Office of Design

4C-2

Bridge End Drains for Capturing Stormwater Runoff

Design Manual
Chapter 4
Drainage
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This section discusses drainage structures used for capturing stormwater runoff from bridges. These structures are commonly referred to as bridge end drains. If water flows away from a bridge corner, a bridge end drain is needed.

Choosing a Bridge End Drain

Runoff from bridges can be captured with intakes or flumes. Typically, flumes are used in rural areas, whereas intakes are used in urban areas or in high fill situations. However, the best option to use depends on site characteristics as well as maintenance and safety concerns.

Intakes

- In urban areas with curb and gutter, use an SW series Standard Road Plan storm sewer intake. Refer to Section 4A-4 for more on urban drainage design.
- In other areas where high fills, high flows, and/or erosive soils are present, use an intake bridge end drain (Standard Road Plans SW-538 and SW-539).

Flumes

- If the area will be mowed regularly or if traversability of errant vehicles is a concern, use a scour protection flume (Standard Road Plan DR-401).
- If mowing and/or traversability are not a concern, use a rock flume (Standard Road Plan DR-402).

Contact the Roadside Development Section in the Office of Design for additional information.

Locating Bridge End Drains

Bridge end drains should not be located immediately adjacent to the bridge end. Paved shoulder panels are often needed to convey drainage away from the bridge to the bridge end drain. For consistency, shoulder panels A, B, C, and D have been defined as shown in Figure 1. Distances from each bridge corner to the center of a proposed bridge end drain (DI-1 and DI-2) are shown as well. DI distances are measured from the center of the bolt hole pattern used to attach guardrail to the bridge.

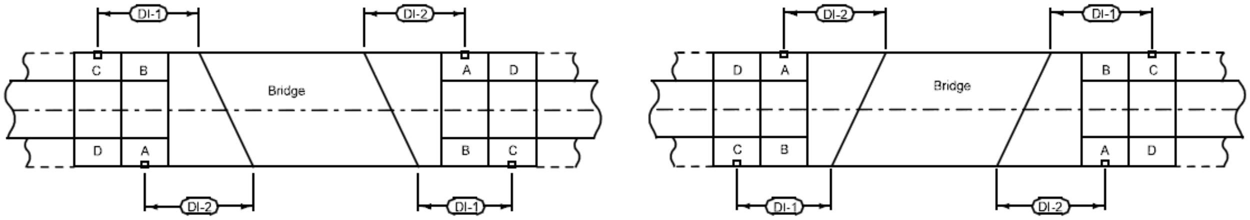

Figure 1: Paved shoulder panel locations**.**

A curb is necessary to carry the runoff from the bridge to the bridge end drain. Therefore, the reinforced bridge approach section, as well as paved shoulder panels, must include a curb. Typically, a 4 inch sloped curb is used. For flumes, the curb terminates at the bridge end drain. For intake bridge end drains, the curb is carried to a point 5 feet beyond the centerline of the intake. Details of this termination are shown on each drainage structure's respective standard road plan.

When guardrail will be installed at a bridge end, the design of the guardrail may influence the location of a proposed drainage structure, as well as the location and shape of any required shoulder panels. Therefore, for ease of design and construction, maintain a tangent guardrail alignment (no flare) until it reaches a point beyond the shoulder panel that contains the bridge end drain. Refer to Chapter 8 for additional information related to guardrail design.

Flumes (DR-401 and DR-402)

Locate flumes beyond the BTS and where guardrail posts are spaced 6'-3" apart to minimize the number of posts in the flume, as shown in Figure 2.

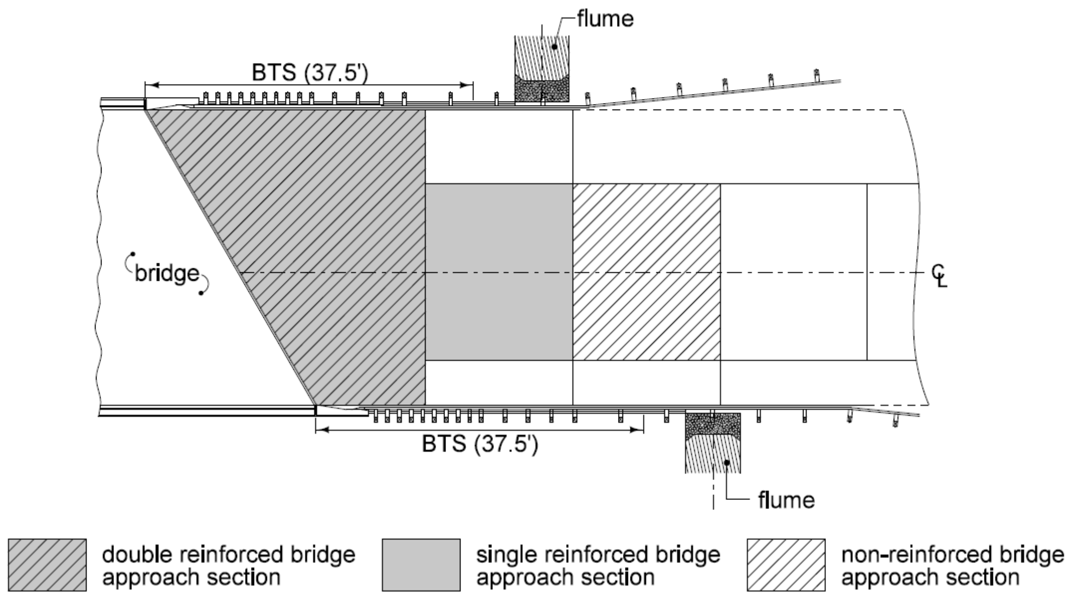

Figure 2: Placement of flumes.

Intake Bridge End Drains (SW-538 and SW-539).

Do not locate intake bridge end drains in the reinforced bridge approach section. Instead, locate them so:

- They are in paved shoulder panels,
- They are located between guardrail posts that are spaced 6'-3" apart to eliminate the risk of a guardrail post penetrating the outlet pipe,
- The center is at least 6 feet from the nearest joint, and
- The curb drop occurs beyond the BTS.

The following example problems demonstrate the process for locating intake bridge end drains.

Example Problem 4C-2_1, Determining Intake Bridge End Drain Location

Example Problem 4C-2_2, Determining Intake Bridge End Drain Location

In the case of narrow bridge shoulders (4 feet or less), locating an SW-538 or SW-539 intake bridge end drain at the proposed location may not be possible. Consider using a flume or drawing up the bridge/guardrail situation to locate the drain further from the bridge in an area where the shoulder panel width can be made greater than 4 feet. Additional panels may be necessary.

Hydraulic Evaluation of Intake Bridge End Drains

Grate Capacity

After locating an intake bridge end drain, compute storm runoff Q in cfs for the design storm (refer to Section 4A-5) and determine grate intercept capacity. When using an SW-538 or SW-539, grate intercept capacity Q_i is determined using the equation:

$$Q_i = EQ \quad \text{(Equation 4C-2\_1)}$$

where:

Q_i = Intercepted flow, ft^3/s.

E = Intake efficiency.

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

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

$$Q_b = Q - Q_i \quad \text{(Equation 4C-2\_2)}$$

where:

Q_b = Bypass flow, ft^3/s.

Q_i = Intercepted flow, ft^3/s.

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

Efficiency

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

The interception capacity of an intake bridge end drain depends on:

- Flow in the gutter section.
- Flow velocity in the gutter.

The efficiency for intake bridge end drains is determined by the following equation:

$$E = R_f E_o + R_s(1 - E_o) \quad \text{(Equation 4C-2\_3)}$$

where:

E = Efficiency.

E_o = Frontal flow to total gutter flow ratio.

R_f = Frontal flow interception.

R_s = Side flow interception.

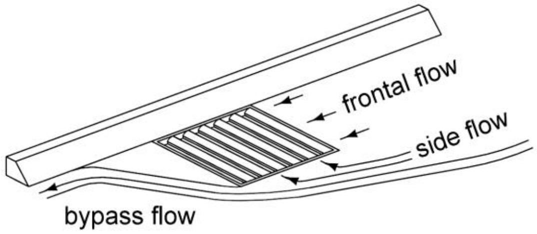

Figure 3: Intake bridge end drain flow definitions.

Frontal Flow to Total Flow Ratio

The ratio of frontal flow to total gutter flow is determined using the following equation:

$$E_o = 1 - \left(1 - \frac{W}{T}\right)^{2.67} \quad \text{(Equation 4C-2\_4)}$$

where:

E_o = Ratio of frontal flow to total gutter flow, (Q_w/Q).

W = Width of grate, ft. Use 1.90 ft, the width of the grate used with the SW-538 and SW-539.

T = Total spread, ft.

Frontal Flow Interception

As shown in Figure 3, frontal flow is the portion of the flow that passes over the upstream side of a grate. The ratio of frontal flow intercepted to total frontal flow, R_f, is determined using the following equation:

$$R_f = 1 - K_f(V - V_o) \quad \text{(Equation 4C-2\_5)}$$

where:

K_f = Empirical coefficient, 0.09.

V = Velocity of flow in the gutter, ft/s.

V_o = Gutter velocity where splash-over first occurs, ft/s. Use 5.6 ft/s, the splash-over velocity for the grate used with the SW-538 and SW-539.

Note: R_f cannot be greater than 1.00. If $V \leq V_o$, then all flow is intercepted. If $V_o > V$, then only a portion of the flow is intercepted.

Velocity of flow in the gutter (V) is determined as follows:

$$V = \frac{2Q}{T^2 S_x} \quad \text{(Equation 4C-2\_6)}$$

where:

Q = Flow in gutter, ft^3/s.

T = Spread, ft.

S_x = Cross slope of pavement, ft/ft.

Side Flow Interception

As shown in Figure 3, side flow interception is flow that is intercepted along the side of a grate inlet. The ratio of side flow intercepted to total side flow, R_s, is determined using the following equation:

$$R_s = \frac{1}{1 + \frac{K_s V^{1.8}}{S_x L^{2.3}}} \quad \text{(Equation 4C-2\_7)}$$

where:

K_s = Empirical Coefficient, 0.15.

V = Velocity of flow in the gutter, ft/s.

S_x = Cross slope, ft/ft.

L = Length of grate, ft. Use 1.90 ft, the length of the grate used with the SW-538 and SW-539.

Once R_f, E_o, and R_s are determined, solve for E using Equation 4C-2_3 and then solve for Q_i and Q_b using Equations 4C-2_1 and 4C-2_2 as illustrated in the following example.

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

The allowable bypass should not exceed 10%. If bypass exceeds 10%, a second intake is needed downstream of the first intake to reduce the amount of bypass. The second intake should also be spaced according to the rules defined earlier. The second intake may be joined to a common storm sewer outlet.

Chronology of Changes to Design Manual Section:

004C-002 Bridge End Drains for Capturing Stormwater Runoff

11/20/2018 Revised

Added SW-539 as intake bridge end drain.

7/31/2015 Revised

Revised information regarding placement of drains to note flumes should be located beyond the BTS and where post spacing is 6'-3" to minimize number of posts in the flume. Revised example problems 4C-2_1 and 4C-2_2 to reflect length of new BTS.

1/22/2015 Revised

Changed references to renumbered standards. Eliminated reference to voided 500-50. Deleted language in introduction that was repetitive and/or redundant.

9/13/2012 Revised

Changed the Title. Rewrote and reorganized for clarity. Added sentence discussing the extension of a tangent guardrail section past flumes.

9/30/2011 Revised

Update to reflect changes with RF-39. Changed to HEC-22 process for determining intake capacity.