7.0 Introduction

This chapter summarizes methods to evaluate runoff conveyance in various street cross sections and curb types and identifies acceptable upper limits of street capacity for minor and major storm events. Sections 7.1 through 7.6 address conventional curb-and-gutter street sections used in the City. The use of roadside ditches in rural areas is covered in Section 7.8. References to the UDFCD Manual are made throughout this chapter, however where criteria in this chapter conflict with those in the UDFCD Manual, those included in this chapter supercede those in the UDFCD Manual. The review of all planning submittals will be based on the criteria presented herein.

7.1 Function of Streets in the Drainage System

7.1.1 Primary Function of Streets. Urban streets not only carry traffic, but stormwater runoff as well. The primary function of urban streets is for traffic movement; therefore, the drainage function is subservient and must not interfere with the traffic function of the street. When runoff in the street exceeds allowable limits, a storm drain system or open channel is required to convey the excess flows.

7.1.2 Design Criteria Based on Frequency and Magnitude. The design criteria for the collection and conveyance of storm water runoff on public streets are based on an allowable frequency and magnitude of traffic interference. The primary design objective is to keep the depth and spread (encroachment) of stormwater on the street below an acceptable value for a given storm event.

7.1.3 Street Function in Minor (5-year) Storm Event. The primary function of streets in a minor storm event is to convey the nuisance flows quickly and efficiently to the next intended drainage conveyance system with minimal disruption to street traffic.

7.1.4 Street Function in Major (100-year) Storm Event. For the major storm event, the function of streets is to provide an emergency passageway for flood flows while maintaining public safety and minimizing flood damage. In the major event, the street becomes an open channel and must be analyzed to determine when flooding depths exceed acceptable levels.

7.2 Street Classification and Drainage Allowances/Requirements

The City of Centennial and Arapahoe County each have their own roadway classifications, which are summarized in Table 7.1 at the end of this chapter. SEMSWA allows the use of streets for drainage conveyance with limitations for the minor and major storm events. In general, the drainage allowances are more restrictive for roadways with higher average daily traffic (ADT).

Minor Storm: Limitations for street drainage for the minor storm are the depth of flow at the curb and gutter and the spread of flow onto the roadway. The maximum allowable street capacity is determined by whichever limitation is more restrictive.

Major Storm: Limitations for street drainage for the major storm are the depth of flow at the curb and gutter and the containment of flow within the roadway right-of-way or dedicated easements.

Table 7.1 includes the drainage allowances and requirements for each roadway classification. Each roadway section will have a different drainage capacity, so it is important to use the appropriate cross-section dimensions for the hydraulic analysis. Cross-section dimensions can be found in the City of Centennial and Arapahoe County roadway design standards.

7.5 Hydraulic Evaluation of Street Capacity

Once the design discharge is calculated (see Chapter 6, Hydrology), hydraulic calculations must be completed to determine the capacity of street gutters and the resulting encroachment onto the street section. All street capacity and encroachment calculations shall be performed using the UDFCD UD-Inlet software (available at www.udfcd.org) and shall conform to the Streets/Inlets/Storm Drains chapter of the UDFCD Manual, unless otherwise noted herein.

Example applications using the UD-Inlet software for several different roadway configurations are provided at the end of this chapter. For more detailed information on the methodology used for the hydraulic evaluation of street capacity see the UDFCD Manual Streets/Inlets/Storm Drains chapter.

7.6 Cross-Street Flow

7.6.1 Cross-Street Flow Conditions. Cross-street flow can occur in an urban drainage system under three conditions. One condition occurs when the runoff in a gutter spreads across the street crown to the opposite gutter. The second is when cross pans are used. The third condition is when the flow in a drainageway exceeds the capacity of a road culvert and/or bridge and subsequently overtops the crown of the street. Criteria for the first two conditions are discussed in the following sections. The third condition regarding allowable cross-street flow and overtopping at culvert crossings is limited by the criteria provided in Chapter 11, Culverts and Bridges.

7.6.2 Influence on Traffic. Whenever storm runoff, other than sheet flow, moves across a traffic lane, traffic movement is affected. The cross flow may be caused by super-elevation of a curve, by the intersection of two streets, by exceeding the capacity of the higher gutter on a street with cross fall, or street design that has not met the criteria provided herein. The problem associated with this type of flow is that it is localized in nature and vehicles may be traveling at speeds that are incompatible with the cross flow when they reach the location.

7.6.3 Allowable Cross-Street Flow Due to Spread Over the Street Crown. The allowable cross-street flow depths for the minor and major storm events are explained below. These criteria apply to all roadway classifications.
Minor: Cross-street flow is NOT allowed based on the allowable flow depth and encroachment criteria provided in Table 7-1.

Major: Allowable cross-street flow is controlled by the criteria and limitations presented in Table 7-1. For example, if the maximum allowable gutter flow depth is 12-inches and the crown of the road is 7-inches above the flowline of the gutter, 5-inches (12-inches minus 7-inches) of cross-street flow is allowed during a major storm event, assuming all other criteria shown in Table 7-1 are met.

7.6.4 Cross-Street Flow Analysis. The analysis to quantify the amount of cross-street flow can be complex due to the fact that the runoff is moving longitudinally down the street. In addition, it is often assumed that runoff being conveyed in the gutter will follow the path of the associated gutter at intersections, which generally requires the full flow to turn corners, without the appropriate consideration being given to the momentum that was established in one direction. There is potential for cross-street flow, if the flow isn't conveyed around the corner, as assumed. It is the responsibility of the design engineer to make conservative assumptions relative to cross-street flow and to design the downstream inlets and storm drain accordingly. Even if the criteria stated above are met, SEMSWA will require inlets and storm drains on the upstream side of the street to be designed to fully convey design flows assuming no cross-flow. Also, inlets and storm drains on the downstream side of the street shall be increased in capacity by the amount of 1.5 times the estimated cross-flow.

7.6.5 Crosspans. Crosspans shall be designed to convey the minor and major storm event within the criteria presented in Sections 7.3 and 7.4. The design engineer shall evaluate the carrying capacity (with calculations provided) of water on the roadway being considered as well as the side street.

7.8 Rural Roadside Ditches

7.8.1 Roadside Ditches. Roadside ditches shall be used in lieu of curb and gutter when rural street sections are approved. Roadside ditches shall be included in the street right-of-way section.

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7.8.2 Roadside Ditch Design Criteria. The allowable flow depth and roadway encroachment in the minor and major storm events can be found in Tables 7-1. For roadside ditches, the allowable flow depth references in Table 7-1 should be applied at the edge of pavement (rather than gutter flowline). The spread of flow shall not extend outside the street right-of-way and at least 12-inches of freeboard shall be provided from the major storm water surface elevation to the lowest point of water entry at any adjacent structures.

Rural roadside ditches shall be designed in accordance with the criteria for minor drainageway grass-lined channels shown in Chapter 12, Open Channel Design.

Grade control structures are required to maintain velocities less than the maximum allowable or riprap lining (soil filled) shall be provided in accordance with the Major Drainage section of the UDFCD Manual.

There are cases when the roadside ditch criteria may need to be more stringent due to the function of the rural road. Even if a rural road has a low traffic volume, it may be important for emergency access to several properties and therefore require special design criteria. SEMSWA reserves the right for more stringent criteria for single point access roads.

See Chapter 11, Culverts and Bridges, for design criteria pertaining to rural roadside ditch culverts.

TABLE 7.1
ROADWAY CLASSIFICATIONS AND CORRESPONDING DRAINAGE ALLOWANCES AND REQUIREMENTS

Roadway Classification	Minor Storm Event		Major Storm Event	
	Allowable Flow Depth at Gutter Flowline[1]	Maximum Street Encroachment	Allowable Flow Depth	Containment of Flow
City of Centennial				
Local	No curb-overtopping	Flow may spread to crown of street	Depth of water at gutter flowline shall not exceed 12-inches	Flow must be contained within public right-of-way or dedicated drainage easements, AND All structures shall be a minimum of 1-foot above the 100-year water surface elevation
Collector		Flow spread must leave at least one 10-foot land free of water (5-feet either side of the street crown)		
Arterial		Flow spread must leave at least two 10-foot lanes free of water (10-feet each side of the street crown or median)		
Arapahoe County				
Urban Local	No curb-overtopping	Flow may spread to crown of street	Depth of water at gutter flowline shall not exceed 12-inches	Flow must be contained within public right-of-way or dedicated drainage easements, AND All structures shall be a minimum of 1-foot above the 100-year water surface elevation[2]
Rural Local				
Collector		Flow spread must leave at least one 10-foot land free of water (5-feet either side of the street crown)		
Rural Secondary				
Arterial		Flow spread must leave at least two 10-foot lanes free of water (10-feet each side of the street crown or median)		
Rural Primary				

[1] If a 4-inch curb with an attached sidewalk is used (i.e. combination or rollover curb), the allowable depth of flow is to the back of the sidewalk within the right-of-way or drainage easement. Maximum depth at the gutter flowline is 6 inches.

[2] For a structure with a finished floor elevation below the curb elevation, an 18-inch high impermeable barrier must be constructed between the curb and the structure, including at any driveways, to contain flow in the street section. If the flow cannot be contained within the impermeable barrier, then the allowable flow in each side of the street shall not exceed the allowable flow shown for the minor (5-year) storm.

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UD-INLET EXAMPLE APPLICATIONS

The UD-Inlet software calculates allowable flow capacity for one-half of the street for both the minor and major storm events. Figure 7.1 shows a diagram of the UD-Inlet parameters and Figure 7.2 shows in user-input interface.

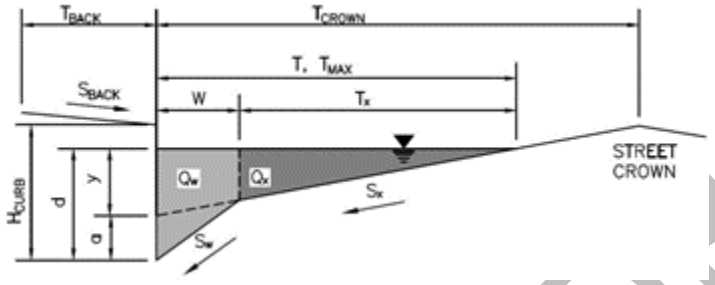


FIGURE 7.1
UD-INLET FIGURE SHOWING REQUIRED STREET AND GUTTER INPUTS FOR ALLOWABLE CAPACITY CALCULATIONS

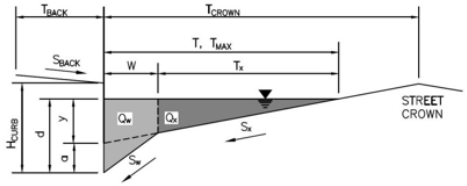
Version 4.05 Released March 2017

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project: Enter Your Project Name Here

Inlet ID: Inlet 1



Hide Details

Clear Worksheet

Gutter Geometry (Enter data in the blue cells)				
Maximum Allowable Width for Spread Behind Curb	T_{BACK} =	10.0		ft
Side Slope Behind Curb (leave blank for no conveyance credit behind curb)	S_{BACK} =	0.020		ft/ft
Manning's Roughness Behind Curb (typically between 0.012 and 0.020)	n_{BACK} =	0.016		
Height of Curb at Gutter Flow Line	H_{CURB} =	6.00		inches
Distance from Curb Face to Street Crown	T_{CROWN} =	16.0		ft
Gutter Width	W =	2.00		ft
Street Transverse Slope	S_x =	0.020		ft/ft
Gutter Cross Slope (typically 2 inches over 24 inches or 0.083 ft/ft)	S_w =	0.083		ft/ft
Street Longitudinal Slope - Enter 0 for sump condition	S_o =	0.020		ft/ft
Manning's Roughness for Street Section (typically between 0.012 and 0.020)	n_{STREET} =	0.016		
		Minor Storm	Major Storm	
Max. Allowable Spread for Minor & Major Storm	T_{MAX} =	16.0	16.0	ft
Max. Allowable Depth at Gutter Flowline for Minor & Major Storm	d_{MAX} =	6.0	12.0	inches
Allow Flow Depth at Street Crown (leave blank for no)		☐	☑	check = yes

FIGURE 7.2
UD-INLET "INLET" TAB SHOWING REQUIRED STREET AND GUTTER INPUTS FOR ALLOWABLE CAPACITY CALCULATIONS

The following examples demonstrate how to apply the UD-Inlet software to several different roadway configurations based on City of Centennial and Arapahoe County roadway standards.

Local Residential with Detached Walk (City of Centennial)

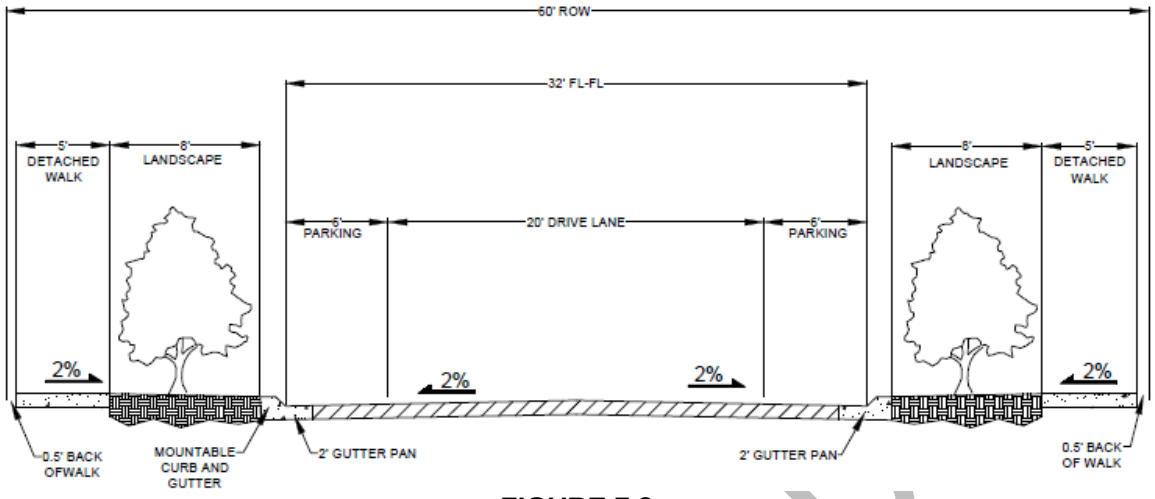


FIGURE 7.3
CROSS-SECTION FOR LOCAL RESIDENTIAL WITH DETACHED WALK FROM CITY OF CENTENNIAL STANDARDS

TABLE 7.2
UD-INLET PARAMETER VALUES FOR LOCAL RESIDENTIAL WITH DETACHED WALK FROM CITY OF CENTENNIAL STANDARDS

UD-Inlet Parameter	Value	Units	Description/Criteria/Assumptions
T_{Back}	13.5	Ft	Measured from back of curb to back edge of detached walk
S_{Back}	2	%	Assumed based on figure. Actual value will be site-specific
n_{Back}	0.016		Typical – Engineer shall verify site conditions and adjust value as necessary
H_{Curb}	6	In	Typical – Engineer shall verify site conditions and adjust value as necessary
T_{Crown}	16	Ft	Measured from back of curb to street crown
W	2	Ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_x	0.020	Ft/ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_w	0.083	Ft/ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_o	-	Ft/ft	Typical – Engineer shall verify site conditions and adjust value as necessary
n_{Street}	0.016		Typical – Engineer shall verify site conditions and adjust value as necessary
T_{max} (minor)	16	Ft	Measured from back of curb to crown of street. Per maximum street encroachment allowances in Table 7.1
T_{max} (major)	16	Ft	Measured from back of curb to crown of street. Per maximum street encroachment allowances in Table 7.1
d_{max} (minor)	6	In	Assuming 6-inch curb and per the Allowable Flow Depth in Table 7.1 (i.e. no curb-overtopping)

d_{max} (major)	12	In	Per Table 7.1. limiting depth of water at gutter flowline to 12 inches

Four-Lane Arterial (City of Centennial)

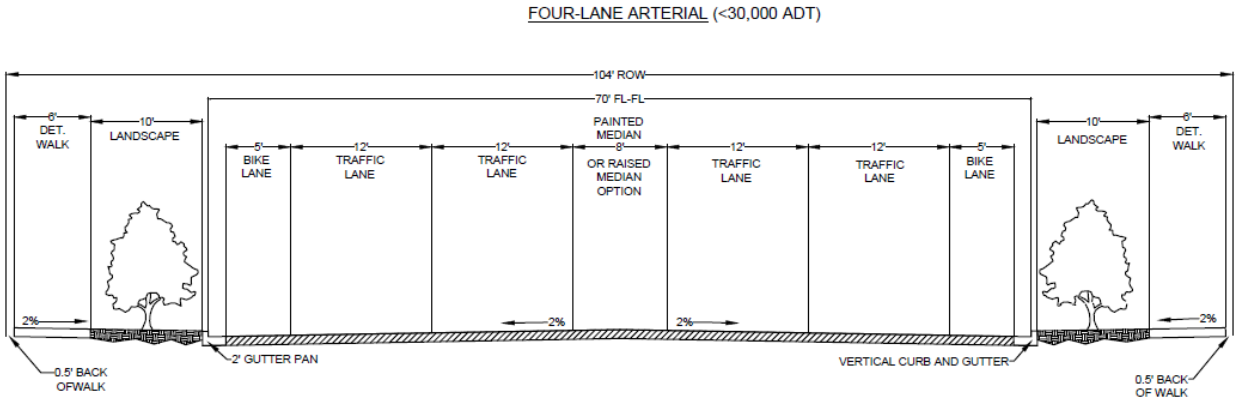


FIGURE 7.4
CROSS-SECTION FOR FOUR-LANE ARTERIAL FROM CITY OF CENTENNIAL STANDARDS

TABLE 7.3
UD-INLET PARAMETER VALUES FOR FOUR-LANE ARTERIAL FROM CITY OF CENTENNIAL STANDARDS

UD-Inlet Parameter	Value	Units	Description/Criteria/Assumptions
T_{Back}	16.5	Ft	Measured from back of curb to back edge of detached walk
S_{Back}	2	%	Assumed based on figure. Actual value will be site-specific
n_{Back}	0.016		Typical – Engineer shall verify site conditions and adjust value as necessary
H_{Curb}	6	In	Typical – Engineer shall verify site conditions and adjust value as necessary
T_{Crown}	35	Ft	Measured from back of curb to street crown
W	2	Ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_x	0.020	Ft/ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_w	0.083	Ft/ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_o		Ft/ft	Site-specific – Engineer shall verify site conditions and adjust value as necessary
n_{Street}	0.016		Typical – Engineer shall verify site conditions and adjust value as necessary
T_{max} (minor)	25	Ft	Measured from back of curb to crown of street, minus 10 feet. Per maximum street encroachment allowances in Table 7.1
T_{max} (major)	35	Ft	Measured from back of curb to crown of street. Per maximum street encroachment allowances in Table 7.1.
d_{max} (minor)	6	In	Assuming 6-inch curb and per the Allowable Flow Depth in Table 7.1 (i.e. no curb-overtopping)

d_{max} (major)	12	In	Per Table 7.1. limiting depth of water at gutter flowline to 12 inches

Four-Lane Collector (Arapahoe County)

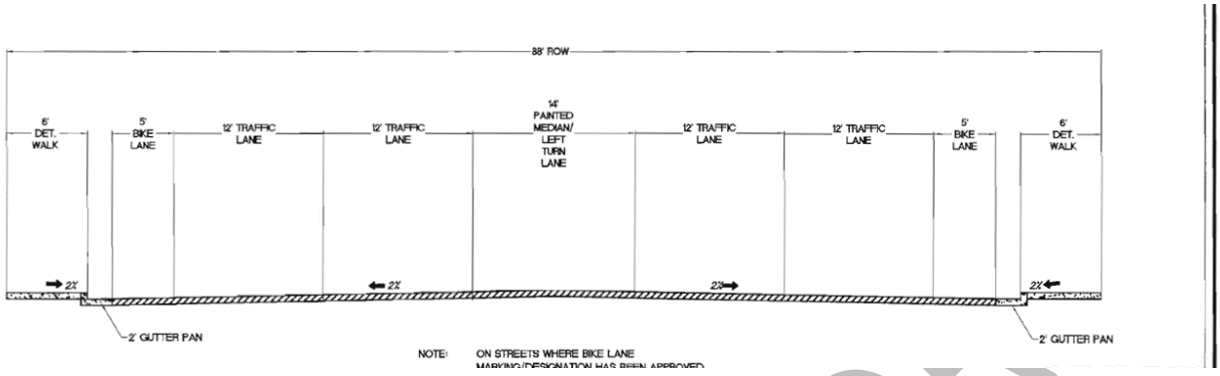


FIGURE 7.4
CROSS-SECTION FOR FOUR-LANE COLLECTOR FROM ARAPAHOE COUNTY STANDARDS

TABLE 7.3
UD-INLET PARAMETER VALUES FOR FOUR-LANE COLLECTOR FROM ARAPAHOE COUNTY STANDARDS

UD-Inlet Parameter	Value	Units	Description/Criteria/Assumptions
T_{Back}	6	Ft	Measured from back of curb to back edge of detached walk
S_{Back}	2	%	Assumed based on figure. Actual value will be site-specific
n_{Back}	0.016		Typical – Engineer shall verify site conditions and adjust value as necessary
H_{Curb}	6	In	Typical – Engineer shall verify site conditions and adjust value as necessary
T_{Crown}	38	Ft	Measured from back of curb to street crown
W	2	Ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_x	0.020	Ft/ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_w	0.083	Ft/ft	Typical – Engineer shall verify site conditions and adjust value as necessary
S_o		Ft/ft	Site-specific – Engineer shall verify site conditions and adjust value as necessary
n_{Street}	0.016		Typical – Engineer shall verify site conditions and adjust value as necessary
T_{max} (minor)	33	Ft	Measured from back of curb to crown of street, minus 5 feet. Per maximum street encroachment allowances in Table 7.1
T_{max} (major)	38	Ft	Measured from back of curb to crown of street. Per maximum street encroachment allowances in Table 7.1.
d_{max} (minor)	6	In	Assuming 6-inch curb and per the Allowable Flow Depth in Table 7.1 (i.e. no curb-overtopping)
d_{max} (major)	12	In	Per Table 7.1. limiting depth of water at gutter flowline to 12 inches