

Example Problem 4C-2_3, Evaluate an Intake Bridge End Drain

Determine intercepted and bypass flows by calculating the efficiency of an intake bridge end drain.

Given:

Cross slope: $S_x = 0.03$ ft/ft.

Manning's coefficient for new pavement: $n = 0.016$.

Total flow rate: $Q = 1.6$ ft³/s.

Longitudinal slope: $S_L = 0.02$ ft/ft.

Allowable spread = 6 ft.

Solution:

1. Use Equation 4A-6_4 from Section 4A-6 to find the gutter spread (T) directly upstream of the intake:

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

Gutter spread is less than allowable spread, so spread is acceptable.

2. Use Equation 4C-2_4 to calculate the grate frontal flow to total gutter flow (E_o):

$$E_o = \left[1 - \left(1 - \frac{W}{T} \right)^{2.67} \right] = \left[1 - \left(1 - \frac{1.90}{5.89} \right)^{2.67} \right] = 0.647 \text{ or } 65\%$$

3. Use Equation 4C-2_6 to calculate the average gutter velocity (V):

$$V = \frac{2Q}{T^2 S_x} = \frac{2 \times 1.6}{5.89^2 \times 0.03} = 3.08 \text{ ft/s}$$

4. Use Equation 4C-8_2 to calculate the frontal flow interception (R_f):

$$R_f = 1 - K_f(V - V_o) = 1 - 0.09(3.08 - 5.6) = 1.23 > 1.0$$

Since the frontal flow interception (R_f) is greater than 1.0, use $R_f = 1.0$

5. Use Equation 4C-2_7 to calculate the side flow interception (R_s):

$$R_s = \frac{1}{1 + \frac{K_s V^{1.8}}{S_x L^{2.3}}} = \frac{1}{1 + \frac{0.15 \times 3.08^{1.8}}{0.03 \times (1.90)^{2.3}}} = 0.104 \text{ or } 10\%$$

6. Use Equation 4C-2_3 to calculate the efficiency (E):

$$E = R_f E_o + R_s(1 - E_o) = (1 \times 0.647) + 0.104(1 - 0.647) = 0.684 \text{ or } 68\%$$

This is less than 90%, so an additional intake is required downstream.

7. Use Equation 4A-8_1 to calculate the intercepted flow (Q_i):

$$Q_i = EQ = 0.68 \times 1.6 = 1.09 \text{ ft}^3/\text{s}$$

8. Use Equation 4A-8_2 to calculate the bypass flow (Q_b):

$$Q_b = Q - Q_i = 1.6 - 1.09 = 0.51 \text{ ft}^3/\text{s}$$

Discussion:

Efficiency is less than 90%, so the designer will need to place a second intake downstream. This intake should also be placed between guardrail posts with the center a minimum of 6 feet (1.5 meters) from the nearest joint. This intake will also need to be evaluated to ensure that bypass does not exceed 10% of the gutter flow coming from the bridge. The second intake may be joined to a common storm sewer outlet.