

Chapter 5 *Drainage of Highway Pavements*

5-1 Introduction

Roadway and structure pavement drainage shall be considered early in a project design, while the roadway geometry is still being developed, because the hydraulic capacity of gutters and inlets is determined by the longitudinal slope and superelevation of the pavement. The imperviousness of the roadway pavement will result in significant runoff from any rainfall event. To ensure safety to the traveling public, careful consideration must be given to removing the runoff from the roadway through structure pavement drainage facilities.

This chapter provides specific guidance on designing the drainage of highway pavements, including assessing site hydrology ([Section 5-2](#)), methods for draining highways ([Section 5-3](#)), gutter flow and determining inlet spacing ([Section 5-4](#)), roadside ditch design ([Section 5-5](#)), drainage structures and grate types and considerations ([Section 5-6](#)), and use of scupper barriers ([Section 5-7](#)). It concludes with a brief discussion of hydroplaning and hydrodynamic drag ([Section 5-8](#)).

The flatter the longitudinal profile is, the wider the shoulders need to be to accommodate increased spread width. However, for narrow shoulders, superelevation and/or widening transitions can create a gutter profile far different from the centerline profile. The hydraulic designer must carefully examine the geometric profile of the gutter to eliminate standing water created by these transitions. These areas shall be identified and eliminated to the greatest extent feasible. This generally requires geometric changes stressing the need for early consideration of drainage; otherwise, additional drainage structures will be required.

Improperly placed superelevation transitions can cause serious problems, especially on bridges. Inlets or other means must pick up gutter flow before the flow crosses to the other side of the pavement. The collection of crossover flow on bridges is complex as effective drain inlets are difficult to place within structure reinforcement. Bridges over waterways and wetlands pose water quality issues and downspouts shall not be allowed to discharge directly into waterways or wetlands without water quality treatment. Also, bridge drain downspouts have a history of plugging.

Inlets on bridges can usually be eliminated by considering drainage early in the design phase through geometric adjustments. Superelevation transitions, zero gradients, and sag vertical curves shall be avoided on bridges. Drainage design at bridge ends requires a great deal of coordination between the RHE, hydraulic designer, and State Hydraulics Office. All bridge drain designs shall be reviewed and approved by the State Hydraulics Office.

Multilane highways create unique drainage situations. The number of lanes draining in one direction shall be considered during the design phase. It may be necessary to complete a hydroplane analysis to assess risk. Coordinate with the RHE for additional requirements and guidance. "Part-time shoulder use" facilities shall be considered a lane. Contact the RHE for additional design guidance.

5-2 Hydrology

The Rational Method is required for determining peak flow rates for pavement drainage. This method is easy to use for pavement drainage design because the time of concentration is generally taken as 5 minutes. For more discussion on the Rational Method, see [Chapter 2](#). The design frequency and spread width are also significant variables in the design of pavement drainage.

5-3 Highway Drainage

When highways are built on fill, roadway drainage is usually allowed to flow uncollected to the sides of the roadway and over the side of the fill slope. Where erosion potential is low, this sheet flow of highway drainage does not present any problem to adjacent property owners, nor is it a threat to the highway fill.

Curbs or other minimizing erosion methods shall be included in projects as a means to protect the slopes from erosion until vegetation is established. Once sufficient vegetation is present to resist erosion and treat runoff, consideration shall be given to eliminating the curb in future overlay contracts as long as the runoff can be properly be dispersed with the use of an energy dissipater per [Section 3-4.7](#), if needed.

A ditch running parallel to the roadway generally drains highways in a cut section. These ditches are designed and sized in accordance with the criteria shown in [Section 5-5](#), including energy dissipators as needed per [Section 3-4.7](#).

5-3.1 Bridge Deck and Downstream End Drainage

The drainage design for bridge decks requires the coordination of the bridge designer, the State Hydraulics Office, and the hydraulic designer. The requirements of [Table 5-1](#) for allowable spreads also apply to bridge decks and along the bridge barriers. The bridge drainage calculations must be included in the hydraulic design report. Chapter 2 of the [Bridge Design Manual](#) has additional information on bridge deck drainage.

The downstream ends of bridges need special attention. If a storm sewer inlet system is not provided, a channel shall be provided at the end of any significant barrier or curb to collect and convey concentrated stormwater away from the bridge.

Bridges with approach slabs generally have an extruded curb beginning at the bridge end and terminating past the approach slab. The concentrated flow shall be directed into a low-risk erosion area. The end of curb shall be located a minimum of 10 feet from an approach slab to avoid approach slab settlement due to the concentrated flow. Inlets also shall be located a minimum of 10 feet downstream from an approach slab to provide adequate construction clearance during installation or future drainage structure replacement.

Bridges without approach slabs and curbing pose yet another set of problems. The concentrated flow runs off the bridge slab and flows off the fill slope or drains behind the wing walls and can compromise the integrity of the structure's geotechnical design. To mitigate this effect, all runoff shall be directed away from wing walls, fill slopes, and

embankments, so that no material is susceptible to erosion. Bridge drains are designed to reduce the amount of concentrated flows off a structure; however, bridge drains tend to get blocked or clogged from roadside debris during normal use. This clogging creates an excess of concentrated flow off the structure, which must be mitigated to prevent subgrade and roadside slope erosion. If the design includes a new bridge or buried structure over a waterway, the hydraulic designer shall coordinate drainage outfalls with the Stream Team (defined in [Chapter 7-1](#)) to ensure that the outfalls do not cause erosion or interfere with any habitat or stream features.

5-3.2 **Slotted Drains and Trench Systems**

Slotted drains and trench systems shall not be used for highway drainage.

5-3.3 **Drop Inlets**

Drop inlets shall not be used for pavement drainage.

5-4 **Gutter Flow and Inlet Spacing**

When stormwater is collected and carried along the roadside in a gutter, or next to a curb or barrier, the allowable top width of the flow prism (Z_d) is dependent on the road classification, as noted in [Table 5-1](#).

For design-bid-build projects, the hydraulic designer shall perform a gutter flow analysis for each construction staging plan of the project using the same allowable spread design criteria in [Table 5-1](#). Not meeting the criteria in [Table 5-1](#) is not considered a *Hydraulics Manual* deviation. The purpose of the required analysis is to identify areas of ponding water for the contractor to be aware of during the construction portion of the project. The gutter spread analysis shall be placed in the Temporary Erosion and Sediment Control (TESC) Plan, Abbreviated TESC Plan, or region equivalent document and shall have concurrence from the RHE.

For design-build projects, the design-builder shall perform a gutter flow analysis for each construction staging plan of the project using the same allowable spread design criteria in [Table 5-1](#). Not meeting the criteria in [Table 5-1](#) is not considered a *Hydraulics Manual* deviation. The purpose of the required analysis is to identify areas of ponding water for the design-builder to be aware of during construction of the project and for the design-builder to manage the risk accordingly. The gutter spread analysis shall be placed in the TESC Plan, Abbreviated TESC Plan, or region equivalent document and shall have concurrence from the RHE.

WSDOT uses gutter flow capacity and inlet spacing (on continuous grades and at sumps) equations from the FHWA's [HEC-22](#). WSDOT gutter flow calculations shall use a uniform gutter section per [HEC-22](#). The project shall only use uniform gutter sections as opposed to depressed gutter sections per [HEC-22](#). The following specific sections of [HEC-22](#) are used for gutter flow capacity and inlet spacing:

- 4.3.4: Flow in Sag Vertical Curves
- 4-4: Drainage Inlet Design
- 4-4.4: Interception Capacity of Inlets on Grade
- 4-4.5: Interception Capacity of Inlets in Sag Locations
- 4-4.6.2: Inlet Spacing on Continuous Grades
- 4-4.6.3: Flanking Inlets

The inlet spacing analysis shall take into account the effects of a shared-use path or bike lane that is already in existence or added as part of the project scope or as a requirement by Complete Streets.

For pedestrian safety considerations, the PEO shall assess the need to install an inlet near a marked pedestrian crossing even when the inlet spacing analysis or sag inlet analysis does not demonstrate the need for an inlet to satisfy flow spread requirements.

Table 5-1 Design Frequency and Allowable Spread

Road Classification		Design Frequency (years)	Allowable Spread (Z_d)
Interstate	<45 mph	10	Shoulder + 2 feet
	≥45 mph	10	Shoulder
	Underpasses and sag	50	Shoulder + 2 feet
Principal, minor arterial, or divided	<45 mph	10	Shoulder + 2 feet ^a
	≥45 mph	10	Shoulder
	Sag	50	Shoulder + 2 feet ^a
Collector and local streets	<45 mph	10	Shoulder + one-half driving lane ^b
	≥45 mph	10	Shoulder
	Sag	50	Shoulder + one-half driving lane ^b
Roundabouts (circulating roadway)	All design speeds	10	One-half driving lane ^b
Roundabouts entry lanes ^c	≤45 mph	10	Shoulder + one-half driving lane ^b
	Sag	50	
Dedicated turn lanes	All design speeds	10	Shoulder + one-half driving lane ^b
	Sag	50	
Ferry terminals	<45 mph	10	Shoulder + 2 feet
	>45 mph	10	Shoulder
	Sag	50	Shoulder + 2 feet
Part-time shoulder use	All design speeds	10	Maintain at least 10 feet of driving width within the multi-use shoulder that is free of water
	Sag	50	

Notes:

mph = miles per hour

- a. When the lane adjacent to the shoulder is less than 12 feet, there shall be a minimum of 10 feet that is free of water.
- b. For multi-lane roadways, only include the width of the driving lane adjacent to the shoulder or gutter.
- c. Entry lanes include exit, bypass, and slip lanes.

5-4.1 Capacity of Inlets on a Continuous Grade

The flow that is not intercepted by an inlet on a continuous grade and continuous run of curb and gutter is considered bypass flow and shall be added to the flow traveling toward the next inlet located downstream. The last inlet on a continuous run of curb (that is not a sag or flanking inlet) is permitted to bypass a maximum of 0.1 cfs for the 10-year MRI storm. The bypass flow rate of 0.1 cfs will not usually cause erosion or hydroplaning problems. The hydraulic designer shall analyze the spread width of flow after the last inlet on a continuous run of curb until the curb ends or the curb enters into a sump. The spread width analysis shall end at the 50-year WSEL determined in the sag analysis. The spread width shall be compliant with [Table 5-1](#). The spread width requirement also applies to the end of the curb or barrier even without an inlet.

A bypass flow more than 0.1 cfs at the curb or barrier end can be allowed with an approved deviation. To protect the roadside slope downstream of the bypass flow, employ erosion protection measures such as installation of rocks or filter blanket for energy dissipation. Coordinate with the RHE on the slope protection design.

In urban situations, with much lower speeds than noted in [Table 5-1](#), it may not be feasible to use the allowable spread in the *Hydraulics Manual*. In this situation, the hydraulic designer shall first consider innovative solutions such as increasing the slope of the gutter (e.g., from 2 to 5 percent), depressing the inlet, or using a combination curb opening and grate inlet. If it is still not possible to meet the allowable spread in [Table 5-1](#), the hydraulic designer shall consider the safety of the intersection, how icing and hydroplaning could affect a driver at this location, and how quickly ponding from the rainfall event will shed off the roadway. The hydraulic designer shall work with the RHE and traffic engineer to develop a solution that best suits the project location and keeps the roadway safe. If, after considering all possible scenarios, it is determined that the spread of runoff is not safe at this location, then more drastic measures such as revising the project scope or seeking more funding may be necessary.

In addition to the requirements above, in areas where a superelevation transition causes a crossover of gutter flow, the amount of flow calculated at the point of zero superelevation shall be limited to 0.1 cfs. The hydraulic designer will find, by the time the roadway approaches the zero point, that the calculated spread (Z_d) will become very wide; because of this, the new inlet shall be placed upstream of the zero point. The flow width criteria will be exceeded at the crossover point, even when the flow is less than 0.1 cfs.

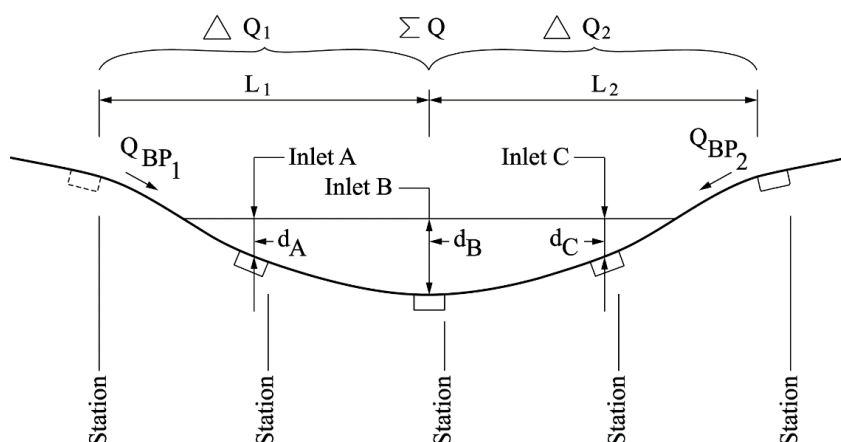
Roundabouts are typically designed to accommodate speed limits of 35 miles per hour (mph) or less; generally, the posted advisory speed limits are between 15 and 25 mph. Potentially, runoff from a roundabout is diverted to multiple different directions and, if it is possible, runoff from the upstream roadway shall be captured so that flow bypass shall be 0.1 cfs or less flowing through the roundabout area. If runoff within a roundabout area is less than 0.1

cfs, no inlets would be necessary. Curb openings could be used to alleviate ponding water at roundabouts. The inlet spacing spreadsheet may not be fully accurate to calculate the flow spread at roundabouts because runoff at a roundabout could flow off in multiple directions. The hydraulic designer shall coordinate with the RHE and Maintenance to address all possible drainage issues expected with design and construction of the roundabout.

5-4.2 Capacity of Inlets at Sag Locations

By definition, a sag is any portion of the roadway where the profile changes from a negative grade to a positive grade. Inlets at sag locations perform differently from inlets on a continuous grade and therefore require a different design criterion. Theoretically, inlets at sag locations may operate in one of two ways: (1) at low ponding depths, the inlet will operate as a weir, or (2) at high ponding depths (5-inch depth above the grated inlet and 1.4 times the grate opening height for combination inlets), the inlet will operate as an orifice. It is very rare that ponding on a roadway will become deep enough to force the inlet to operate as an orifice. As a result, this section focuses on inlets operating as a weir with flow spilling in from the three sides of the inlet that are exposed to the ponding.

Figure 5-1 Sag Analysis



Where:

Inlet B = sag inlet

Inlet A and Inlet C = flanking inlets

$$d_A = d_C = 0.5d_B$$

Inlets at sag locations can easily become plugged with debris; therefore, it is good engineering practice to provide some type of relief. This relief can be accomplished by locating flanking inlets, on either side of the sag inlet, so they will operate before water exceeds the allowable spread into the travel lane at the sag. Flanking inlets shall be located so that the depth of water at the flanking inlets ponds to half the allowable depth at the sag (or $0.5d_{B \text{ allowable}}$); see Figure 5-1 above. Flanking inlets are required only when the sag is located in a depressed area and water has no outlet except through the system. A tall curb, traffic barrier, retaining wall, or other obstruction that prevents the runoff from flowing off of the traveled roadway generally represents this condition because it contains this ponded area. However, if runoff is capable of overtopping the curb and flowing away from the

roadway before exceeding the allowable sag limits noted in [Table 5-1](#) above, flanking inlets are not required. With this situation, there is a low potential for danger to the drivers of the roadway if the inlets do not function as designed. Before flanking inlets are removed in this situation, the hydraulic designer shall consider the potential damage of water going over the curb. The hydraulic designer shall use the guidelines provided in this section for locating flanking inlets. If the hydraulic designer suspects that flanking inlets are unnecessary, consult the RHE earlier in the design.

Any section of roadway located in a sag shall be designed according to the criteria described below and further detailed in the WSDOT Sag Worksheet located on the [State Hydraulics Office web page](#).

Once an inlet has been placed in a sag location, the total actual flow to the inlet can be determined as shown below. q_{Total} must be less than $Q_{allowable}$, as described in Equation 5-1.

$$Q_{TOTAL} = Q_{BP1} + Q_{BP2} + \Delta Q_1 + \Delta Q_2 \quad (5-1)$$

where:

$Q_{BP1\&2}$ = bypass flow from the last inlet on either side of a continuous grade

$\Delta Q_{1\&2}$ = runoff that is generated from last inlet on either side of the continuous grades; see [Figure 5-1](#).

The effective perimeter of the flanking and sag inlets can be determined using the lengths and widths for various grates provided in [Table 5-2](#). This would be the sum of the three sides of the inlet where flow spills in and where ponding would occur. Only the sides that receive gutter flow (see [Figure 5-1](#)) would be assumed to be 50 percent plugged (except for the Combination Inlet, Standard Plan B-25.20-02, which shall be considered 0 percent plugged). This will be the grate widths (and not grate length) that are reduced by 50 percent. The total available perimeter that would receive flow is represented by Equation 5-2. This adjustment is in addition to reducing the perimeter to account for the obstruction caused by the bars in the grate. [Table 5-2](#) lists perimeters for various grates with reductions already made for bars.

$$P_n = L + 2(W/2) \quad (5-2)$$

where:

P_n = effective perimeter of the inlet “n” (sag or flanking inlet)

L = length of the inlet “n” from [Figure 5-1](#)

W = width of the inlet “n” from [Figure 5-1](#)

When using a Combination Inlet, the width of the inlet, W , in Equation 5-2 shall not be divided by 2.

The allowable capacity of an inlet operating as a weir, that is the maximum $Q_{allowable}$, can be found depending on the inlet layout as described below:

When there is only a single inlet at the sag (no flanking inlets), Equation 5-3 shall be used:

$$Q_{allowable} = C_W \times P \times d_{B allowable}^{1.5} \quad (5-3)$$

where:

C_W = weir coefficient, 3.0 for English Units

P = effective perimeter of the grate in feet

$d_{B allowable}$ = maximum depth of water at the sag inlet in feet

Flanking inlets shall be located laterally from the sag inlet at a distance equal to that required to produce a depth of $0.5d_{B allowable}$. $Q_{allowable}$ can be simplified to Equation 5-4 below. Equation 5-4 assumes that all grates are the same size and are oriented the same (all rotated or not rotated):

$$\Sigma Q = C_W \times P \times [2(0.5d_B)^{1.5} + (d_B)^{1.5}] \quad (5-4)$$

where:

d_B = depth of water at the sag inlet (ft)

In some applications, locating inlets so water ponds to $0.5 d_{B allowable}$ is too long of a distance (generally in cases with long flat slopes). The PEO shall instead calculate $Q_{allowable}$ using Equation 5-5 and check that the spread width of surface water does not exceed those noted in [Table 5-1](#).

$$Q_{allowable} = C_W P [d_A^{1.5} + d_B^{1.5} + d_C^{1.5}] \quad (5-5)$$

where:

d_n = depth of water at the flanking inlets and the sag (ft)

The actual depth of water over the sag inlet can be found with Equation 5-6 and must be less than $d_{B allowable}$. If, however, the inlets are not located at $0.5 d_{B allowable}$, Equation 5-6 will need to be modified to reflect this.

$$d_B = \left[\frac{q_{Total}}{(C_{WA}P_A 0.3536 + C_{WB}P_B + C_{WC}P_C 0.3536)} \right]^{\frac{2}{3}} \quad (5-6)$$

where:

q_{Total} = actual flow into the inlet in cfs

C_W = weir coefficient, 3.0

P_N = effective grate perimeter, in feet; see [Table 5-2](#)

d_B = actual depth of ponded water at the inlet in feet

After the analysis is completed, the PEO shall verify that the allowable depth and allowable flow have not been exceeded ($Q_{allowable} > q_{Total}$ and $d_{B allowable} > d_B$). If both the allowable

depth and allowable flow are greater than the actual, then the maximum allowable spread will not be exceeded and the design is acceptable. If the actual depth or flow is greater than the allowable, then the runoff will spread beyond the maximum limits and the design is not acceptable. In this case, the PEO shall add flanking inlets or use different inlets that have larger openings. Additional flanking inlets shall be placed close to the sag inlet to increase the flow interception and reduce the flow into the sag.

5-5 Roadside Ditch Design Criteria

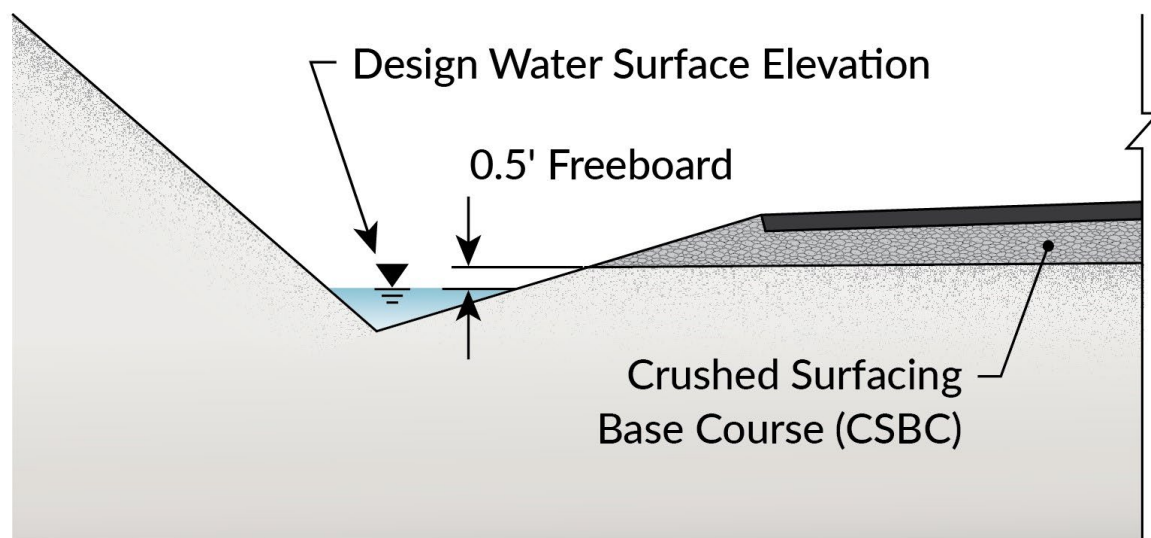
Roadside ditches are generally located alongside uncurbed roadways with the primary purpose of conveying runoff away from the roadway. Ditches shall be designed to convey the 10-year recurrence interval with 0.5 foot of freeboard (from the ditch design WSEL to the bottom of the pavement subgrade or ditch spill) and a maximum side slope of 2H:1V (Figure 5-2). Side slopes of 4H:1V or flatter are desirable; see WSDOT [Design Manual Exhibit 1239-4](#) for requirements for slopes steeper than 4H:1V.

The preferred cross section of a ditch is trapezoidal; however, a “V” ditch that meets the design requirements can also be used where ROW is limited. In those cases where the grade is flat, preventing adequate freeboard, the depth of channel shall still be sufficient to remove the water without saturating the subgrade shoulder.

If the freeboard is less than 0.5 foot, a deviation is required. Justification by the hydraulic designer including coordination with the RHE and Region Maintenance to allow the installation of an impermeable ditch liner or an underdrain system underneath the ditch to prevent saturation of the roadway subgrade.

To maintain the integrity of the channel, ditches are usually lined. See [HDS-4](#) and [HEC-15](#) for additional guidance.

Figure 5-2 Drainage Ditch Detail



Ditches should not be confused with biofiltration swales. In addition to collecting and conveying drainage, biofiltration swales provide runoff treatment by filtering out sediment. (See the [Highway Runoff Manual](#) for design guidance for biofiltration swales.) Roadside ditches are to be designed such that the integrity or geometry of the roadway is not compromised.

A drainage inlet can be placed at a low point or at the end of the ditch to convey the water to its intended discharge point. Ditch inlets operate as weirs under low water depth conditions or as orifices at greater depths. Orifice flow begins at depths dependent on the grate size. Flows in a transition stage could yield water depths fluctuating between weir and orifice control.

Ditch inlets are more susceptible to clogging from sediments and debris. Ensure that the grate is adequately sized to satisfy the ditch freeboard requirement or prevent water from spilling over onto the roadway. Contact the RHE for ditch inlet analysis.

5-6 Drainage Structures

Many variables are involved in determining the hydraulic capacity of an inlet structure including depth of flow, grade, superelevation, and placement. The depth of flow next to the curb is a major factor in the interception capacity of an inlet structure. Slight variations in grade or superelevation of the roadway can also have a large effect on flow patterns, and placement of an inlet can result in dramatic changes in its hydraulic capacity. These variables can be found by collecting the following information prior to starting an inlet design: plan sheets, road profiles, curb/barrier profiles, cross sections, superelevations, and contour maps.

Drainage structures shall not be placed directly in the wheel path. While many are traffic rated and have lockdown grates, the constant pounding of traffic causes unnecessary stress and wear on the structure, frame, and grate. Inlets shall be installed at the curb/barrier face and at the proper elevation relative to the pavement. The structure offset shown in the plans shall be to the center of the grate, not to the center of the structure, to ensure that the grate is located along the curb face. There shall be no gap between the structure and the curb/barrier face as this would lead to other issues.

Debris floating in the gutter tends to collect at the inlets, plugging part or all of the grate opening. Inlet locations on a continuous grade are calculated using the full width of the grate with no allowance needed for debris. Inlets located in a sag are analyzed with an allowance for debris blocking half of the grate. Areas with deciduous trees and large pedestrian populations are more prone to debris plugging. Bark from logging operations and agricultural areas is also known to cause debris problems. These areas may require additional maintenance.

5-6.1 Inlet Structure Types

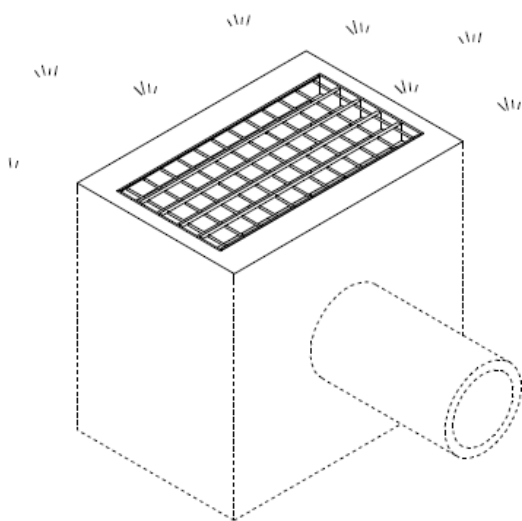
WSDOT uses grate inlets, catch basins, and manholes to capture runoff for WSDOT projects. Each inlet structure type has different variations and advantages for use in certain

situations. On top of each inlet structure type is a grate that allows water to flow into the structure. This section briefly describes each structure type.

5-6.1.1 Grate Inlet Type 1 Structure: Standard Plan B-35.20-00

Grate inlet Type 1 structures are cast-in-place and use a sump by placing the outlet pipe's invert elevation higher than the bottom of the structure (Figure 5-3). This allows suspended sediment within the water to settle and reduce turbidity prior to entering the downstream stormwater system. Type 1 inlet structures require more construction because they are cast-in-place; however, this allows the hydraulic designer to tie into existing stormwater infrastructure without modifying the hydraulic gradient.

Figure 5-3 Grate Inlet Type 1 Structure

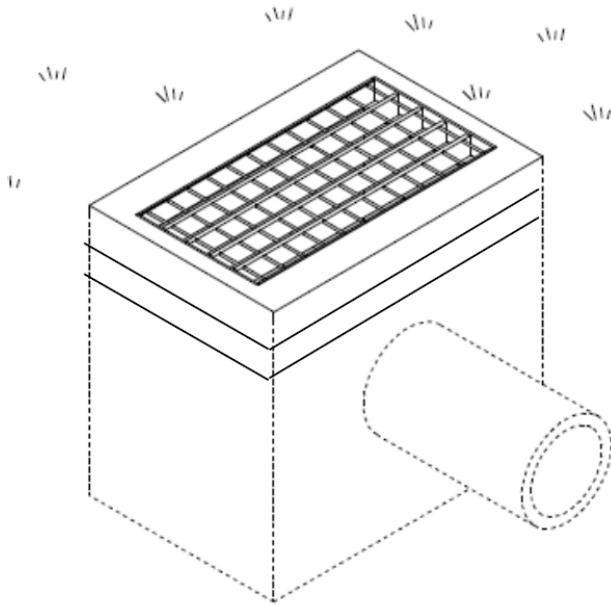


5-6.1.2 Grate Inlet Type 2 Inlet Structure: Standard Plan B-35.40-00

Grate inlet Type 2 structures are constructed using sections of precast reinforced concrete (Figure 5-4). These precast sections can be stacked to meet the required height, thus reducing construction time and cost. This inlet structure is similar to grate inlet Type 1 in that they both have an invert elevation higher than the structure bottom. This creates a sump that allows suspended sediment to settle prior to entering the downstream

stormwater system. The grate inlet Type 2 shall be used in areas where existing infrastructure is easy to tie into.

Figure 5-4 Grate Inlet Type 2 Structure



5-6.1.3 Catch Basins

Catch basins are designed to retain sediment and debris transported by stormwater into a storm sewer system. Catch basins include a sump for collection of sediment and debris. Catch basin sumps require periodic cleaning to be effective and may become an odor and mosquito nuisance if not properly maintained. Catch basins are used to link long runs of storm sewer pipes and to help change directions of the storm sewer system. See the following:

- Standard Plan B-5.20-03 Catch Basin Type 1
- Standard Plan B-5.40-02 Catch Basin Type 1L
- Standard Plan B-5.60-02 Catch Basin Type 1P (for Parking Lot)
- Standard Plan B-10.20-02 Catch Basin Type 2
- Standard Plan B-10.40-02 Catch Basin Type 2 with Flow Restrictor
- Standard Plan B-10.70-02 Catch Basin T-PVC

Within WSDOT ROW, a T-PVC catch basin can be used as an inlet or as a junction box in locations not subject to traffic loading such as ditches, landscaped or vegetated areas, and separated pedestrian paths. The use of a T-PVC catch basin requires the approval of the State Hydraulics Office through the RHE. The RHE shall not recommend approval without first getting concurrence from Region Maintenance. If approved for installation, T-PVC catch basin shall not be connected to a drainage system that is fully or partially installed within a roadway, sidewalk adjacent to the roadway, and the paved surface of a rest area.

5-6.1.4 Manholes

Similar to catch basins, manholes are to convey stormwater as a part of a storm sewer system. They are used to also change the direction of a storm sewer system. Manholes do not have a sump. They can have solid locking lids that block water from entering the manhole. They can also be configured to have a grate to allow water to flow into the manhole. See the following:

- Standard Plan B-15.20-01 Manhole Type 1
- Standard Plan B-15.40-01 Manhole Type 2
- Standard Plan B-15.60-02 Manhole Type 3

5-6.1.5 Concrete Inlet: Standard Plan B-25.60-02

A concrete inlet is used when a sump to catch sediments is not desired and the maximum inside pipe diameter is less than or equal to 15 inches.

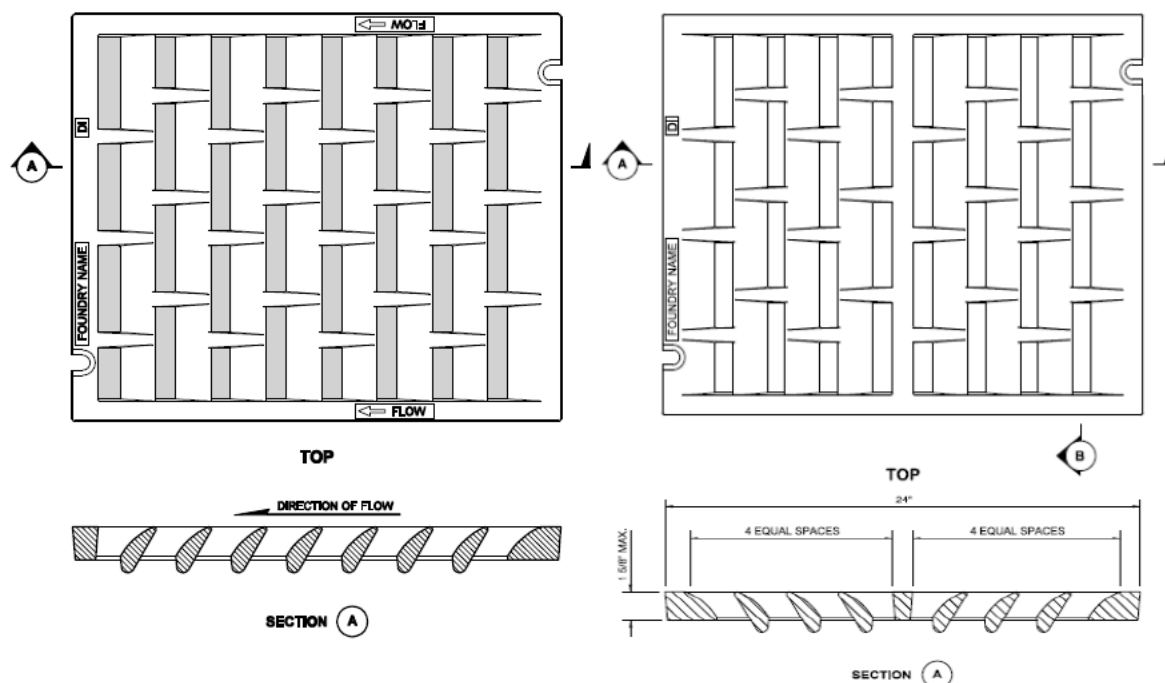
5-6.2 Grate Types

Grates are an essential component in ensuring the efficiency of a drainage system. The following grates (except the rectangular herringbone grate) shall be used for new construction, where applicable.

5-6.2.1 Rectangular Vaned Grate: Standard Plan [B-30.30-03](#) and Rectangular Bi-Directional Vaned Grate: Standard Plan [B-30.40-03](#)

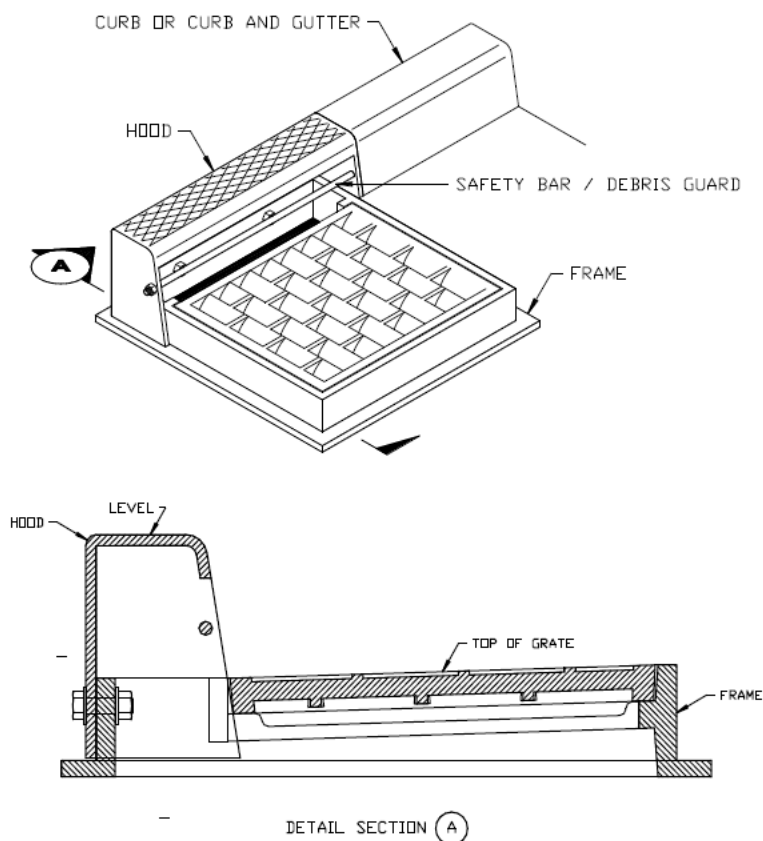
The vaned grate has a higher capacity for passing debris and shall be used in place of the herringbone grate in all new installations. Installation of the vaned grate is critical as the grate is directional. If installed backward the interception capacity is severely limited. The rectangular bi-directional vaned grate shall be used at all sump locations. [Figure 5-5](#) depicts a rectangular vaned grate and a rectangular bi-directional vaned grate.

Figure 5-5 Rectangular Vaned Grate and Rectangular Bi-Directional Vaned Grate



5-6.2.2 Combinations Inlet: Standard Plan B-25.20-02

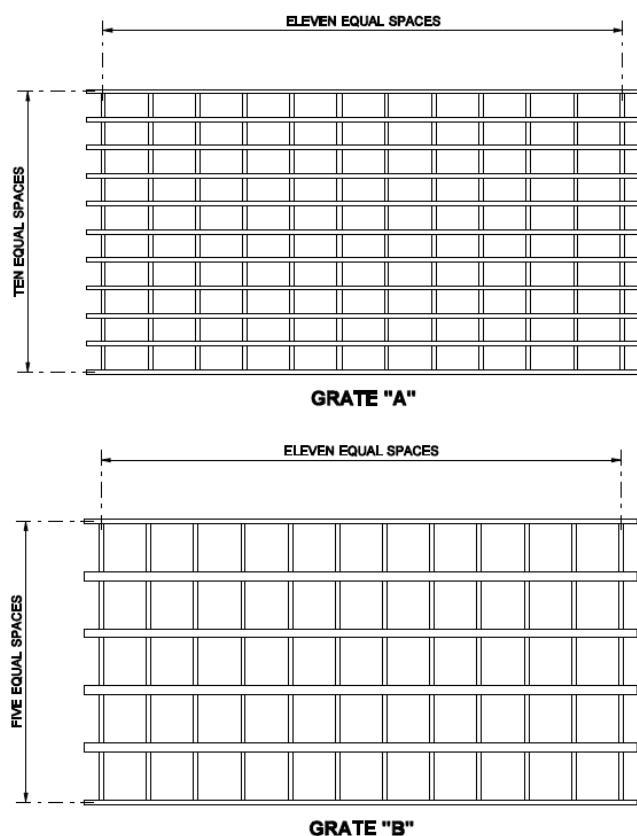
The combination inlet is a vaned grate on a catch basin with a hooded curb cut area (Figure 5-6). The vaned grate is debris efficient, and, if the grate does become clogged, the overflow goes into the hooded opening. These inlets are useful for sag condition installations, although they can also be effective on continuous grades. The interception capacity of a combination inlet is only slightly greater than with a grate alone. Therefore, the capacity is computed neglecting the curb opening and the PEO shall follow the same analysis as for a vaned grate alone (see Standard Plan B-30.30-03).

Figure 5-6 Section and Isometric View Combination Inlet Frame, Hood, and Vaned Grate

5-6.2.3 Welded Grates for Grate Inlet, Grate A and Grate B: Standard Plan B-40.20-00

Both welded grates (Types A and B) have large openings that can compensate for debris problems (Figure 5-7); however, there are limitations in their usage. Because of structural failure of Grates A and B, neither of these grates can be installed in heavy traffic areas where wheel loads will pass directly over. Grate B has large openings and is useful in ditches or non-paved median locations, in areas where there is no pedestrian or bicycle traffic. Grate A can be used anywhere Grate B is used as well as at the curb line of a wide interstate shoulder. Grate A may occasionally be subject to low-speed traffic or parked on, but it cannot withstand repeated interstate loading or turning vehicles.

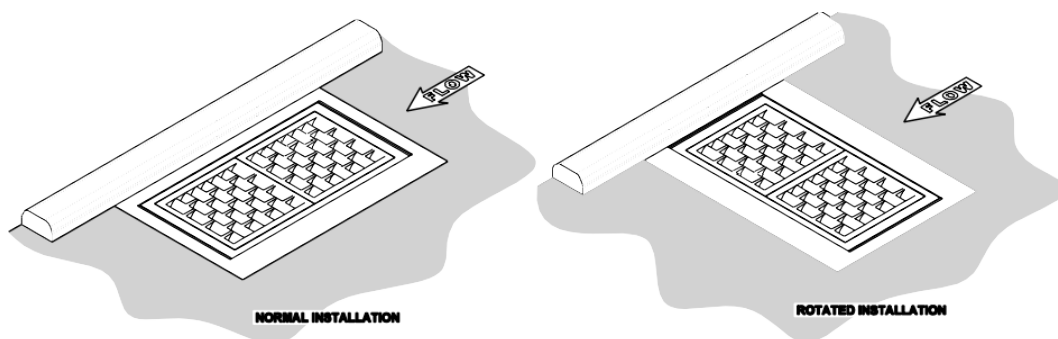
Figure 5-7 Grates A and B



5-6.2.4 Frame and Dual Vaned Grates for Grate Inlet: Standard Plan B-40.40-02

Standard Plan B-40.40-02 has been tested in H-25 loading and was determined compatible with heavy traffic installations. This frame and double-vaned grate shall be installed in a Unit H on top of a grate inlet Type 2 (Figure 5-8). The frame and vaned grates may be used in either new construction or retrofit situations. When used in areas of highway speeds, lockdown grates shall be specified. This grate can also be rotated 90 degrees to increase the flow interception capacity.

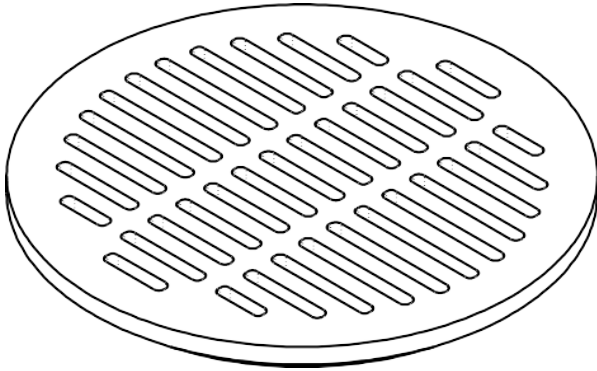
Figure 5-8 Frame and Vaned Grates for Installation on Grate Inlet



5-6.2.5 Circular Grate or Standard Plan B-30.80-01

Circular grates are intended for use with dry wells, see [Standard Plans](#) B-20.20-02 and B-20.60-03 for details ([Figure 5-9](#)). Install with circular frames (rings) as detailed in Standard Plan B-30.70-04.

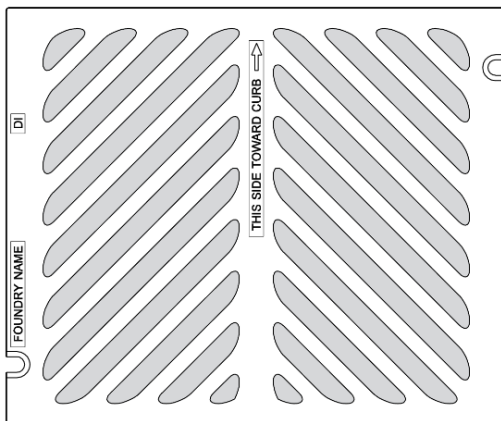
Figure 5-9 Circular Grate



5-6.2.6 Rectangular Herringbone Grate: Standard Plan B-30.50-03

Herringbone grates ([Figure 5-10](#)) shall not be used on WSDOT projects. Replacement of existing herringbone grates shall be considered during preservation projects. Historically, use of the vaned grate was limited because of cost considerations. The cost difference now is minimal; the vaned grate is bicycle safe and is hydraulically superior under most conditions.

Figure 5-10 Herringbone Pattern



Grate inlet properties are summarized in [Table 5-2](#).

Table 5-2 Properties of Grate Inlets

Standard Plan	Description Properties of Grate Inlets	Continuous Grade ^a		Sag Location ^b Perimeter Flows as Weir	
		Grate Width (ft)	Grate Length (ft)	Width (ft)	Length (ft)
B-30.50-03 ^c	Rectangular herringbone grate	1.67	2.0	0.69	0.78
B-30.30-03 or B-30.40-03 ^d	Vaned grate for catch basin and inlet	1.67	2.0	1.31	1.25
B-25.20-02 ^b	Combination inlet	1.67	2.0	1.31	1.25
B-40.20-00	Grate inlet Type 1 (Grate A or B ^e)	2.01	3.89	1.67	3.52
		3.89 ^f	2.01 ^f	3.52	1.67
B-30.80-01	Circular grate	1.52		2.55 ^g	
B-40.40-02	Frame and dual vaned grates for grate inlet Type 1 or Type 2	1.75 ^h	3.52 ^h	1.29	2.58
		3.52 ^f	1.75 ^f	2.58 ^f	1.29 ^f

Notes:

- Inlet widths on a continuous grade are not reduced for bar area or for debris accumulation.
- The perimeters and areas in this portion of the table have already been reduced for bar area. These values shall be cut in half when used in a sag location as described in [Section 5-6.2](#), except for the combination inlet, [Standard Plans](#).
- Shown for informational purposes only (see [Section 5-6](#)).
- For sag conditions, inlets shall use a bidirectional vaned grate (as shown in [Standard Plans](#)).
- Type B grate shall not to be used in areas of pedestrian or vehicular traffic (see [Section 5-6](#) for further discussion).
- Rotated installation (see [Standard Plans](#)).
- Only the perimeter value has been provided for use with weir equations.
- Normal installation (see [Standard Plans](#)).

5-7 Scupper Barrier

Scupper barrier designs are available for both Type F (Standard Plan C-60.15) and Single-Slope (Standard Plan C70.15) concrete barriers. See [Design Manual 1610.06\(1\)\(e\)](#) for more information.

Scuppers in median barriers shall not be used in the following situations:

- Passing runoff from one side of a median barrier to a drainage structure or curb-and-gutter section on the other side (downstream) of the median barrier
- Passing runoff through the median barrier so that the runoff continues to flow across highway lanes on the other side (downstream) of the median barrier

For the above scenarios, flows shall be captured by placing inlets on each side of the median barrier as shown in Standard Plan B-95.20-02, allowing runoff to pass between the structures in a pipe.

In locations where a scupper barrier is used specifically to pass stormwater to flow across highway lanes on the other side of the median barrier, the scuppers shall be analyzed for potential plugging and consider site-specific details such as accumulation of debris or

maintenance sand as well as impacts or risk associated with snow and ice obstructing the passage of stormwater. In sag profile locations, the project shall consider secondary means of removing stormwater, should scuppers be plugged, by installation of drainage structures. To analyze the hydraulic capacity of scuppers or curb-opening inlets, refer to Section 7-2.2 in FHWA's [HEC-22](#) for guidance.

Contact the RHE to determine the appropriate level of consideration and analysis appropriate for a specific project or design.

5-8 Hydroplaning and Hydrodynamic Drag

FHWA's [HEC-22](#) provides an in-depth discussion on the factors that contribute to hydroplaning on roadways and offers rules of thumb to help reduce hydroplaning.