

## CHAPTER 3

### STORM DRAINAGE SYSTEMS

#### 3.3 Gutter Flow Calculations

##### 3.3.1 Formula

The following form of Manning's Equation should be used to evaluate gutter flow hydraulics:

$$Q = [0.56 / n] S_x^{5/3} S^{1/2} T^{8/3} \quad \text{(Eq 3.3.1-1)}$$

Where:

- Q = Gutter flow rate (cfs)
- n = Manning's roughness coefficient
- S<sub>x</sub> = Pavement cross slope (ft/ft)
- S = Longitudinal slope (ft/ft)
- T = Width of flow or spread (ft)

##### 3.3.2 Manning's n Table

<b>Table 3.3.2-1</b>	
<b>Manning's n Values For Street And Pavement Gutters</b>	
<u>Type of Gutter or Pavement</u>	<u>Manning's n</u>
Concrete gutter, troweled finish	0.012
Asphalt pavement:	
Smooth texture	0.013
Rough texture	0.016
Concrete gutter with asphalt pavement:	
Smooth	0.013
Rough	0.015
Concrete pavement:	
Float finish	0.014
Broom finish	0.016
For gutters with small slopes, where sediment may accumulate, increase above values of n by	0.002
Note: Estimates are by the Federal Highway administration Reference: USDOT, FHWA, HDS-3 (1961)	

### 3.3.3 Manning's n Nomograph

Nomograph for Equation 3.1.1-1 is presented on figure 3.3.3-1

**Figure 3.3.3-1**

#### Flow In Triangular Gutter Sections

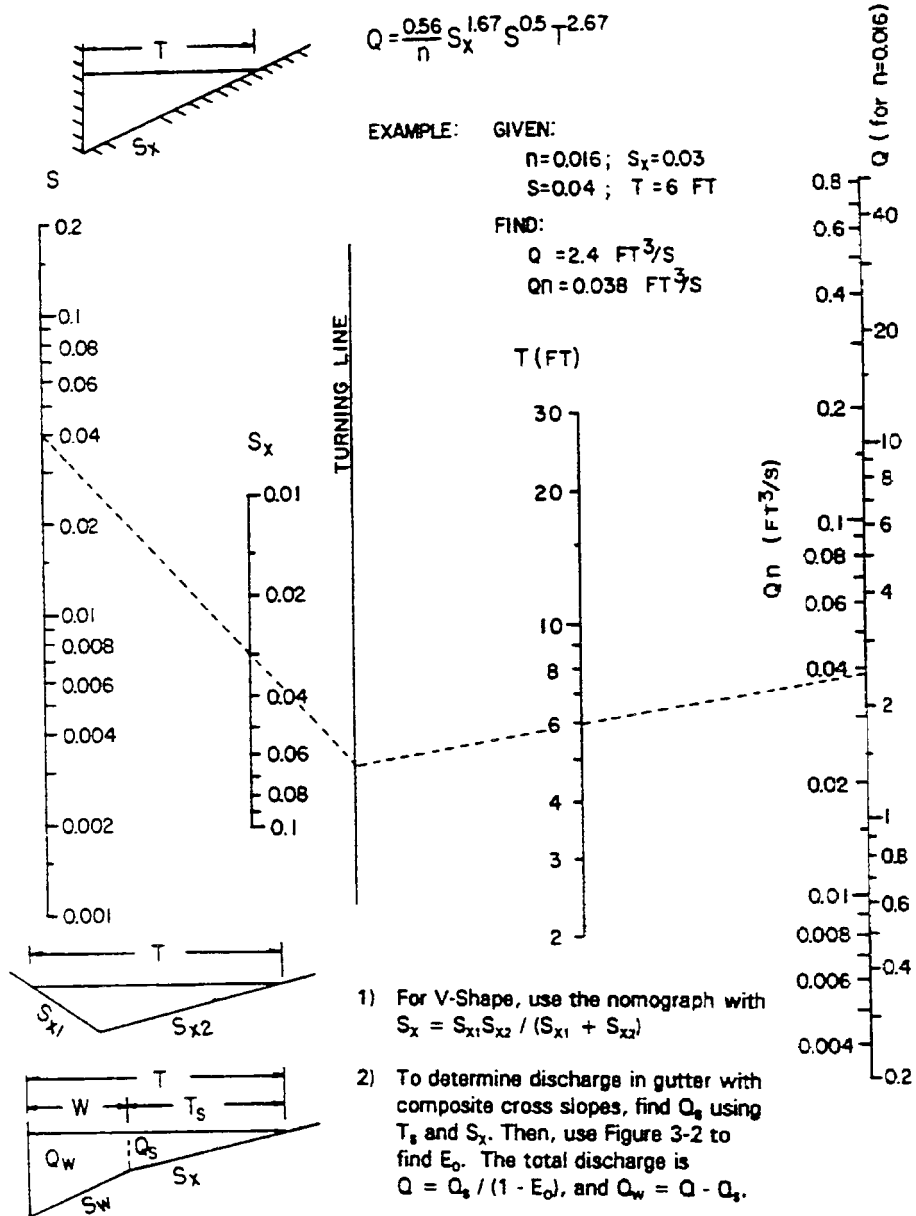
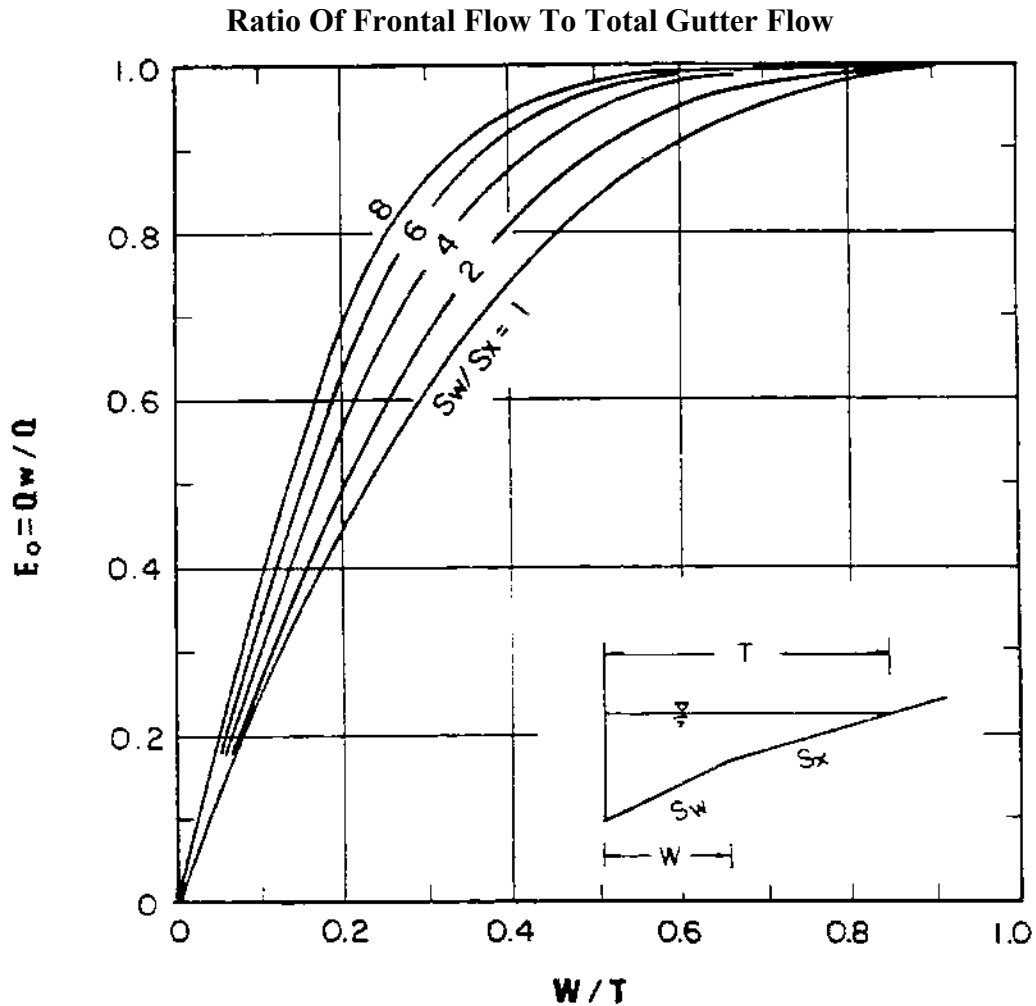


Figure 3.3.3-2



### 3.3.4 Uniform Cross Slope

The Nomograph in Figure 3.3.3-1 is used with the following procedures to find gutter capacity for uniform cross slopes:

#### 3.3.4.1 Condition 1: Find spread, given gutter flow.

- Step 1 Determine input parameters, including longitudinal slope ( $S$ ), cross slope ( $S_x$ ), gutter flow ( $Q$ ), and Manning's  $n$ .
- Step 2 Draw a line between the  $S$  and  $S_x$  scales and note where it intersects the turning line.

- Step 3 Draw a line between the intersection point from Step 2 and the appropriate gutter flow value on the capacity scale. If Manning's  $n$  is 0.016, use  $Q$  from Step 1; if not, use the product of  $Q$  and  $n$ .
- Step 4 Read the value of the spread ( $T$ ) at the intersection of the line from Step 3 and the spread scale.

3.3.4.2 Condition 2: Find gutter flow, given spread.

- Step 1 Determine input parameters, including longitudinal slope ( $S$ ), cross slope ( $S_x$ ), spread ( $T$ ), and Manning's  $n$ .
- Step 2 Draw a line between the  $S$  and  $S_x$  scales and note where it intersects the turning line.
- Step 3 Draw a line between the intersection point from Step 2 and the appropriate value on the  $T$  scale. Read the value of  $Q$  or  $Qn$  from the intersection of that line on the capacity scale.
- Step 4 For Manning's  $n$  values of 0.016, the gutter capacity ( $Q$ ) from Step 3 is selected. For other Manning's  $n$  values, the gutter capacity times  $n$  ( $Qn$ ) is selected from Step 3 and divided by the appropriate  $n$  value to give the gutter capacity.

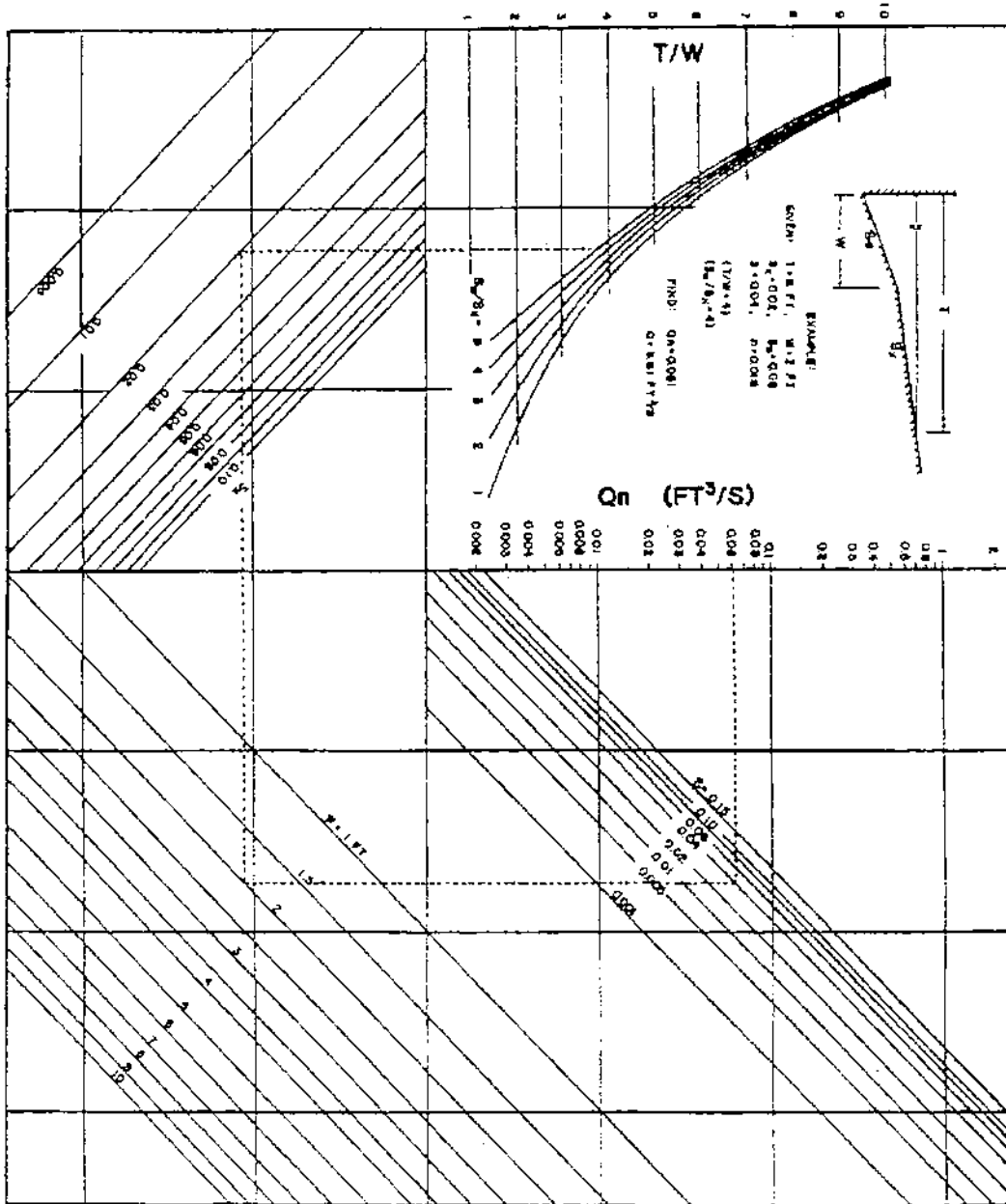
3.3.5 Composite Gutter Sections

Figure 3-3.3-2 in combination with Figure 3.3.3-1 can be used to find the flow in a gutter with width ( $W$ ) less than the total spread ( $T$ ). Such calculations are generally used for evaluating composite gutter sections or frontal flow for grate inlets.

Figure 3.3.5-1 provides a direct solution of gutter flow in a composite gutter section. The flow rate at a given spread or the spread at a known flow rate can be found from this figure. Figure 3.3.5-1 involves a complex graphical solution of the equation for flow in a composite gutter section. Typical of graphical solutions, extreme care shall be exercised in using the figure necessary to obtain accurate results.

Figure 3.3.5-1

Flow In Composite Gutter Sections



3.3.5.1 Condition 1: Find spread, given gutter flow.

Step 1 Determine input parameters, including longitudinal slope (S), cross slope ( $S_X$ ), depressed section slope ( $S_W$ ), depressed section width (W), Manning's n, gutter flow (Q), and a trial value of the gutter capacity above the depressed section ( $Q_S$ ).

Step 2 Calculate the gutter flow in W ( $Q_W$ ), using the equation:

$$Q_W = Q - Q_S \quad \text{(Eq 3.3.5-1)}$$

Step 3 Calculate the ratios  $Q_W/Q$  or  $E_O$  and  $S_W/S_X$  and use Figure 3-2 to find an appropriate value of W/T.

Step 4 Calculate the spread (T) by dividing the depressed section width (W) by the value of W/T from Step 3.

Step 5 Find the spread above the depressed section ( $T_S$ ) by subtracting W from the value of T obtained in Step 4.

Step 6 Use the value of  $T_S$  from Step 5 along with Manning's n, S, and  $S_X$  to find the actual value of  $Q_S$  from Figure 3-1.

Step 7 Compare the value of  $Q_S$  from Step 6 to the trial value from Step 1. If values are not comparable, select a new value of  $Q_S$  and return to Step 1.

3.3.5.2 Condition 2: Find gutter flow, given spread.

Step 1 Determine input parameters, including spread (T), spread above the depressed section ( $T_S$ ), cross slope ( $S_X$ ), longitudinal slope (S), depressed section slope ( $S_W$ ), depressed section width (W), Manning's n, and depth of gutter flow (d).

Step 2. Use Figure 3.3.3-1 to determine the capacity of the gutter section above the depressed section ( $Q_S$ ). Use the procedure for uniform cross slopes (Condition 2), substituting  $T_S$  for T.

Step 3 Calculate the ratios W/T and  $S_W/S_X$ , and, from Figure 3.3.3-2, find the appropriate value of  $E_O$  (the ratio of  $Q_W/Q$ ).

Step 4 Calculate the total gutter flow using the equation:

$$Q = Q_s / (1 - E_o) \quad \text{(Eq 3.3.5-2)}$$

Where:  $Q$  = Gutter flow rate (cfs)

$Q_s$  = Flow capacity of the gutter section above the depressed section (cfs)

$E_o$  = Ratio of frontal flow to total flow ( $Q_w/Q$ )

Step 5 Calculate the gutter flow in width (W), using Equation 3.3.5-1.

### 3.3.6 Examples

#### Example 1

Given:  $T = 8$  ft  $S_x = 0.025$  ft/ft

$$n = 0.015 \quad S = 0.01 \text{ ft/ft}$$

Find: Flow in gutter at design spread

Flow in width ( $W = 2$  ft) adjacent to the curb

Solution:

From Figure 3.3.3-1  $Q_n = 0.03$

$$Q = Q_n/n = 0.03/0.015 = 2.0 \text{ cfs}$$

$$T = 8 - 2 = 6 \text{ ft}$$

$Q_n(2) = 0.014$  (Figure 3.3.3-1) (flow in 6 ft width outside of width W)

$$Q = 0.014/0.015 = 0.9 \text{ cfs}$$

$$Q_w = 2.0 - 0.9 = 1.1 \text{ cfs}$$

Flow in the first 2 ft adjacent to the curb is 1.1 cfs and 0.9 cfs in the remainder of the gutter.

Example 2

Given:  $T = 6$  ft       $S_w = 0.0833$  ft/ft

$$T_s = 6 - 1.5 \text{ ft/ft} \quad W = 1.5 \text{ ft}$$

$$S_x = 0.03 \text{ ft/ft} \quad n = 0.014$$

$$S = 0.04 \text{ ft/ft}$$

Find : Flow in the composite gutter

Solution:

Use Figure 3.3.3-1 to find the gutter section capacity above the depressed section.

$$Q_{sn} = 0.038$$

$$Q_s = 0.038/0.014 = 2.7 \text{ cfs}$$

Calculate  $W/T = 1.5/6 + 0.25$  and

$$S_w/S_x = 0.0833/0.03 = 2.78$$

Use Figure 3.3.3-2 to find  $E_o = 0.64$

Calculate the gutter flow using equation 3.3.5-2

$$Q = 2.7/(1 - 0.64) = 7.5 \text{ cfs}$$

Calculate the gutter flow in width,  $W$ , using Equation 3.3.5-1

$$Q_w = 7.5 - 2.7 = 4.8 \text{ cfs}$$

END OF SECTION 3.3