intensity (Inches/Hour)						
Duration	*Return Period (Years)*					
	2	5	10	25	50	100
5 Min.	4.63	5.43	6.12	7.17	8.09	9.12
10 Min.	3.95	4.63	5.22	6.12	6.90	7.78
15 Min.	3.44	4.03	4.55	5.33	6.01	6.77
20 Min.	3.04	3.56	4.02	4.71	5.31	5.99
30 Min.	2.46	2.88	3.25	3.81	4.29	4.84
40 Min.	2.05	2.41	2.71	3.18	3.59	4.05
50 Min.	1.76	2.06	2.33	2.73	3.07	3.47
1 Hr.	1.54	1.80	2.03	2.38	2.68	3.03
1.5 Hrs.	1.07	1.23	1.42	1.63	1.91	2.24
2 Hrs.	0.83	0.95	1.11	1.37	1.60	1.87
3 Hrs.	0.59	0.72	0.84	1.04	1.22	1.42
4 Hrs.	0.47	0.58	0.68	0.84	0.99	1.15
5 Hrs.	0.40	0.49	0.58	0.71	0.83	0.97
6 Hrs.	0.35	0.43	0.50	0.62	0.72	0.85
7 Hrs.	0.31	0.38	0.44	0.55	0.64	0.75
8 Hrs.	0.28	0.34	0.40	0.49	0.57	0.67
9 Hrs.	0.25	0.31	0.36	0.45	0.52	0.61
10 Hrs.	0.23	0.28	0.33	0.41	0.48	0.56
12 Hrs.	0.20	0.24	0.29	0.35	0.41	0.48
14 Hrs.	0.17	0.22	0.25	0.31	0.36	0.42
16 Hrs.	0.16	0.19	0.23	0.28	0.32	0.38
18 Hrs.	0.14	0.17	0.20	0.25	0.29	0.34
20 Hrs.	0.13	0.16	0.19	0.23	0.27	0.31
24 Hrs.	0.11	0.14	0.16	0.20	0.23	0.27

Source: Purdue,A.M., et. al., "Statistical Characteristics of Short Time Incremental Rainfall", Aug., 1992. (Values in this table are based on IDF equation and coefficients provided for Indianapolis, IN.)

TABLE 201-3: Rainfall Depths for Various Return Periods

Rainfall Depth (Inches)						
Duration	*Return Period (Years)*					
	2	5	10	25	50	100
24 Hrs.	2.66	3.27	3.83	4.72	5.52	6.46

Source: Purdue,A.M., et. al., "Statistical Characteristics of Short Time Incremental Rainfall", Aug., 1992.(Values in this table are based on IDF equation and coefficients provided for Indianapolis, IN.)

TABLE 201-4: NRCS Type 2 Rainfall Distribution Ordinates
(for use when not already built in the computer program)

Cumulative Percent of Storm Time	*Cumulative Percent of Storm Depth*	*Cumulative Percent of Storm Time*	*Cumulative Percent of Storm Depth*
0	0	52	73
4	1	53	75
10	2.5	54	77
15	4	55	78
20	6	56	80
25	8	57	81
30	10	58	82
33	12	60	83.5
35	13	63	86
38	15	65	87
40	16.5	67	88
42	19	70	89.5
43	20	72	91
44	21	75	92
45	22	77	93
46	23	80	94
47	26	83	95
48	30	85	96
48.5	34	87	97
48.7	37	90	98
49	50	95	99
50	64	100	100
51	71		