Chapter 8
Inlets

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1.0 Introduction

Criteria and methodology for design and evaluation of storm sewer inlets are presented in this chapter. The review of all planning submittals will be based on the criteria presented herein.

2.0 General

2.1 Function of Inlets

The primary purpose of storm drain inlets is to intercept excess surface runoff and convey it into a storm drainage system, thereby reducing or eliminating surface flooding. Roadway geometry often dictates the location of street inlets along the curb and gutter. In general, inlets are placed at all low points (sumps), along continuous grade curb and gutter, at median breaks, intersections and crosswalks. The spacing of inlets along a continuous grade segment of roadway is governed by the allowable spread of flow. See further details of allowable spread of flow in Chapter 7, Street Drainage.

2.2 Types of Inlets

There are four major types of inlets approved for use within the right-of-way:

- Denver No.14 curb opening inlets,
- CDOT Type R curb opening inlets,
- Denver No. 16 combination inlets, and
- CDOT Type C area inlets.

Other types of inlets may be acceptable with review and approval of the City Engineer. Inlets are further classified as being on a "continuous grade" or in a "sump." The term "continuous grade" refers to an inlet placed in a curb and gutter or roadside ditch or swale so that the grade of the street or ditch has a continuous slope past the inlet and, therefore, water ponding does not occur at the inlet. A sump condition exists whenever an inlet is located at a low point, resulting in ponding water.

Photograph 8-1. Inlet in sump

Photograph 8-2. Inlet on grade

2.3 General Design Guidelines

The following guidelines shall be used when designing inlets along a street section:

- Design and location of inlets shall take into consideration pedestrian and bicycle traffic. All inlet grates shall be pedestrian and bicycle-safe.

- Design and location of inlets shall be in accordance with the allowable spread and depth criteria established in Chapter 7, Street Drainage.

- Maintenance of inlets shall be considered when determining inlet locations. The slope of the street, the potential for debris and ice accumulation, the distance between inlets and/or manholes, and other factors shall be considered. Maintenance access shall be provided for all inlets.

- To avoid potential damage from large vehicles driving over the curb return and interference with pedestrian traffic, inlets shall not be placed in the curb return radii.

- Selection of the appropriate inlet grate shall be based on a number of factors, including, but not limited to, the adjacent land use and potential for pedestrian or bicycle traffic, the potential for debris and ice accumulation, visibility, expected loading from vehicles, and hydraulic capacity.

- In many cases, inlets are necessary at grade breaks, where street or ditch grades change from steep to relatively flat, because of the reduced conveyance capacities. Additionally, it is common for icing or sediment deposition to occur with nuisance flows in reaches where grades are relatively mild.

2.4 Nuisance Flows

The location of inlets is important to address the effects of nuisance flows and avoid icing. Nuisance flows are urban runoff flows that are typically most notable during dry weather and come from sources such as over-irrigation and snow melt. Nuisance flows can pose problems such as algae growth and ice in both warm and cold weather months. While it is possible to minimize nuisance conditions through design, irrigation practices in the summer and snow and ice removal in the winter make it very difficult to eliminate nuisance flows entirely.

In the summer months, over-irrigation of lawns and landscaping can be a major contributor to nuisance flows. Car washing is another summertime cause of excess flows. In homes with poor or improper drainage, excessive sump pump discharge may also contribute.

In winter months, snow and ice melt are the primary causes of nuisance flows and associated icing problems (see Photograph 8-3). Discharges from sump pumps to the sidewalk and/or street can also lead to icing.

Flows over sidewalks and driveways due to summertime nuisance flows can cause algae growth, especially if fertilizer is being used in conjunction with over-irrigation. Such algae growth is both a safety issue due to increased falling risk resulting from slippery surfaces and an aesthetic issue. Nuisance flows laden with fertilizer, sediment, and other pollutants also have the potential to overload stormwater BMPs, which are generally designed for lower pollutant concentrations found in typical wet weather flows. Additionally, continually moist conditions can create an environment where fecal indicator bacteria thrive, either becoming an on-going dry weather source of bacteria loading or a source that is subsequently mobilized under wet weather conditions, such as in the case of biofilm soughing.

Snow and ice melt can re-freeze on streets and sidewalks, where it poses hazards to the public and is difficult to remove. Often, icing is most significant on east-west streets that have less solar exposure in the winter. Trees, two-story houses, fences and topography can also create shady areas where ice accumulates. Snow and ice may also clog drains and inlets, leading to flooding. Snowmelt has been found to have high pollutant concentrations, which can stress treatment facilities. Because many of the issues related to winter nuisance flows are beyond the control of municipalities (especially in areas that area already developed), identifying problem areas and planning for maintenance is often the most effective practice for minimizing nuisance conditions.

Photograph 8-3. The location of inlets is important to address the effects of nuisance flows.

Public education about proper irrigation rates and irrigation system maintenance (e.g., broken or misaligned sprinkler heads) can help reduce occurrences of excess flow over sidewalks. Additionally, homeowners can be encouraged to direct downspout and sump pump discharges to swales, lawns, and gardens (keeping away from backfill zones) where water can infiltrate. Algae growth is encouraged by the presence of nutrients, which can come from fertilizer and organic matter. Algae growth can be reduced by educating homeowners on proper application of fertilizer (both rates and timing of application), using phosphorus-free fertilizer, and sweeping up dead leaves and plant matter on impervious surfaces. Whenever feasible, impervious surfaces should be swept rather than sprayed down with water. When power-washing of outdoor surfaces is conducted, the Colorado Department of Public Health and Environment (CDPHE) requirements must be followed.

Table 8-1 provides the various sources, problems and avoidance strategies associated with nuisance flows.

Table 8-1. Nuisance Flows: Sources, Problems and Avoidance Strategies

	Warm Weather	**Cold Weather**
Examples/Sources	• Over-irrigation of lawns and landscaping • Car washing • Sump pump discharge	• Snowmelt • Ice melt • Sump pump discharge (freezing)
Problems	• Poor water quality • High nutrient concentration • High pollutant concentration • Algae growth	• Icing leading to inlet blockage and flooding • Ice on streets and sidewalks • High pollutant concentrations
Avoidance Strategies	• Irrigation, drainage, and fertilizer education • Proper drainage design • Minimization of directly connected impervious area • Sidewalk chase drains	• Inlet and sidewalk maintenance • Prompt and frequent snow and ice removal • Consider additional inlets in strategic locations • Shoveling snow onto grassy areas away from streets and inlets • Locate inlets and sumps away from shaded areas

Homeowners, business owners, maintenance and city workers should be educated and encouraged to use proper snow and ice removal techniques. These include removal of snow and ice promptly and frequently, keeping drains and gutters clear, and placing shoveled snow onto lawns or grassy areas.

Locating inlets in areas where water can be intercepted before it accumulates or slows down and has the opportunity to freeze in the most effective way to minimize icing from the design perspective. To the extent practical, locate inlets away from areas that will be heavily shaded during winter months (in particular the north side of buildings) to help prevent ice build-up and allow proper flow. For areas where shading is unavoidable, consider providing additional inlet capacity at strategic locations. For example, if a street with a southern exposure will drain to an east-west street that is shaded, having additional inlet capacity at the intersection may be advisable, especially if the flow is intended to turn and follow the east-west street. It is also important to consider potential future vegetative growth when evaluating shading effects. Although trees may be small and have little canopy when originally planted, they will grow and ultimately provide tree canopy far greater than when initially planted. Tree canopy may vary seasonally, depending on the tree species (i.e., “solar shade trees” lose their leaves in the fall, so less canopy is present in the winter). Ultimately, even with careful placement of inlets and avoidance of shading to the extent practical, icing in some locations will still likely occur due to shading from buildings, fences and other improvements on private property, and maintenance to remove accumulated ice will be necessary. For areas that are already developed, maintenance (i.e., snow and ice removal) to control icing from nuisance flows is the primary method to address icing, and this is an ongoing part of the City’s street maintenance programs.

During all times of the year, it is important that nuisance flows can be properly conveyed to storm drain outlets. Ponding on streets and sidewalks promotes both ice and algae growth. Sidewalk chase drains may be appropriate to aide in proper drainage of nuisance flows (for sump pump discharges, in particular); however, sidewalk chases can be problematic in terms of clogging and icing if they are located in areas with heavy loads of gross solids (leaves, grocery bags, Styrofoam, etc.) or if they are located in areas with poor solar exposure in winter months.

For more information on nuisance flows, multiple Colorado-based publications are available to provide guidance related to landscape management practices and snow and ice removal. Representative resources include:

- USDCM Volume 3, Source Control BMPs
- GreenCO BMP Manual
- Colorado State University Extension Yard and Garden Fact Sheets.

3.0 Standard Inlets

3.1 Applicable Settings for Various Inlet Types

Table 8-2 provides information on the appropriate application of the different types of inlets, along with advantages and disadvantages of each. The information provided in this table should be considered when selecting the inlet for a given site condition.

Table 8-2. Inlet Type Summary
(Source: UDFCD 2002)

Inlet Type	Applicable Setting	Advantages	Disadvantages
Grate	Sumps and continuous grades (should be made bicycle safe)	Perform well over wide range of grades	Susceptible to clogging, lose some capacity with increasing grade
Curb-opening	Sumps and continuous grades (but not steep grades)	Do not clog easily, bicycle safe	Lose capacity with increasing grade
Combination	Sumps and continuous grades (should be made bicycle safe)	High capacity, do not clog easily	More expensive than grate or curb-opening acting alone
Slotted	Locations where sheet flow must be intercepted	Intercept flow over wide section	Susceptible to clogging

3.2 Standard Inlets Accepted for Use

Table 8-3 summarizes the standard inlets permitted for use in Woodland Park.

Table 8-3. Standard City Inlets

Inlet Type	Standard Detail	Drawing No.	Permitted Use
Curb-Opening Inlet – CDOT	Type R	M-604-12	All street types with 6- vertical or mountable curb and gutter with appropriate transitions. Available inlet lengths 5’, 10’, 15’.
Curb-Opening Inlet – City & County of Denver	Type 14	S-620.1 S-620.2	All street types with 6-inch vertical curb and gutter, with appropriate transitions. Available inlet lengths 6’, 9’, 12’, 15’.
Grate Inlet – CDOT	Type C	M-604-10	Roadside or median grass swales; Landscaped area drains; generally non-pedestrian accessible areas; Used in sump condition.
Combination Curb-Opening and Grate Inlet – City & County of Denver	Type 16	S-616.1 S-616.2 S-616.3	All street types with 6-inch vertical or mountable curb and gutter, with appropriate transitions. Available inlet lengths single (4’8”), double (8’5”) and triple (12’3”).

Photos of various inlet types can be found in the UDFCD spreadsheet UD-Inlet. Following are photos of the inlets described above. These are single inlets. Multiple inlet configurations such as double or triple inlets are also possible.

Photograph 8-4. Denver No. 14 Curb Opening Inlet (UDFCD Volume 1)

Photograph 8-5. CDOT Type R Curb Opening Inlet (UDFCD Volume 1)

Photograph 8-6. Denver No. 16 Combination Inlet in need of maintenance (UDFCD Volume 1)

Photograph 8-7. CDOT Type C Grate Inlet (UDFCD Volume 1)

Other inlets must be reviewed and approved by the City Engineer. UD-Inlet can be used for hydraulic analysis of 18 different typical inlet/grate combinations, as well as multiple inlets, which are often a good choice to provide additional interception without additional structures. Design of non-standard inlets will require detailed computations and justification for their use.

4.0 Hydraulic Evaluation of Inlets

4.1 Inlet Location and Spacing

The location and spacing of inlets is based upon street design considerations, topography (sumps), maintenance requirements, and the allowable spread of flow within the street. A significant amount of cost savings can be realized if inlets are placed in locations where their efficiency is maximized. The greater the efficiency of an inlet, the smaller the carryover flow, which may result in a smaller number of inlets downstream. Inlets are most efficient in a sump condition or along mild continuous street grades.

4.2 Inlet Capacity Factors

The capacity of an inlet located on a continuous grade is dependent upon a variety of factors including gutter slope, depth and velocity of flow in the gutter, height and length of the curb opening, street cross slope, and the amount of depression at the inlet. Inlets placed on continuous grades rarely intercept all of the flow in the gutter during the minor storm. This results in flow continuing downstream of the inlet and is typically referred to as "carryover." The amount of carryover must be accounted for in the drainage system evaluation, as well as in the design of the downstream inlet. Inlets are most efficient in a sump condition or along mild continuous street grades. The capture efficiency of a curb-opening inlet depends on the length of the opening, the depth of flow at the curb, the street cross slope, and the longitudinal gutter slope. If the curb opening is long, the flow rate is low, and the longitudinal gutter slope is small, all of the flow may be captured by the inlet. However, a portion of the stormwater often bypasses the inlet as indicated by the inlet efficiency. See the Streets/Inlets/Storm Sewers Chapter in Volume 1 of the UDFCD Manual for additional information on the efficiency and design of curb opening inlets on continuous grades.

4.3 Design of Inlets on Continuous Grade

Figures 8-1 through 8-3 (located at the end of this chapter) provide capacity charts for the three recommended curb opening inlets (Denver No. 14, CDOT Type R and Denver No. 16 combination) on continuous grades along standard street sections for the minor and major storm events, based on the maximum allowable flow in the street section, incorporating appropriate clogging factors. Sump condition figures are also provided, including curves for an Area (CDOT Type C) Inlet. These charts may be used to evaluate the street if it is at the maximum allowable flow. The Colorado Springs and Denver Manuals includes charts for other types of inlets, which may be considered and approved on a case-by-case basis if standard inlets are not sufficient.

When flow in the gutter is less than the maximum flow, the UD-Inlet spreadsheets shall be used to determine the interception by the proposed inlet. See the Streets/Inlets/Storm Sewers Chapter of the UDFCD Manual for further discussion on the use of UD-Inlet for less than maximum allowable flow.

The Streets/Inlets/Storm Sewers Chapter of the UDFCD Manual provides detailed instruction on the appropriate analysis of inlet capacities including equations, coefficients, and examples. The worksheets are the most accurate means of determining inlet capture rates and capacity calculations. The spreadsheets analyze both street capacities and inlet interception rates for both the minor and major storm events simultaneously. The UD-Inlet Spreadsheets may be downloaded from the UDFCD web site at www.udfcd.org.

4.4 Inlets in Sump Conditions

Inlets located in sumps (low points) must be sized to intercept all of the design storm flows at an allowable depth of ponding. The capacity of an inlet in a sump is dependent upon the depth of ponding above the inlet and the amount of debris clogging the inlet. Ponded water is a nuisance and can be a hazard to the public; therefore curb opening and combination inlets (where approved for use) are highly recommended for sump conditions due to their reduced clogging potential versus grate inlets acting alone. Capacity charts for curb opening and combination inlets in a sump condition are provided in Figures 8-4 through 8-5. These charts are based upon the depth of ponding above the inlet. The depth of ponded water shall not exceed the maximum allowable water depth for the given street classification as summarized in Chapter 7, Street Drainage.

4.5 Emergency Overflow Path with Drainage Tract

A surface flow path shall be provided at all sump inlets to provide for emergency overflows if the inlet becomes clogged or if storm runoff exceeds design flows. The emergency overflow shall be designed to convey the major storm discharge assuming that no flow is carried in the storm sewer. The depth of ponding shall not exceed the maximum allowable water depth for the given street classification as summarized in Chapter 7, Street Drainage. Channels conveying overflows shall be designed based on criteria for open channels and shall be contained within public right-of-way or a tract, including the required freeboard.

4.6 Roadside Inlets

For roadside swales and ditches, the City Engineer shall review and approve alternate, non-standard street sections. Roadside swales are used in conjunction with curbless (or intermittent curb) streets. When the capacity of the roadside swale or ditch is reached, given the criteria for depth and spread of flow into the street, then roadside inlets may need to be placed. The standard roadside inlet is a CDOT Type C inlet. Alternate inlets shall be reviewed and approved by the City Engineer.

The capacity curves provided in Figure 8-4 for CDOT Type C inlets include a 50% reduction factor for a standard grate and a 75% reduction factor for a close mesh grate. If a CDOT Type C inlet is placed in an area with pedestrian traffic, a close mesh grate shall be used.

5.0 Other Design Considerations

5.1 Median Inlets

Median curbs are typically configured to direct flows away from the median or are normally “spill” curbs. In situations where the street configuration directs flows toward medians or where runoff from medians is concentrated, inlets must be placed to collect the flows. Inlets are required along or within the median to reduce ponding at curb and gutter low points and to eliminate concentrated flow crossing over the lanes of traffic. The final design and construction drawings must address inlet sizing, dimensions, and required curb and gutter transitions. In some cases, using a depressed, vegetated median with an inlet at the bottom of the depression can be an effective way to disconnect impervious area.

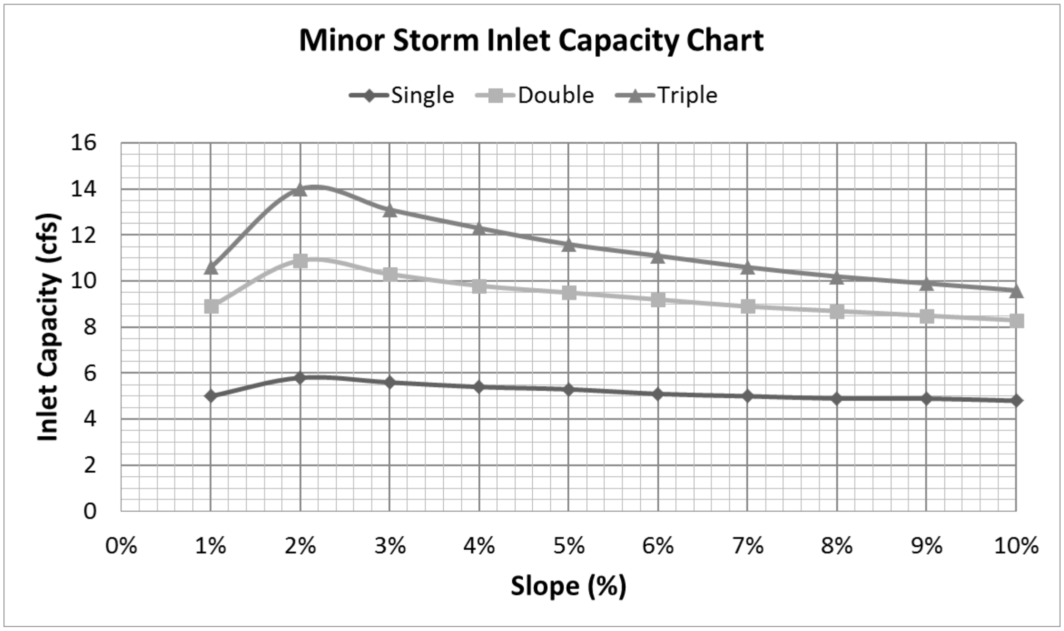
5.2 Maximum Inlet Length

Inlets shall be designed to blend in with the streetscape, and not present a dramatic structural departure from the general surroundings. The use of extremely long inlets is discouraged, as they are generally not aesthetic, require increased maintenance, and are viewed as a hazard by the public. In addition, studies by the UDFCD show that excessively long inlets do not significantly increase interception rates. The maximum length of an inlet in a specific location shall not exceed 9 feet for Denver No. 16 inlets, and 15 feet for CDOT Type R inlets.

5.3 Matching Inlet to Street Slope

Inlets, whether precast or cast-in-place shall be constructed so that the cap or top of the inlet matches the slope of the street. This is particularly important on streets with steep slopes, as the elevation difference between the beginning and end of the inlet can be significant, particularly when double or triple inlets are used.

Street Section Data: Street Width Flowline to Flowline = 28'
Type of Curb and Gutter: Type I 6" vertical and Type II 6" mountable



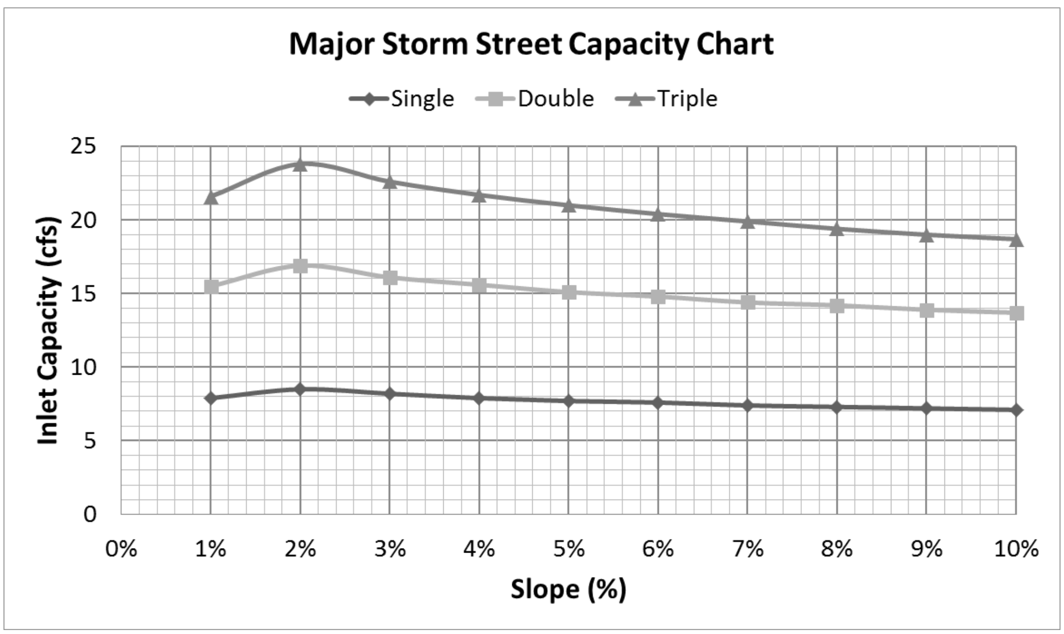


Figure 8-1. Inlet Capacity Chart, Residential (Local) Streets Inlets on Grade Denver No. 14 Curb Opening

The standard street section parameters as defined in Chapter 7 must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets. The maximum spread width is limited by the curb height based on no curb overtopping during a minor storm and flow being contained within the public right-of-way during the major storm.

Street Section Data: Street Width Flowline to Flowline = 28'
Type of Curb and Gutter = Type I 6" vertical and Type II 6" mountable

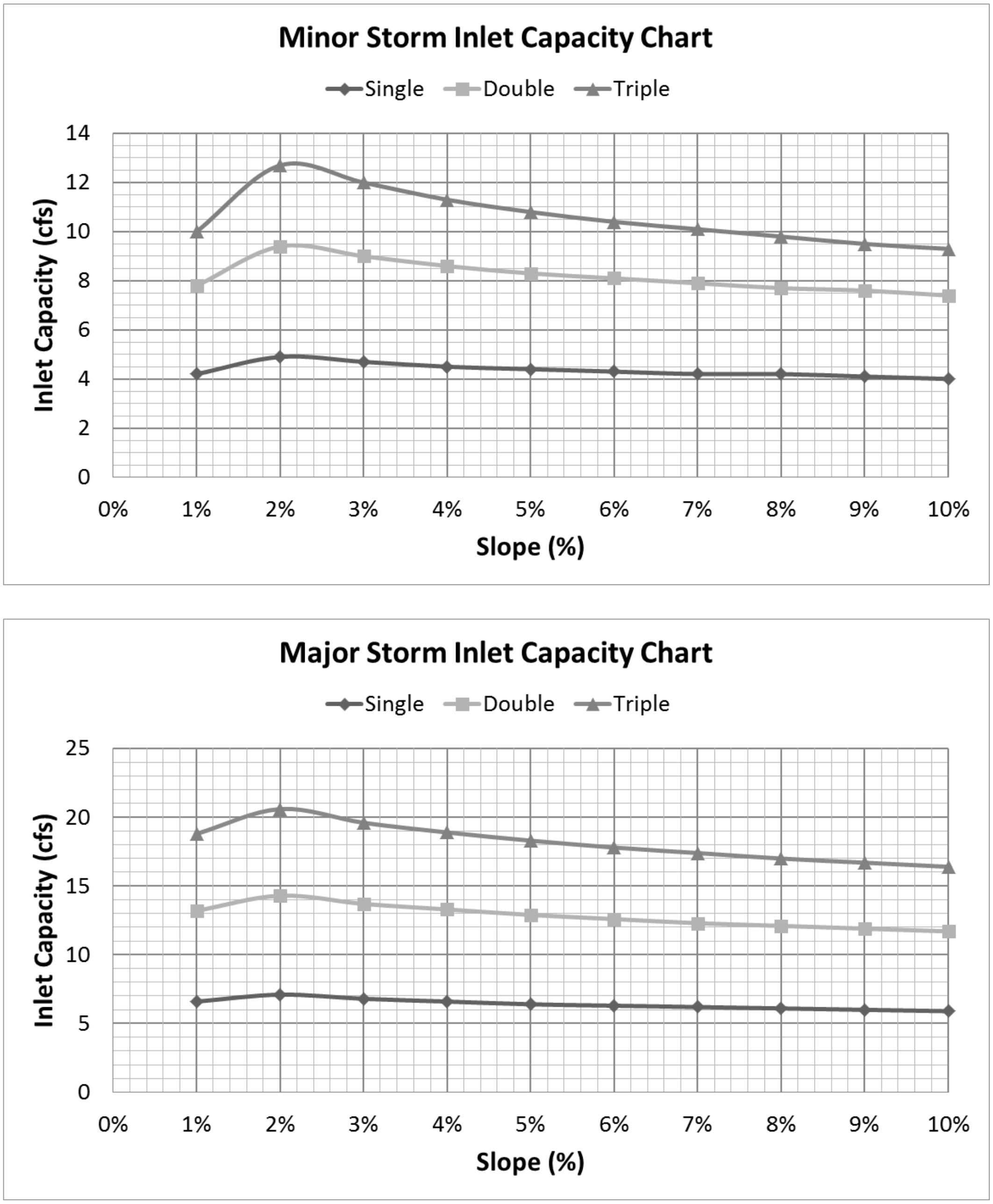
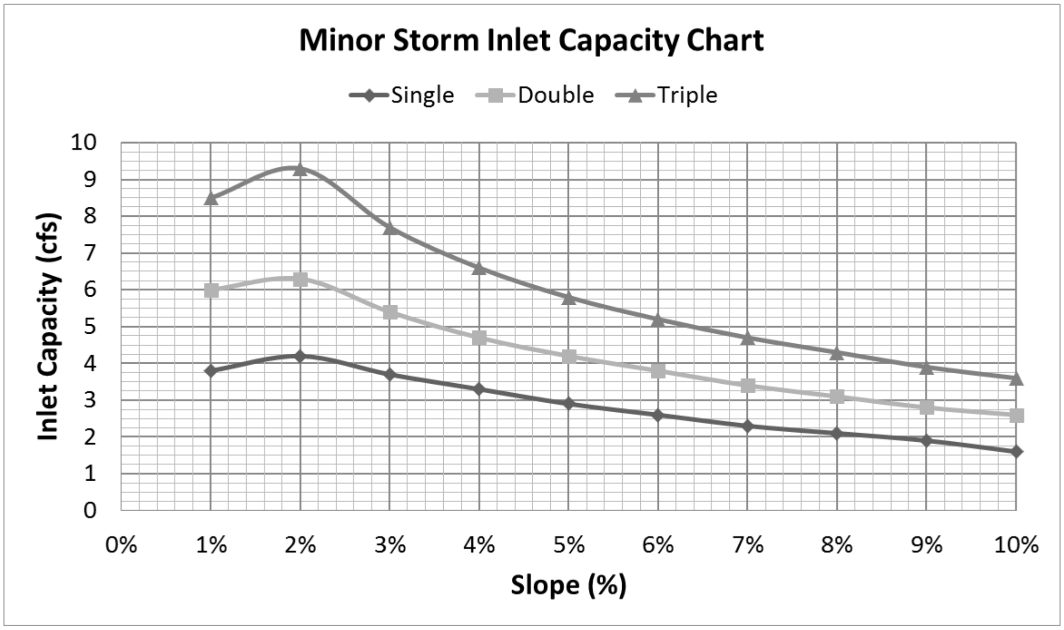


Figure 8-2. Inlet Capacity Chart, Minor Residential (Local) Streets Inlets on Grade CDOT Type R Curb Opening

The standard street section parameters as defined in Chapter 7 must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets. The maximum spread width is limited by the curb height based on no curb overtopping during a minor storm and flow being contained within the public right-of-way during the major storm.

Street Section Data: Street Width Flowline to Flowline = 28’
Type of Curb and Gutter = Type I 6” vertical and Type II 6” mountable



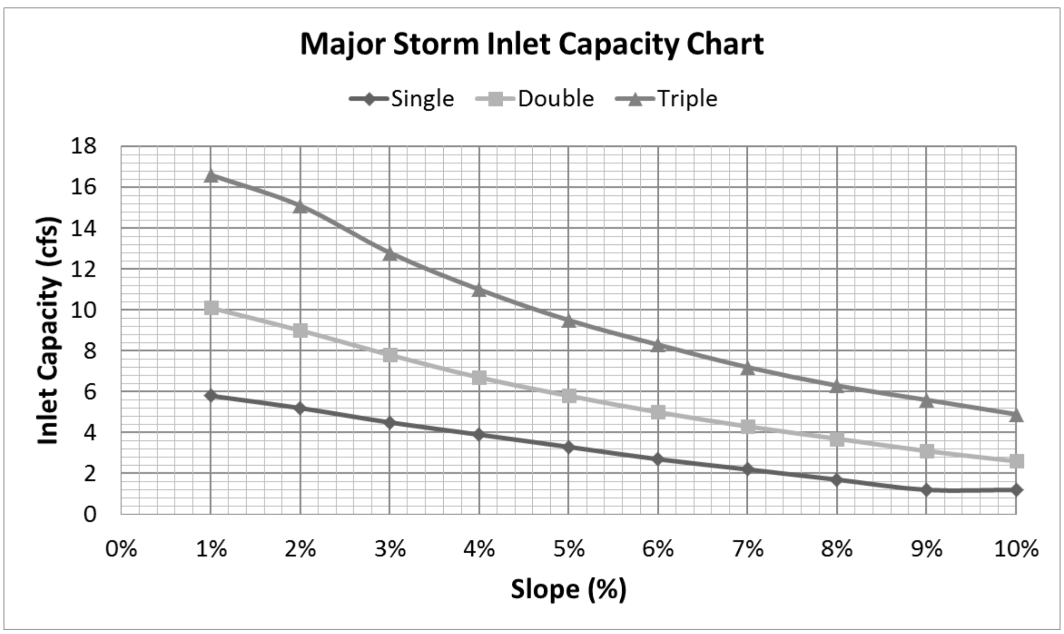
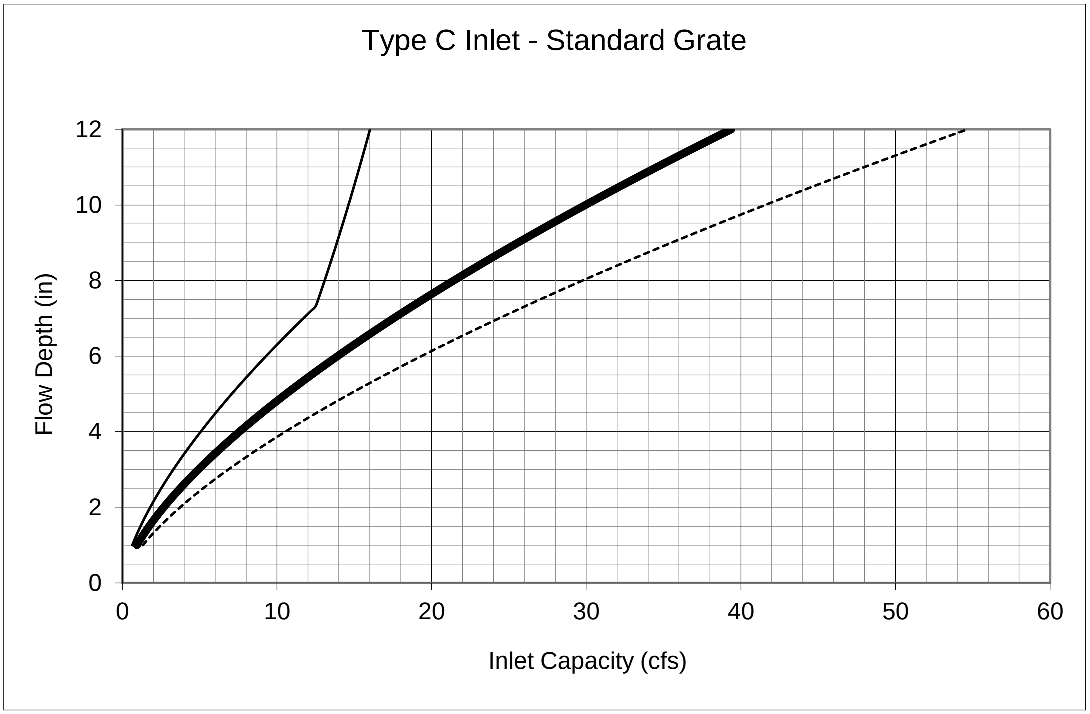


Figure 8-3. Inlet Capacity Chart, Minor Residential (Local) Streets Inlets on Grade Denver No. 16 Combination

The standard street section parameters as defined in Chapter 7 must apply to use these charts. For non-standard sections, the inlet capacity shall be calculated using the UDFCD spreadsheets. The maximum spread width is limited by the curb height based on no curb overtopping during a minor storm and flow being contained within the public right-of-way during the major storm.



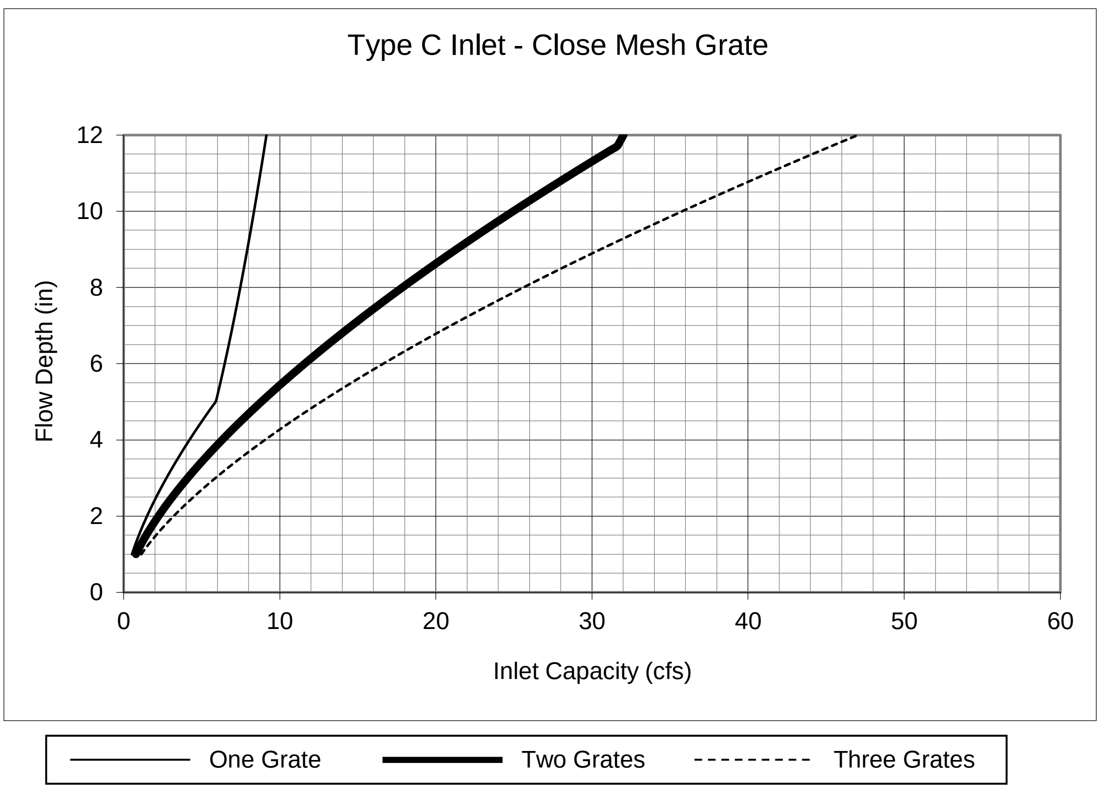
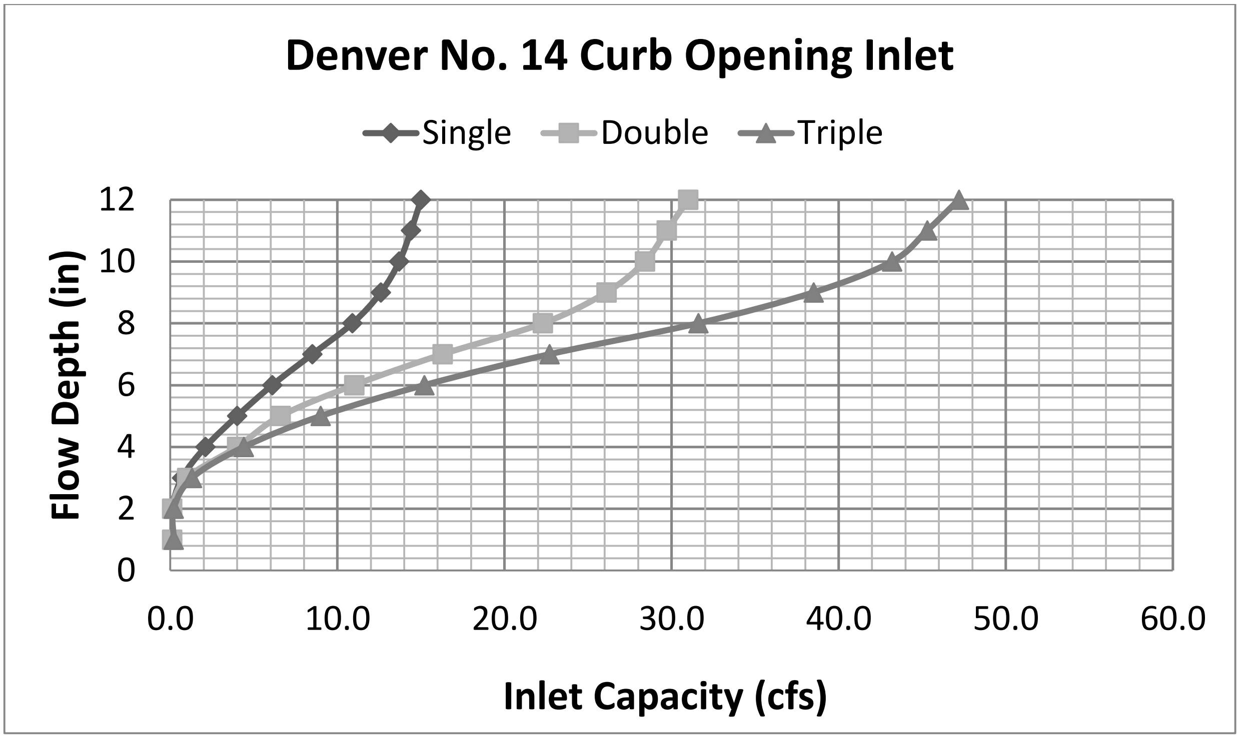


Figure 8-4. Inlet Capacity Chart Sump Conditions, Area (CDOT Type C) Inlet

Note: The City of Woodland Park standard inlet parameters must apply to use these charts.



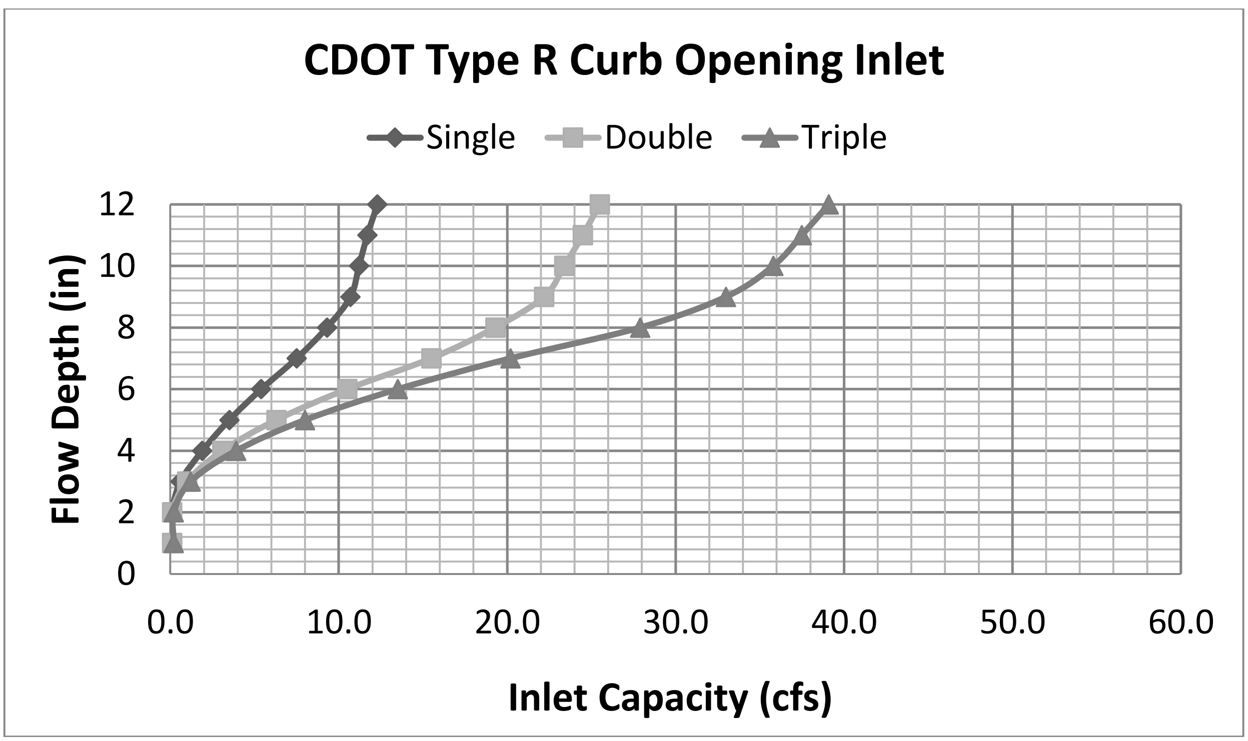
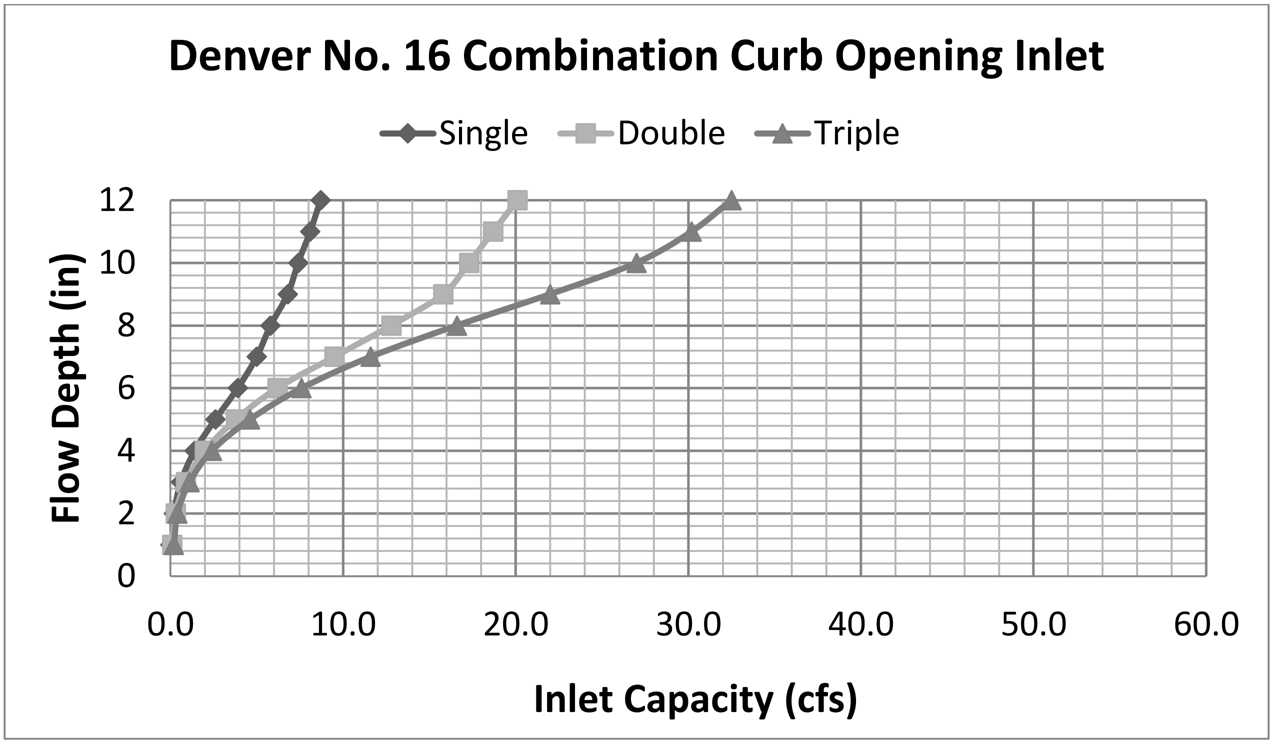


Figure 8-5. Inlet Capacity Chart Sump Conditions, Curb Opening Inlets

Note: The City of Woodland Park standard inlet parameters must apply to use this chart.



Note: The City of Woodland Park standard inlet parameters must apply to use this chart.

Figure 8-5 (cont.). Inlet Capacity Chart Sump Conditions, Curb Opening Inlet