Example Problem 4A-7_1, Open Throat Curb Intake on Continuous Grade

Determine the size and efficiency of an open-throat curb intake on a continuous grade.

Given:

Cross slope: S_x = 0.03 ft/ft.

Manning's coefficient: n = 0.016 (new pavement).

Gutter Flow: Q = 1.6 ft^3/s.

Longitudinal slope: S_L = 0.02 ft/ft.

Empirical Coefficient: K_u = 0.56.

Empirical Coefficient: K_T = 0.60.

The well for the intakes will be located outside of the pavement.

Width of depression: W = 2 feet. (see Table 1, SW-507-510 and SW-545).

Depth of depression: a = 6 inches. (see Table 1, SW-507-510 and SW-545).

Assume allowable width of spread is 6.0 feet.

Solution:

1. Calculate spread (T) using the process for Triangular Gutter Sections (Equation 4A-6_4):

$$T = \left[\frac{nQ}{K_u S_x^{1.67}\sqrt{S_L}}\right]^{0.375} = \left[\frac{0.016\times 1.6}{0.56\times 0.03^{1.67}\sqrt{0.02}}\right]^{0.375} = 5.89 \text{ feet}$$

   This is within the allowable limit.

2. Since this is an intake with a depression, calculate the equivalent cross slope (S_e) using Equation 4A-7_5:

$$S_e = S_x + \frac{a}{12W}\times\left(1-\left(1-\frac{W}{T}\right)^{8/3}\right) = 0.03+\frac{6}{12\times 2}\times\left(1-\left(1-\frac{2}{5.89}\right)^{8/3}\right) = 0.20.$$

3. Calculate the curb-opening length required to intercept 100% of the gutter flow (L_T) using Equation 4A-7_4 (S_e is used in place of S_x):

$$L_T = K_T Q^{0.42} S_L^{0.3}\left(\frac{1}{nS_e}\right)^{0.6} = 0.6\times 1.6^{0.42}\times 0.02^{0.3}\left(\frac{1}{0.016\times 0.20}\right)^{0.6} = 7.10 \text{ feet}$$

4. Calculate the throat opening length (L) needed to intercept 85% of the flow using Equation 4A-7_6:

$$L = 0.6514L_T = 0.6514 \times 7.10 = 4.62 \text{ feet}$$

5. An intake with a throat opening of 4.62 feet is required. From Table 2, choose an intake which has a throat opening length (L) of 8 feet.

6. Determine the efficiency of the intake:

   Since $L > L_T$, E = 100%.

7. Determine the intercepted flow (Q_i) by using Equation 4A-7_1:

$$Q_i = EQ = 1.00 \times 1.60 = 1.60 \text{ ft}^3/\text{s}.$$

8. Determine the Bypass flow (Q_b) by using Equation 4A-7_2:

$$Q_b = Q - Q_i = 1.60 - 1.60 = 0.00 \text{ ft}^3/\text{s}.$$

Discussion:

Item 6 is the theoretical efficiency of the intake and does not account for debris or damage to the inlet and assumes weir flow (assumes the inlet is not submerged).

The 8' inlet efficiency is higher than 85%, however, if a 4 foot opening is chosen:

$$E = 1 - \left(1 - \frac{4}{7.10}\right)^{1.8} = 78\%.$$

$$Q_i = EQ = 0.78 \times 1.60 = 1.25 \text{ ft}^3/\text{s}$$

$$Q_b = Q - Q_i = 1.60 - 1.25 = 0.35 \text{ ft}^3/\text{s}.$$

This efficiency (sometimes referred to as “percent capture”) could be too low, especially if this intake precedes a crosswalk. As it may be difficult to visualize how much flow 0.35 ft^3/s is, Equation 4A-6_2 and Equation 4A-6_4 could be used to further evaluate the depth and spread of water expected at the curb due to the bypass flow in this scenario.