Calculating Spread and Checking Intake Location

Design Manual
Chapter 4
Chapter Title
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This section provides procedures for calculating spread on roadways with various geometric features. The following items are addressed:

- Spread design parameters,
- Spread calculation procedure,
- Calculation of total flow rate,
- Spread geometry and calculations,
- Checking intake locations, and
- Locating flanking intakes.

Spread Design Parameters

In this manual, spread (T) refers to the distance from the face of curb to the limit of water on the roadway, while encroachment refers only to how far the water encroaches on the traveled lanes of the roadway. See Figure 1.

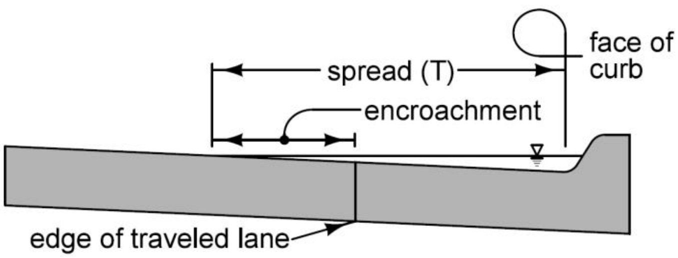

Figure 1: Curb section showing spread and encroachment.

Quick Tip: For a quick check of intake location, assume a spread equal to the maximum allowable and calculate the peak flow (Q) based on gutter capacity. Refer to "Tips for Determining Preliminary Intake Spacing and Drainage Areas".

Interstates, Freeways, Expressways, and Primary Highways

Table 1 provides maximum allowable encroachment. More stringent requirements may be necessary in areas where encroachment or ponding can result in traffic delays, property damage, or safety concerns such as ice forming in the path of pedestrians.

Staged Construction or Detour

Recurrence interval is discussed in Section 4A-5. Use the same encroachment limits as in Table 1.

Local Streets

Recurrence interval is discussed in Section 4A-5. Contact the local jurisdiction for encroachment information.

Table 1: Design storm recurrence interval and allowable encroachment.

situation	design storm recurrence interval	maximum allowable encroachment
Interstates, Freeways, and Expressways		
intake on continuous grade	10 year	no encroachment
intake at a sag point	50 year	
major storm check	100 year	equivalent of one 12 foot driving lane open to traffic in each direction
Primary Highway (posted speed ≥ 45 mph)		
intake on a continuous grade	10 year	no encroachment
intake at a sag point	50 year	3 feet[(a)]
major storm check	100 year	[(b)]
Primary Highway (posted speed < 45 mph)		
intake on a continuous grade	10 year	3 feet[(a)]
intake at a sag point	50 year	
major storm check	100 year	[(b)]

[(a)] For cross sections with no shoulder, allowable encroachment for two lane roadways is 3 feet onto the traveled lane. Where there are two or more adjacent lanes in a given direction, allowable encroachment is 6 feet onto the traveled lane in that direction.

[(b)] The equivalent of one 12 foot lane width open to traffic for two-lane roadways. The equivalent of one 12 foot lane width open to traffic in each direction for three (or more) lane roadways. Note a lane width could be two partial lanes if they are adjacent and not obstructed.

Spread Calculation Procedure

Following is a step-by-step procedure. Explanations and examples are then provided.

Use the Rational Method (Section 4A-5) to find the design storm peak rate of runoff (Q) from each drainage area. Start at the upstream end and follow the steps below for each area:

- Calculate the total flow rate to the intake.
- Calculate the design storm spread (T) to determine how much water is encroaching on the roadway.
- Use the calculated spread to determine whether the preliminary intake locations are appropriate for the design event. If spread exceeds maximum allowable for the minor design storm, adjust intakes and recalculate Q and spread as required.

Once intake locations are established meeting maximum allowable spread for the minor design storm, evaluate spread for the major design storm.

- Calculate Q and spread for the major design storm.
- Evaluate intake locations for the major design storm. Also evaluate overland flow paths to determine where the water will go when it overtops the curb or crown of the roadway.

Spread at sag locations for curb-opening intakes and grate intakes is discussed in Sections 4A-7 and 4A-8 respectively.

Calculation of Total Flow Rate

$$Q = Q_{bp} + Q_a \text{ (Equation 4A-6\_1)}$$

where:

Q = Total flow rate, ft^3/s.

Q_{bp} = Bypass flow (flow not intercepted by the upstream intake), ft^3/s.

Q_a = Flow from the drainage area after the upstream intake, ft^3/s.

Spread Geometry and Calculations

A curb and gutter combination forms a triangular channel that can carry runoff without interrupting traffic. Spread for a given peak flow (Q) value depends on the type of gutter section used: triangle or multi-triangle.

Triangle

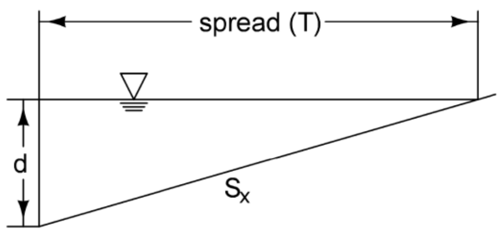

Figure 2: Triangle section.

In Figure 2, d is the depth of water at the curb for a spread of T and S_x is the pavement cross slope. The spread could include part of a shoulder or traveled lane. The Triangle section has the assumption that the pavement cross slope under the width of spread is constant. When the spread is known, the depth of water in the gutter at the curb (see Figure 2) can be calculated:

$$d = T \times S_x, \text{ ft (Equation 4A-6\_2).}$$

where:

d = Depth at curb for allowable spread, ft (see Figure 4).

T = Spread, ft.

S_x = Pavement cross slope, ft/ft.

Manning's equation (modified for triangular gutter flow) is used to determine gutter flow:

$$Q = \frac{K_u}{n} S_x^{1.67} T^{2.67} \sqrt{S_L} \text{ (Equation 4A-6\_3)}$$

where:

T = Spread, ft (m).

Q = Total gutter flow, ft^3/s.

K_u = 0.56.

n = Manning's coefficient (see Table 2).

S_x = Cross slope of gutter, ft/ft (Note: this is often steeper than the cross slope of the traveled lanes).

S_L = Longitudinal slope of the gutter, ft/ft.

Table 2: Manning's roughness coefficients for gutters and pavement.[1]

type of gutter or pavement	Manning's n*
Concrete Gutter:	
Troweled finish	0.012
Asphalt Pavement:	
Smooth texture	0.013
Rough texture	0.016
Concrete gutter-asphalt pavement:	
Smooth	0.013
Rough	0.015
Concrete pavement:	
Float finish	0.014
Broom finish	0.016

*For gutters with small slope, where sediment may accumulate, evaluate width of spread by increasing the above values of "n" by 0.02.

When the gutter flow rate is known, the spread can be calculated by rearranging Equation 2:

$$T = \left[\frac{nQ}{K_u S_x^{1.67} \sqrt{S_L}} \right]^{0.375} \quad \text{(Equation 4A-6\_4)}$$

The designer should be aware of how selection of a variable affects results. For example, using a larger n value to account for potential future sediment or older pavement will result in a smaller Q value in Equation 4A-6_3 and a larger T value in Equation 4A-6_4. Thus, using a larger n value will be conservative with respect to width of spread determinations; however, it will be less conservative with respect to inlet and pipe sizing.

Example Problem 4A-6_1, Calculating Spread (Simple Triangle)

Multi-triangle (Composite Section)

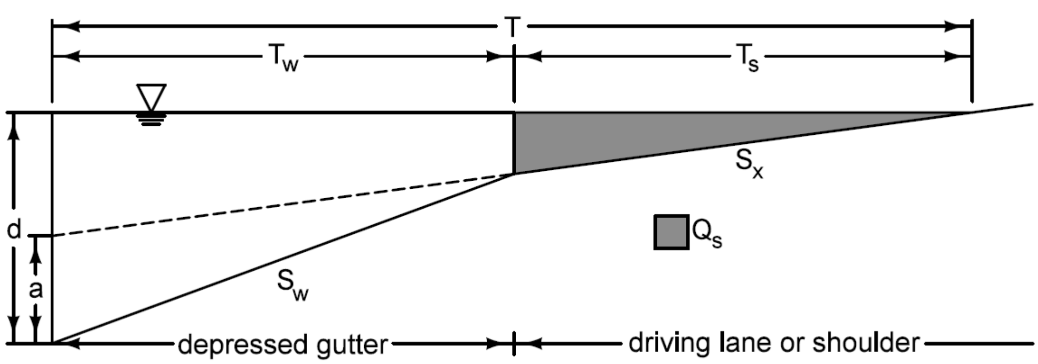

Figure 3: Multi-triangle section.

A Multi-triangle (depressed) section is more complicated than the simple triangle section and requires different calculations. For calculating spread in a depressed gutter section, use the following formula:

$$T = T_w + T_s \text{ (Equation 4A-6\_5)}$$

where:

T = Spread, ft.

T_w = Depressed gutter section spread, ft.

[1] FHWA, *Design Charts for Open-Channel Flow, Hydraulic Design Series No. 3 (1977 reprint).*

T_s = Spread outside of the depressed gutter section, ft. T_s is calculated as follows:

$$T_s = \frac{T_w \times \frac{S_w}{S_x}}{\left[\frac{\frac{S_w}{S_x}}{\frac{Q}{(Q-Q_s)}-1}+1\right]^{0.375}-1} \quad \text{(Equation 4A-6\_6)}$$

where:

Q = Total gutter flow, ft^3/s.

Q_s = Flow outside of the depressed gutter section, ft^3/s.

S_x = Cross slope of driving lane, ft/ft.

S_w = Cross slope of depressed gutter, ft/ft (m/m). S_w is determined as follows:

$$S_w = S_x + \frac{a}{12T_w} \text{ English units}$$

where a is the depth of the depressed gutter section in inches or mm (see Figure 3).

Example Problem 4A-6_2, Calculating Spread (Multi-Triangle)

NOTE: If a multi-triangle gutter section is selected for design, the calculations can be simplified by assuming a uniform cross slope of S_x. A uniform cross slope produces a wider spread than a multi-triangle section for the same value of Q. Assuming a uniform cross slope results in more conservative (closer) intake spacing.

Checking Intake Locations

After calculating spread:

- Compare calculated spread to the allowable spread.
- If spread exceeds allowable limits, relocate or resize the intake, or add an additional intake.
- If relocating an intake, recalculate Q for the new drainage area(s) and calculate new values of spread.
- Repeat the procedure of relocating and adding intakes until spread is within acceptable limits.

Example Problem 4A-6_3, Intake Location Check

Locating Flanking Intakes

On major highways, interstates, freeways, and other roadways on the National Highway System, flanking intakes are required on each side of sag intakes. Flanking intakes function to:

- Pick up silt before the velocity in the gutter becomes too slow.
- Reduce ponding at the low point if volumes of water are high or if the intake at the low point becomes plugged.

Flanking intakes are to act in relief, not to intercept flow in order to reduce bypass flow. Therefore, do not include the effects of flanking intakes when sizing and spacing other intakes.

Note: If the low point falls at the end of a return, take care not to place a flanking intake within the return.

Flanking intakes should be located so each will receive half of the flow should the sag intake become clogged. They should do this before spread at the sag intake exceeds allowable minor design storm spread. If SW-507 or SW-508 intakes are used as flanking intakes, locate them at an elevation of 0.17d above the sag intake, where d is the depth at curb for the maximum allowable spread. If SW-509 or SW-510 intakes are used, locate them at an elevation of 0.37d above the sag intake. When barrier grate intakes (SW-547, SW-548, and SW-549) are being used, locate flanking intakes at an elevation of 0.37d above the sag intake. Refer to Sections 4A-7 and 4A-8 for information on determining d for sag intakes.

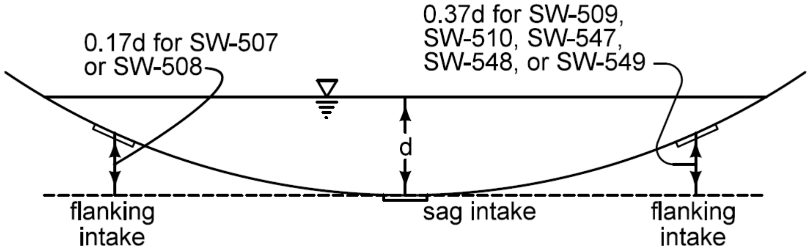

Figure 4: Locating flanking intakes for a sag intake.

Urban areas can present challenges when locating flanking intakes. Designers may not be able to properly locate flanking intakes without placing them in intersections with side streets or driveways. In addition, speeds in urban areas are lower, which allows for higher K values for vertical curves. As a result, locating a flanking intake at the proper elevation may result in the intake being placed too close to the sag intake. For situations such as these, designers will need to explore alternatives or obtain a design exception to exclude flanking intakes.

Additional Considerations

HEC-22 discusses additional typical gutter sections, shallow swales, and intake spacing design and provides several examples.

Chronology of Changes to Design Manual Section:

004A-006 Calculating Spread and Checking Intake Location

2/9/2017	Revised Replaced logo and deleted metric units.
7/18/2013	Revised Changed df from 0.37d to 0.63d for SW-509, SW-510, SW-547, SW-548, or SW-549 in the figure included in the "Locating Flanking Intakes for a Sag Intake" calculations referenced by Figure 4. Minor technical edit to Tips.
9/30/2011	Revised Revise information regarding placement of flanking intakes
10/29/2010	Revised Rewritten material from old 4A-5. Material in old 4A-6 moved to 4A-7.