9.0 Introduction

This chapter summarizes design criteria and evaluation methods for storm drain systems. References to the UDFCD Manual are made throughout this chapter, however where criteria in this chapter conflict with those in the UDFCD Manual, those included in this chapter supercede those in the UDFCD Manual. The review of all planning submittals will be based on the criteria presented herein.

9.1 Design Storms for Sizing Storm Drains

Two design storms shall be considered for sizing storm drains: the minor (5-year) storm and the major (100-year) storm. In each case, storm drains are to be sized to carry the portion of the runoff that cannot be conveyed on the surface, as dictated by the available capacity in streets and swales.

9.1.1 Minor Event Storm Drain Design. At a minimum, storm drains are to be sized to pick up any minor storm runoff that exceeds the minor event (5-year) capacity of the street or roadside swales (discussed in Chapter 7, Street Drainage). Inlets shall be located at these points to intercept excess minor event flow and direct it to the storm drain. The storm drain shall be sized to convey the minor storm without surcharging the pipelines. Section 9.8 provides additional information on hydraulic design methods for the minor storm.

9.1.2 Major Event Storm Drain Design. There are conditions when the storm drain system needs to be sized to convey flows greater than the minor storm runoff (and as much as the major storm runoff), including the following:

1. Locations where the street capacity for the major storm is exceeded.
2. Locations where major storm flows can split off in an undesirable direction (i.e. flow splits at intersections).
3. Locations where the storm drain system is accepting flow from an upstream storm drain system or branch that is designed for the major storm.
4. Regional storm drains designed for the major storm.
5. Locations where storm drains must convey undetained flows to a regional detention pond.

If a storm drain is to be designed to carry major storm flows, the inlets to the storm drain shall be designed accordingly. The major storm event hydraulic grade line is allowed to rise above the top of the storm drain pipe and surcharge the system. The major event hydraulic grade line elevation shall be a minimum of 1.0 foot below all manhole lid, inlet grate and inlet curb opening elevations. Where sump locations exist, inundation depths must be shown per Chapter 8. In no case shall the surcharge create system velocities in excess of 18 feet per second.

The major storm event hydraulic grade line must also be analyzed for storm drain systems designed to convey the minor storm event runoff. Since the flow depth in the street during the major storm will typically be greater than the minor

storm, inlets may intercept additional runoff and the flow in the storm drain will be greater than during the minor storm event. Any surcharge created by conveyance of the additional runoff is subject to the limits outlined above.

9.2 Storm Drain Pipe Material and Size

9.2.1 Storm Drain Pipe Material. All storm drains located within public rights-of-way, public easements or in private streets shall be constructed with reinforced concrete pipe (RCP). Circular pipe is the most cost effective option for reinforced concrete, but elliptical pipe may be a more appropriate option in areas where available cover is limited or there are utility conflicts.

Alternate pipe materials may be used for private storm drains with SEMSWA approval prior to submittal of drainage reports or construction drawings for SEMSWA review. A private storm drain system is defined as a system that conveys runoff generated by one subdivided lot or parcel. When a storm drain system conveys runoff from two or more subdivided lot or parcels, it is considered a "public" system. The alternate pipe material that is proposed must conform to the requirements set forth in the *UDFCD Storm Sewer Pipe Material Technical Memorandum (3rd Edition, updated 2010)*, however, SEMSWA will recognize changes in applicable standards and specifications since that document was published. For instance, AASHTO M294 – Type S – Corrugated Polyethylene Pipe is applicable for pipe diameters from 12-inches to 60-inches. Trench details, installation specifications, minimum cover or fill height limits, and construction testing requirements for alternate pipe materials shall be consistent with those recommended by the manufacturer/supplier or as determined by SEMSWA.

Outlets into detention or water quality ponds and connections to the public storm drain system must be constructed with RCP. This typically requires a change in pipe material at the privately owned structure (i.e. manhole or inlet) immediately upstream from the connection to the public storm drain or the pond outfall.

9.2.2 Minimum Pipe Size. The minimum allowable pipe diameter for storm drains located within public right-of-way and drainage easements is 18 inches.

9.2.3 Driveway Culverts. See Chapter 11, Culverts and Bridges, for SEMSWA criteria on driveway culverts.

9.3 Other Design Considerations

9.3.1 RCP Pipe Class, Fill Height, and Installation Trench. The minimum class of reinforced concrete pipe shall be Class III, however, the depth of cover, live load, and field conditions may require structurally stronger pipe. Installation of RCP shall conform to Colorado Department of Transportation (CDOT) M-603-2 standards, https://www.codot.gov/business/designsupport/standard-plans/copy_of_2012-m-standards-plans. It is the responsibility of the design engineer to develop and submit alternate trench and installation details when

project specific conditions or loadings require modification to the standard installation. It is also the responsibility of the design engineer to meet manufacturer recommendations for trench installation (i.e. maximum/minimum cover). Alternate designs shall follow ASTM C1479.

9.3.2 Storm Drain Joints. All storm drain installations within public and private roadways and public easements shall be constructed with water-tight joints, using rubber gaskets. ASTM Standard C443 covers flexible watertight joints for circular concrete storm drain and culvert pipe and precast manhole sections using rubber gaskets for sealing the joints.

9.3.3 Trash Racks. Trash/safety racks shall not be used at storm drain outlets.

9.3.4 Conduit Outlet Structures. See Chapter 10, Conduit Outlet Structures, for discussion regarding conduit outlet structures at storm drain outfalls.

9.4 Easements and Maintenance

9.4.1 Drainage Easements. Drainage easements are required in order to ensure the proper construction and maintenance of storm drains and related facilities. Easements shall be provided for all storm drain systems that convey or impact the public storm drainage system. Refer to Chapter 3, Stormwater Management and Development for further discussion regarding drainage easements.

9.4.2 Minimum Acceptable Drainage Easements. Table 9-1 presents the minimum acceptable easement requirements for storm drain systems. The design of the storm drain shall include the easement width that is necessary to ensure that adequate space is provided for the access, construction and maintenance of the facility.

TABLE 9-1
MINIMUM ACCEPTABLE DRAINAGE EASEMENT WIDTHS

Pipe Size	Easement Width
Less than 36-inch diameter	20 feet*
36-inch diameter and larger	25 feet*

*Or as required in order to meet Occupational Safety and Health Administration (OSHA) and/or construction requirements.

The pipe shall be constructed within the middle one-third of the easement width to allow for stockpiling of material on one side of the storm drain trench. The minimum widths provided in Table 9-1 assume a shallow pipe depth. Deeper pipes are required to be constructed in accordance with OSHA requirements, and appropriate easements are required to allow for construction and potential future repair or replacement. Easements to provide access to the storm drain, outlet, and other appurtenances are required if not accessible from a public right of way.

Trees shall be a minimum of 10 feet from all storm pipes and outside of the easement, if one is required. The design engineer shall also consult with a landscape professional to determine if the distance between a tree and storm pipe should be greater than 10 feet to prevent root penetration.

9.4.3 Allowable Landscaping and Surface Treatment in Drainage Easements. Although storm drain systems are designed to have a significant service life, it is recognized that there are circumstances that may require the storm drain to be accessed for inspection, maintenance, repair or replacement. Drainage easements also convey above ground flows in the event the storm drain or inlet becomes clogged or full. It is therefore necessary to limit uses on the surface of the easement to ensure that the above ground conveyance is not obstructed, and to allow maintenance access to the storm drain if necessary. Minor landscaping including, rock, shrubs etc. may be appropriate where it can be demonstrated that the function of the easement is not compromised by the presence of the materials, however the property owner assumes responsibility for replacement in the event it is necessary to remove it access the pipe. Pavement over a drainage easement is allowable, providing that the property owner assumes responsibility for replacement in the event it is necessary to remove it to access the pipe. Improvements that are not allowed on drainage easements include structures of any kind, retaining walls, permanent fencing, trees, and others if determined by SEMSWA to be a problem and/or costly to replace. Surface treatments within drainage easements shall be shown on the recorded or approved site plan, and accepted by SEMSWA.

9.5 Storm Drain Vertical Alignment

9.5.1 Minimum Cover. All storm drains shall be constructed so that the minimum cover is maintained to withstand AASHTO HS-20 loading on the pipe. The minimum cover depends upon the pipe size, type and class, and soil bedding condition, but shall be not less than 12-inches at any point along the pipe.

There are numerous factors that ultimately affect the depth of cover over a pipe and in most cases it is likely that the cover will have to be greater than the minimum allowed due to other design considerations and factors. Some of the other factors that affect the depth of the pipe are hydraulic grade line elevations, inlet depths, adjacent utilities or utility crossings, including water and drain services lines along residential streets, and connections to existing storm drain systems.

9.5.2 Minimum Cover in Roadways. A minimum cover of 30-inches shall be required in roadways, unless it is demonstrated by the design engineer that less cover is needed given the pavement design and soils reports. The roadway subgrade, which supports the pavement section is typically plowed to a certain depth, moisture treated and compacted prior to the placement of the sub-base, base course, and surfacing. There are also instances where the subgrade material must be excavated and replaced or treated to a certain depth to mitigate swelling soils. These efforts can impact the storm drain system if it has not been

designed with adequate depth. The design engineer shall use the best information available, including pavement design or soils reports (if available) to ensure that storm drain pipes have adequate depth.

9.5.3 Utility Clearance. For all storm drain crossings at water and/or sanitary drain lines, the appropriate agency (i.e. water and sanitation district) shall be contacted to determine the agency's requirements for the crossing.

SEMSWA requires a minimum vertical clearance of 18-inches between a storm drain and a water main (including non-potable water mains), above or below (all clearances are defined as outside-of-pipe to outside-of-pipe). Additional requirements may be required by the specific utility provider.

The minimum vertical clearance between a storm drain and a sanitary drain, above or below, shall also be 18-inches. In addition, whenever a sanitary drain main lies above a storm drain the sanitary drain shall have an impervious encasement for a minimum of 10-feet on each side of the storm drain. Additional requirements may be required by the specific utility provider.

If 18-inches of clearance from the storm drain cannot be maintained, additional measures will be required to address potential concerns associated with minimum separation. Additional measures may include concrete cradles for additional structural support, encasement, or other improvements as needed to address potential impacts to either pipe system.

9.6 Horizontal Alignment

9.6.1 Storm Drain Alignment. The storm drain alignment between drainage structures (inlets or manholes) shall be straight. If a change of alignment is necessary, a manhole shall be used. Curvilinear alignment for storm drains is NOT allowed. Storm drains shall not be installed under sidewalks.

9.6.2 Utility Clearance. For all storm drain pipes constructed within a utility corridor (i.e. roadway), the appropriate agency (i.e. water and sanitation district) shall be contacted to determine the agency's requirements for horizontal clearance between the utilities.

SEMSWA requires a minimum clearance of 10-feet between a storm drain and a water line (including non-potable) or sanitary drain line, with the exception of service lines unless the appropriate water and sanitary districts dictate differently. The 10-feet of clearance shall occur from the outer diameter of the storm drain pipe to the outer diameter of the water or drain pipe. The design engineer shall give careful consideration to the required horizontal clearance and the potential impacts to the existing utility construction trench and bedding material. The required horizontal clearance may be reduced, at the approval of SEMSWA, if the vertical elevations of the pipes provide adequate clearance to prevent impacts to the existing and proposed construction trench. If the 10-foot

clearance cannot be met with the utility provider, the clearances must be evaluated by SEMSWA.

9.7 Manholes

9.7.1 Required Locations. Manholes are required along straight segments of pipe in order to provide maintenance access. Manholes are also required whenever there is a change in size, direction, or grade of a storm drain pipe. A manhole shall also be constructed when there is a junction of two or more drain pipes. The maximum spacing between manholes for various pipe sizes shall be as 400 feet.

9.7.2 Manhole Types and Minimum Sizes. The required manhole type and size is dependent on the diameter of the largest pipe entering or exiting the manhole and the horizontal and vertical alignments of all pipes entering or exiting the manhole. Table 9-2 presents general guidance regarding acceptable manhole types and minimum diameters, based on the diameter of the storm drain pipe.

TABLE 9-2
MANHOLE SIZE BASED ON PIPE DIAMETER*

Pipe Diameter	Minimum Manhole Diameter	Acceptable Manhole Types
18”**	4’	Cast-in-place
>18” - 42”	5'	Cast-in-place Slab Base
48 ”- 54”	6’	Cast-in-place Slab Base
60”	7’	Box Base, Denver Type “P”
72” – 78”	8’	Box Base, Denver Type “P”, T-Base
78” – 96”	5’ (Riser)	Box Base, T-Base
Larger than 96”	5’ (Riser)	T-Base

*Table is based on pipes with a straight through alignment (no horizontal alignment change from the upstream to the downstream pipe) or changes in alignment accommodated in the standard design for large pipe manhole structures.
** 4’ manhole shall not be used in public right-of-way, 5’ or greater shall be used

Table 9-2 provides general guidance and in many cases, it is likely that the minimum diameter of manhole size will need to be increased to account for more significant changes in pipe alignment or multiple incoming pipes. There must be

a minimum of 12-inches clearance from the outside of pipes adjacent to each other. This 12-inch dimension must be measured on the inside wall of the manhole. Pipes shall not be allowed to enter or exit a manhole through the corner of the manhole structure. It is the responsibility of the design engineer to determine the required manhole size to achieve adequate space between the pipes entering or exiting the manhole structure. This same analysis and dimension check must be performed when an inlet is used as a junction structure. In those cases where modifications to standard manhole construction details are required or where special junction structure designs are required, additional construction details must be developed and included in the construction drawing set.

9.7.3 Large Pipe Manhole Structures. A manhole with a large diameter or a special junction structure may be required, depending on the degree of horizontal bend, the use of large pipes, or the presence of multiple laterals into a manhole. There are a number of different options available for these special cases:

1. Box Base Manhole. It is appropriate to use this manhole for large pipe diameters with a horizontal alignment change of less than 45 degrees. The Box Base Manhole shall be constructed per CDOT's M-604-20 standard plans.
2. T-Base Manhole. This manhole is acceptable for 72-inch diameter pipes and larger when there is no horizontal or vertical alignment change at the structure. The T-Base manhole shall be constructed per CDOT's M-604-20 standard plans. Horizontal or vertical alignment changes using a three piece elbow or bend in conjunction with a T-Base may be considered through the variance process for very large pipes where the base structure for a Box Base or Type P manhole would be excessively large.
3. Type "P" Manhole. This manhole is appropriate for 30 degree and 45 degree deflections (horizontal alignment changes) where the use of a box base manhole would result in excessive dimensions. The Type "P" Manhole shall be constructed per Denver's S-504.1 and S-504.2 standard plans.
4. Special Junction Structures. Special junction structures may have to be designed when pipe sizes and alignment changes exceed those that can be accommodated by standard manhole types.

9.7.4 Steps and Platforms. Steps are required in all manholes exceeding 3.5 feet in height and shall be in accordance with AASHTO M 199. OSHA has specific standards for fixed ladders used to ascend heights exceeding 20-feet. Cages and/or landing platforms may be required to satisfy these requirements in excessively deep manhole structures. It is the design engineer's responsibility to ensure that the appropriate measures are designed and construction details are developed and included in the construction drawings, as needed to comply with the OSHA standards. When landing platforms are proposed, considerations shall be given to the potential maintenance activities and the expected loadings on the platform.

9.7.5 Drop Manholes. The drop within a manhole from the upstream to downstream pipe invert should not exceed 1-foot. There are cases when a drop larger than 1-foot may be necessary (to avoid a utility conflict, reduce the slope of the downstream pipe, or to account for the energy losses in the manhole). Drops that exceed 1-foot will be evaluated on a case-by-case basis, and additional analysis may be required. The details referenced in Section 9.7.3 for the Box Base and Type P manholes do not accommodate a significant elevation difference between the pipes entering and exiting the manhole, therefore use of these manholes would require a special design.

9.7.6 Energy Dissipation in Manholes for Small Storm Drainage Outfalls. Small storm drainage outfalls are defined as outfall systems that have a design flow rate of 20 cubic feet per second or less at the outlet point into a drainageway or detention pond. Small storm drainage outfall systems are commonly proposed to drain cul-de-sacs or other small tributary areas. In many cases, a relatively steep slope is required for the pipe to outlet into an adjacent drainageway or detention pond. In the design of these systems, manholes will be allowed to have drops to a maximum of 4.5-feet in order to provide energy dissipation within the system. In order for a manhole to qualify as an energy dissipation structure upstream of the storm drain outlet, the minor storm flow must have sufficient velocity to impact the opposite side of the manhole. These minimum velocities based on the drop height, are provided in Figure 9-1. The information provided in Figure 9-1 is based on the use of a 4-foot manhole (inside diameter).

9.7.7 Manhole Shaping. All manholes shall be constructed with fill concrete to the top of the highest crown of the highest top of pipe entering or exiting the manhole. The shaping shall match the pipe section below pipe springline and consist of vertical walls above pipe springline. This shaping significantly reduces manhole losses. The appropriate loss coefficient can be determined using Figure 7-13 of the UDFCD Manual for full shaping. CDOT's M-604-20 standard plans provide construction details for channelization in slab base and box base manholes.

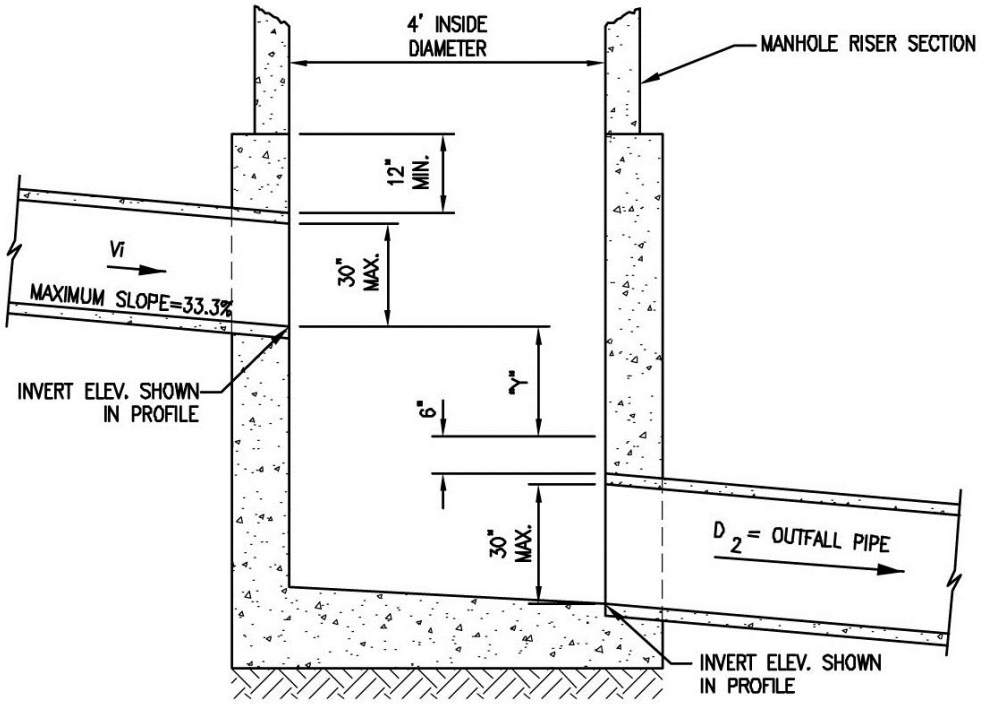
9.7.8 Other Design Considerations. The following design criteria shall be met:

- The elevation of the pipe crowns shall be matched when the downstream pipe is larger than the upstream pipe. This will minimize the backwater effects on the upstream pipe.
- The invert of a manhole shall be constructed with a slope between the upstream and downstream pipes. The slope shall be the average of the upstream and downstream pipe slopes or based on a fall of 0.1-foot minimum through the manhole.
- It is critical that gutter pans, curb heads, and any other problematic locations be avoided when determining the horizontal placement of manholes.

9.8 Hydraulic Design

Hydraulic design of storm drain systems shall follow the methods specified in the Streets, Inlets and Storm Drain chapter of the UDFCD Manual. A minimum velocity of 3 feet per second is required when the storm drain conveys runoff from frequently occurring events.

FIGURE 9-1
ENERGY DISSIPATION IN MANHOLES FOR
SMALL STORM DRAINAGE OUTFALLS



DROP MANHOLE SECTION

MAX. "Y" DIMENSION

D_2=	18"	21"	24"	27"	30"
	2.50'	2.25'	2.00'	1.75'	1.5'

"Y" DIMENSION	MIN. VELOCITY (Vi) (fps)
0.50'	23.0
0.75'	19.0
1.00'	16.0
1.25'	14.0
1.50'	13.0
1.75'	12.0
2.00'	11.0
2.25'	10.5
2.50'	10.0