Design Bureau

4A-8

Barrier Grate Intakes

Design Manual
Chapter 4
Drainage
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This section discusses the design processes for use with SW-547 triple barrier grate intakes and SW-548 and SW-549 single barrier grate intakes. The following concepts are addressed:

- Intercepted Flow.
- Bypass Flow.
- Efficiency of Barrier Grate Intakes on a Continuous Grade.
- Barrier Grate Intakes Located in Sags.

The processes are based on the procedures used in FHWA's *Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22*.

Other standard grate intakes (SW-501, SW-502, 503, 504, 505 and 506) are intended for use on the Secondary Road System and local streets, and should not be used on the Iowa DOT Primary Road System unless interagency agreements provide otherwise. When these grate intakes are used, design them according to the Iowa Statewide Urban Design and Specifications (SUDAS) design manual.

Intercepted Flow

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

$$Q_i = EQ \quad \text{(Equation 4A-8\_1)}$$

where:

Q_i = Intercepted flow, ft^3/s.

E = Intake efficiency.

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

Note: In areas where landscaping or trash may result in debris collecting at intakes, designers may want to consider including a reduction factor to intake calculations. SUDAS suggests 90% for intakes located on a continuous grade and 80% for intakes locate in a sag (i.e. multiply the results obtained from Equation 4A-8_1 by 0.90 for continuous grade or 0.80 for sag).

Bypass Flow

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

$$Q_b = Q - Q_i \quad \text{(Equation 4A-8\_2)}$$

where:

Q_b = Bypass flow, ft^3/s.

Q_i = Intercepted flow, ft^3/s.

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

Efficiency of Barrier Grate Intakes on a Continuous Grade

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 a barrier grate intake depends on:

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

Intake efficiency for barrier grate intakes is determined by the following equation:

$$E = R_f E_o + R_s(1 - E_o) \quad \text{(Equation 4A-8\_3)}$$

where:

E = Efficiency.

E_o = Frontal flow to total gutter flow ratio.

R_f = Frontal flow interception.

R_s = Side flow interception.

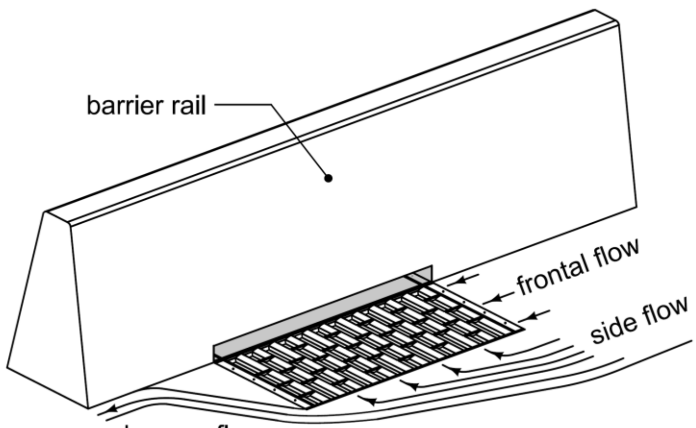

Figure 1: Grate intake flow definitions.

Barrier grate intakes on continuous grades should be placed to intercept no less than 50% of the minor storm design flow.

Frontal Flow to Total Flow Ratio

The ratio of frontal flow to total gutter flow for a uniform cross slope is determined using the following equation:

$$E_o = 1 - \left(1 - \frac{W}{T}\right)^{2.67} \quad \text{(Equation 4A-8\_4)}$$

where:

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

W = Width of grate, feet. Use 2.09, the width of the grate used with the SW-547, SW-548, and SW-549.

T = Total spread, feet.

Note: An adjusted frontal flow area ratio is required if a depressed gutter section wider than the grate is used. Refer to HEC-22.

Frontal Flow Interception

As shown in Figure 1 above, 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:

$$R_f = 1 - K_f(V - V_o) \quad \text{(Equation 4A-8\_5)}$$

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 (m/s). Use 8.3 ft/s, the splash-over velocity for the grate used with the SW-547, SW-548, and SW-549.

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

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

$$V = \frac{2Q}{T^2 S_x} \quad \text{(Equation 4A-8\_6)}$$

where:

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

T = Spread, feet.

S_x = Cross slope of pavement, ft/ft.

Side Flow Interception

As shown in Figure 1 above, side flow interception is flow that is intercepted along the side of a grate intake. The ratio of side flow intercepted to total side flow, R_s, is determined using the following equation:

$$R_s = \frac{1}{1 + \frac{K_s V^{1.8}}{S_x L^{2.3}}} \quad \text{(Equation 4A-8\_7)}$$

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 3.33 feet, the length of the grate used with the SW-547, SW-548, and SW-549.

Once R_f, E_o, and R_s are determined, solve for E using Equation 4A-8_3 and then solve for Q_i and Q_b using Equations 4A-8_1 and 4A-8_2 as illustrated in the following example.

Example Problem 4A-8_1, Evaluate an SW-547 On-grade Median Barrier Grate Intake

HEC-22 provides additional guidance on how to evaluate and compare the interception capacity of intakes on grade.

Barrier Grate Intakes Located in Sags

When a barrier grate intake is located at the low point, or sag, of a vertical curve, the following procedures should be used to evaluate the intake:

- 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 barrier grate 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). The process for calculating spread at the intake is discussed in more detail at the end of this section. If spread at the sag intake exceeds allowable encroachment, relocate or resize upstream intakes to reduce spread at the sag intake.

A barrier grate intake in a sag location operates as either a weir (gravity controls flow) or an orifice (pressure controls flow) depending on the depth of the water at the grate. Barrier grate intakes typically operate as a weir up to a depth of approximately 0.4 feet, at which point flow begins to transition to orifice flow. In order to determine if a barrier grate intake is operating under weir flow or orifice flow, Equations 4A-8_9 and 4A-8_11 should be solved for a given intercepted flow (Q_i). The equation resulting in the largest calculated depth determines the control type.

When performing weir and orifice flow calculations for barrier grate intakes, assume the top of the grate is set at the same slope as the median.

Weir Flow

Weir flow is flow over a horizontal obstruction controlled by gravity. To determine weir flow, the average depth across the grate is needed. Figure 2 shows how this is determined.

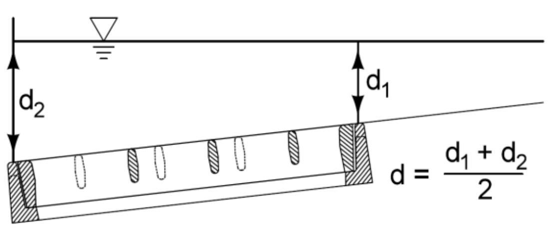

Figure 2: Average depth across the grate (d).

The capacity of a barrier grate intake operating as a weir is:

$$Q_i = C_w P d^{1.5} \text{ (Equation 4A-8\_8)}$$

where:

Q_i = Intercepted flow, ft^3/s.

C_w = Weir coefficient, 3.0.

P = Perimeter of the grate (disregarding the side against the curb, ft). Use 7.52 feet, the perimeter, disregarding the side against the curb, for the grate used with the SW-547, SW-548, and SW-549.

d = Average depth across the grate, feet.

Rearranging Equation 4A-8_8 and solving for d yields:

$$d = \left(\frac{Q_i}{C_w P}\right)^{2/3} \quad \text{Equation 4A-8\_9}$$

where:

d, Q_i, C_w, and P are as defined above.

Orifice Flow

Orifice flow is the flow of water into an opening that is submerged. Pressure forces control the flow. The capacity of a barrier grate intake operating as an orifice can be approximated as:

$$Q_i = C_o A_g \sqrt{2gd} + C_o h L \sqrt{2g\left(d - \frac{h}{2}\right)} \quad \text{(Equation 4A-8\_10)}$$

where:

Q_i = Intercepted flow, ft^3/s.

C_o = Orifice coefficient, 0.67.

A_g = Clear opening area of the grate, ft^2. Use 2.3 ft^2, the clear opening for the grate used with the SW-547, SW-548, and SW-549.

g = Gravity, 32.16 ft/s^2.

d = Depth at the curb, feet.

h = Height of opening. Use 0.25 feet, the height of the opening for the SW-547, SW-548, and SW-549.

L = Length of opening. Use 3.33 feet, the length of the opening for the SW-547, SW-548, and SW-549.

Solving for d requires a trial and error process.

Once depth has been determined, use the equation below to approximate spread at the intake:

$$T = \frac{d}{S_x} \quad \text{Equation 4A-8\_11}$$

where:

d = Depth determined by either equation 4A-8_9 or 4A-8_10, feet.

S_x = Cross slope, ft/ft.

Example Problem 4A-8_2, Barrier Grate Intake in a Sag

Chronology of Changes to Design Manual Section:

004A-008 Median Barrier Grate Intakes

6/26/2023	Revised Revised Figure 1 to show single slope barrier. Updated formatting in example problems.
11/26/2019	Revised Revise note related to Equation 4A-8_5: If Vo<V, then only a portion of the flow is intercepted.
9/30/2011	Revised Add in process for calculating capture for median barrier grate intakes.
10/29/2010	NEW New section. Material in old 4A-8 moved to 4A-10.