



# Open-throat Curb Intakes

Design Manual

Chapter 4

Drainage

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This section addresses the following:

- [Intercepted flow.](#)
- [Bypass flow.](#)
- [Efficiency of Open-throat Curb Intakes on a Continuous Grade.](#)
- [Sizing Open-throat Curb Intakes on a Continuous Grade.](#)
- [Open-throat Curb Intakes Located in Sags.](#)

These processes are based on the procedures used in [FHWA's Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22.](#)

## Intercepted Flow

Intercepted flow is flow intercepted by an intake under a given set of conditions. The interception capacity of an open-throat curb intake is equal to the efficiency of the intake multiplied by the total gutter flow. The general equation relating efficiency to intercepted flow is:

$$Q_i = EQ \text{ (Equation 4A-7_1)}$$

where:

$Q_i$  = Intercepted flow, ft<sup>3</sup>/s (m<sup>3</sup>/s).

$E$  = Intake efficiency.

$Q$  = Design gutter flow, ft<sup>3</sup>/s (m<sup>3</sup>/s).

## Bypass Flow

Bypass flow is flow bypassing an intake. The general equation relating bypass to intercepted flow is:

$$Q_b = Q - Q_i \text{ (Equation 4A-7_2)}$$

where:

$Q_b$  = Bypass flow, ft<sup>3</sup>/s (m<sup>3</sup>/s).

$Q_i$  = Intercepted flow, ft<sup>3</sup>/s (m<sup>3</sup>/s).

$Q$  = Design gutter flow, ft<sup>3</sup>/s (m<sup>3</sup>/s).

## Efficiency of Open-throat Curb Intakes on a Continuous Grade

Efficiency is the percent of total flow that the intake will intercept under a given set of conditions. Efficiency changes with changes in inlet geometry and pavement cross slope, longitudinal slope, and roughness, as well as total gutter flow.

Intake efficiency (E) for open-throat curb intakes is determined by the following equation:

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8} \quad (\text{Equation 4A-7}_3)$$

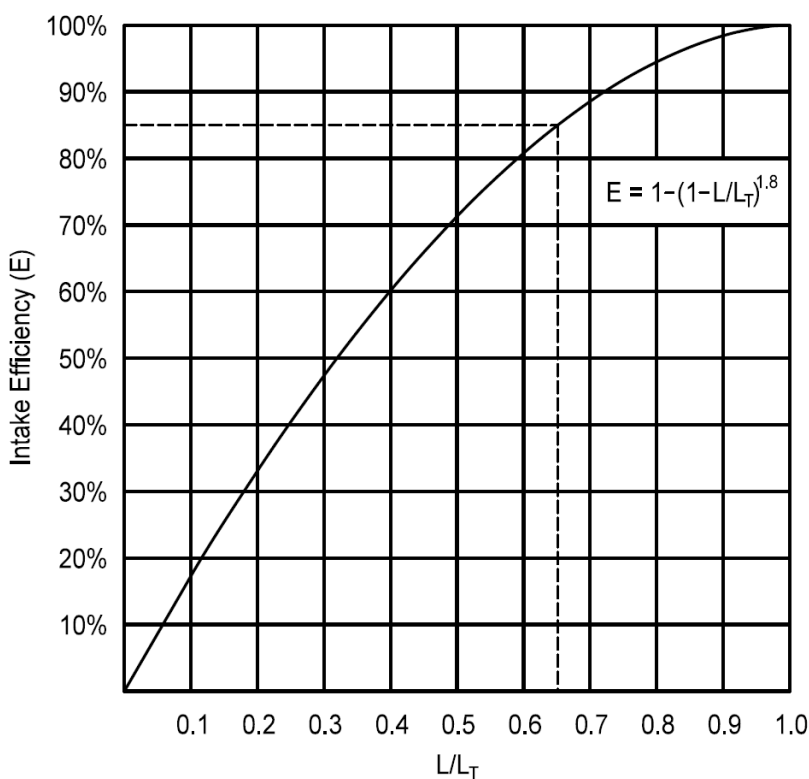
where:

E = Intake efficiency.

L = Throat opening length, ft (m).

$L_T$  = Throat opening length required to intercept 100 % of the gutter flow, ft (m).

Figure 1 shows the relationship between throat opening length and interception efficiency. The graph shows the point at which a large change in the length produces only a small increase in the percentage of gutter flow intercepted. This occurs at an efficiency of around 85%. As an example, if  $L_T = 12$  ft and  $L = 4$  ft, the efficiency is about 50%. Increasing the throat length to 8 ft produces an efficiency of about 85%, an increase of 35%. However, increasing the throat length another 4 ft to 12 ft produces an additional increase in efficiency of only 15%.



**Figure 1:** Intake interception efficiency for open-throat curb intakes.

## Sizing Open-throat Curb Intakes on a Continuous Grade

Use 85% as an initial guideline for sizing open-throat curb intakes for the minor design storm. Efficiencies less than 85% are acceptable, but in cases such as these, designers should examine the downstream effect of increasing the throat length. Intakes downstream may be eliminated as a result of increasing the throat lengths of upstream intakes.

In some cases, it is desirable for intakes to operate at efficiencies greater than 85% in order to minimize bypass flow. For example, intakes upstream of pedestrian crossings should be sized to minimize bypass flow to reduce the potential for ponding or icing at crosswalks.

Sizing open-throat curb intakes is a two-step process:

1. Determine the length of throat opening required to intercept 100% of the gutter flow ( $L_T$ ).

The length of throat opening required to intercept 100% of the gutter flow ( $L_T$ ) is calculated as:

$$L_T = K_T Q^{0.42} S_L^{0.3} \left( \frac{1}{n S_x} \right)^{0.6} \quad (\text{Equation 4A-7}_4)$$

where:

$K_T$  = 0.6 English units (0.817 metric units).

$Q$  = Gutter flow, ft<sup>3</sup>/s (m<sup>3</sup>/s).

$S_L$  = Longitudinal slope, ft/ft (m/m).

$n$  = Manning's coefficient (see Table 2 in Section 4A-6). For new pavements  $n = 0.016$ .

$S_x$  = Cross slope, ft/ft (m/m).

For an intake with a depressed section at the opening, an equivalent cross slope ( $S_e$ ) is used in place of  $S_x$ :

$$S_e = S_x + \frac{a}{12W} \times \left[ 1 - \left( 1 - \frac{W}{T} \right)^{\frac{8}{3}} \right] \quad (\text{Equation 4A-7}_5 \text{ for English units})$$

$$S_e = S_x + \frac{a}{1,000W} \times \left[ 1 - \left( 1 - \frac{W}{T} \right)^{\frac{8}{3}} \right] \quad (\text{Equation 4A-7}_5 \text{ for metric units})$$

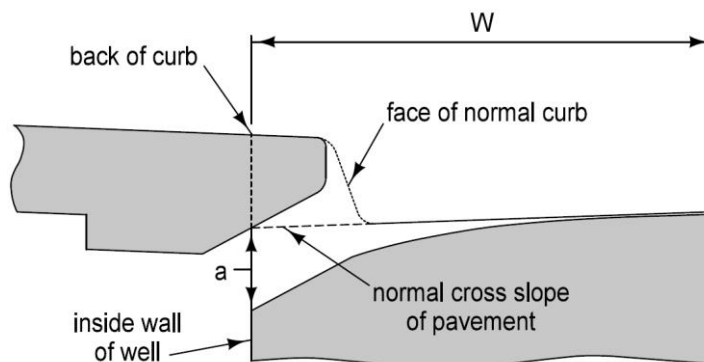
where:

$S_x$  = Cross slope, ft/ft (m/m).

$a$  = Gutter depression depth measured from an extension of the pavement cross slope at the inside wall of the well, inches (mm); see Figure 2 and Table 1.

$W$  = Gutter depression width, ft (m); see Figure 2 and Table 1.

$T$  = Spread, ft (m).



**Figure 2:** Illustration of  $a$  and  $W$  dimensions.

- Choose an intake with a throat opening that will intercept approximately 85% of the gutter flow. To determine this, set  $E = 0.85$  and rearrange equation 4A-7\_3:

$$L = 0.6514 L_T \quad (\text{Equation 4A-7}_6)$$

#### [Example Problem 4A-7\\_1, Open-throat Curb Intake on continuous Grade](#)

[HEC-22](#) provides additional guidance on how to evaluate and compare the interception capacity of inlets on grade.

**Table 1: Standard Iowa DOT open-throat curb intakes and features.**

type	well location with respect to pavement	width of depression (W)		depth of depression (a)		length of opening (L)	
SW-507	outside	2 ft.	0.60 m	6 in.	150 mm	4 ft.	1.2 m
SW-508	outside	2 ft.	0.60 m	6 in.	150 mm	4 ft.	1.2 m
SW-509	outside	2 ft.	0.60 m	6 in.	150 mm	8 ft.	2.4 m
SW-510	outside	2 ft.	0.60 m	6 in.	150 mm	8 ft.	2.4 m
SW-541	under	14 in.	0.36 m	6 in.	150 mm	4 ft.	1.2 m
SW-541 with SW-542 extension	under	14 in.	0.36 m	6 in.	150 mm	9 ft.-2 in.	2.75 m
SW-541 with two SW-542 extensions	under	14 in.	0.36 m	6 in.	150 mm	14 ft.-4 in.	4.25 m
SW-545	outside	2 ft.	0.60 m	6 in.	150 mm	12 ft. to 18 ft.	3.6 m to 5.4 m
SW-546	outside	2 ft.	0.60 m	6 in.	150 mm	4 ft.	1.2 m
SW-550	outside	2 ft.	0.60 m	6 in.	150 mm	4 ft. or 8 ft.	1.2 m or 4.25 m

## Open-throat Curb Intakes Located in Sags

To accommodate possible debris blockage, use double box intakes (SW-509 or SW-510) in sags. The following conditions need to be satisfied:

- Use a 50-year recurrence interval (2% chance storm) for the minor design storm.
- Use a 100-year recurrence interval (1% chance storm) for the major design storm.
- For the minor design storm, the intake needs to pick up 100% of the gutter flow from both sides at the maximum allowable spread.
- In addition to checking the maximum allowable spread, check for roadway crown or curb overtopping and resulting overland flow.



Ignore flanking intakes when evaluating intakes in sags (refer to Section [4A-6](#) for more on flanking intakes).

Check the spread on both sides of sag intakes. Use a longitudinal slope of 0.003 ft/ft (the minimum slope required to carry water in the gutter just before reaching the intake). If spread exceeds allowable encroachment, relocate or resize upstream intakes or add additional upstream intakes to reduce spread approaching the sag intakes.

Once the spread requirements on both sides of the intake are satisfied, verify the spread at the intake itself does not exceed allowable encroachment (see Table 1, Section [4A-6](#)). Check the spread by determining the depth of ponding (d) shown in Figure 3 and using [Equation 4A-6\\_2](#) to calculate spread. If spread at the sag intake exceeds allowable encroachment, relocate or resize upstream intakes to reduce spread at the sag intake.

How d is determined depends on whether the intake operates as a weir (gravity controls flow) or an orifice (pressure controls flow). Since d is not known, the designer must make an initial assumption about how the intake is operating. Start by assuming weir flow. For weir flow, d is determined as:

$$d = \left[ \frac{Q}{C_w \times (L + 1.8W)} \right]^{-0.67} \quad (\text{Equation 4A-7_7})$$

where:

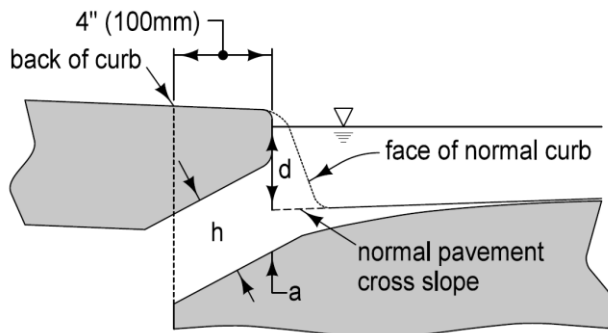
d = Depth of ponding at the curb measured from an extension of the pavement cross slope, ft (m). Refer to Figure 3.

Q = Intercepted flow, ft<sup>3</sup>/s (m<sup>3</sup>/s).

$C_w$  = Weir coefficient, 2.3 English units (1.25 metric units).

$L$  = Length of throat opening, 8 ft (2.4 m) for SW-509 and SW-510.

$W$  = Width of gutter depression, 2 ft for English units (0.6 m for metric units).



**Figure 3:** Illustration of  $d$ ,  $h$ , and  $a$  dimensions.

Equation 4A-7\_7 applies if:

$$d \leq h + \frac{a}{12} = 0.75 \text{ ft (English units)}$$

$$d \leq h + \frac{a}{1,000} = 225 \text{ mm (metric units)}$$

where:

$h$  = the height of the intake opening = 5 in. (0.42 ft or 125 mm) for Iowa DOT inlets, see Figure 3.

$a$  = depth of gutter depression at the gutterline = 4 in. (0.33 ft or 100 mm), see Figure 3.

If  $d > 0.75$  ft (225 mm), then the intake is considered to be operating as an orifice. To determine  $d$ , first the depth at the lip opening needs to be determined:

$$d_i = \frac{1}{2g} \left[ \frac{Q}{0.67hL} \right]^2 + \frac{h}{2} \sin\theta \quad (\text{Equation 4A-7_8})$$

where:

$d_i$  = Depth at the lip of the curb opening, ft (m). Refer to Figure 4.

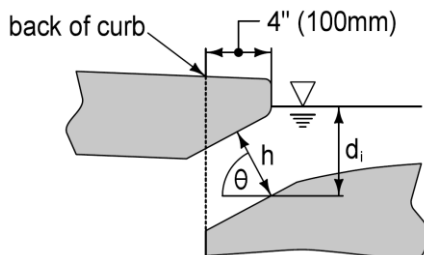
$Q$  = Intercepted flow,  $\text{ft}^3/\text{s}$  ( $\text{m}^3/\text{s}$ ).

$h$  = Height of curb-opening orifice, 0.42 ft (125 mm for metric units) for SW-509 and SW-510.

$L$  = Length of throat opening, 8 ft (2.4 m) for SW-509 and SW-510.

$g$  = Gravity,  $32.2 \text{ ft/s}^2$  ( $9.81 \text{ m/s}^2$ ).

$\theta = 67^\circ$ .



**Figure 4:** Depth at the lip of the curb opening.

To determine  $d$ , subtract 0.33 ft (100 mm), the depth of the depression at the gutterline, from  $d_i$ .

[Example Problem 4A-7\\_2, Open-throat Curb Intake in a Sag](#)

# Chronology of Changes to Design Manual Section:

## 004A-007 Open Throat Curb Intakes

- 11/30/2011    Revised  
Discussed with SUDAS. Change depression depth to 6" for on grade and 4" for sag. Update example problems.  
Update example problems.
- 10/29/2010    Revised  
Rewritten material from old 4A-6. Material in old 4A-7 moved to 4A-9.