10.0 Introduction

This section addresses the design of culvert outlets, which are typically oriented in-line with the flow in a drainageway, and storm sewer outlets, which are typically oriented perpendicular to the flow in a drainage channel or detention facility. This chapter contains references to the UDFCD Manual for design procedures applying to both of these outlet types, however where criteria in this chapter conflict with those in the UDFCD Manual, those included in this chapter supercede those in the UDFCD Manual.

Conduit outlet structures are necessary to dissipate energy at culvert and storm sewer outlets and to provide a transition from the conduit to an open channel. A conduit outlet structure is comprised of an end section or headwall and wingwalls, safety rails (if required), and a riprap or concrete structure to dissipate flow energy at the exit of the conduit.

Occasionally, other hydraulic controls are located at culvert outlets. These hydraulic controls can include drop structures, which are discussed in Chapter 12, Open Channel Design.

10.1 General Layout Information

10.1.1 Inlet and Outlet Configuration. All conduits 54-inches in diameter and larger within the urbanized area shall be designed with headwalls and wingwalls. Conduits 48-inches in diameter and smaller may use headwalls and wingwalls or flared end sections at the inlet and outlet. In rural areas the use of flared end sections and rip rap stabilization in lieu of concrete headwalls and wingwalls shall be considered on a case-by-case basis. Appropriate justification and detailed design information will be required to be provided by the design engineer.

10.1.2 Safety Rails. Conduit headwalls and wingwalls shall be provided with guardrails, handrails, or fencing in conformance with local building codes, roadway design safety requirements and/or the International Building Code, whichever is more restrictive. Those criteria include both “drop” and height requirements. Handrails shall be required in areas frequented by pedestrians or bicycles (including in areas that are also fenced). Acceptable materials include, but are not limited to, galvanized or painted steel, aluminum, and chain link fence.

10.1.3 Flared End Sections. Flared end sections shall not protrude from the embankment. Flared end sections require joint fasteners and toe walls at the inlet and outlet. Toe walls shall extend from the top of the vertical portion at the end of the flared end section to at least 3-feet below the invert. The width of the wall shall be as necessary to extend a 3:1 slope from the flared end section invert at the edge of the end section to the top of the wall (this slope shall be protected with riprap). Refer to the Pipe Outfalls and Rundowns section of the Hydraulic Structures Chapter of the UDFCD Manual for design details.

A minimum of one joint or 15 feet connecting the last pipe segment to the flared end section, shall be mechanically locked with joint fasteners as shown in Figure 10-2. Joint fasteners shall be constructed consistent with the details provided in CDOT Standard Plan No. M-603-10 and the UDFCD Manual.

Concrete headwalls may be used as an alternative to flared-end sections at pipe inlets and outlets. Refer to the Pipe Outfalls and Rundowns section of the UDFCD Manual for additional design guidance on using these methods.

10.1.4 Conduit Elevations Relative to Drainageways. In general, in-line culvert inlet and outlet elevations are to match drainageway invert elevations upstream and downstream. Outlets shall be provided with erosion protection per Section 10.2.

Storm sewer outlets shall be set with their inverts 2 feet above the water surface elevation for the 2-year storm event in the receiving channel and provided with erosion protection per Section 10.2. The drop is to reduce backwater affects in the storm sewer due to sedimentation.

In either case, if the existing drainageway has experienced degradation and the channel is incised, restoration improvements may raise the channel bottom back up to its former elevation. The design engineer shall determine the appropriate outlet elevations considering, at a minimum, the stability of the existing channel and any potential stabilization or grade control improvements that would change the longitudinal grade or elevations along the channel. To ensure that outlets and energy dissipation improvements function properly, inlet and outlet elevations shall be set based on field survey information, rather than topographic mapping generated from aerial photography.

10.2 Conduit Outlet Erosion Protection

10.2.1 Types of Erosion Protection. Erosion protection in the form of riprap or concrete basins is required at the outlet of conduits to control scour. Erosion protection shall be designed for conduit outlets in accordance with Table 10-1. These are general guidelines only and are meant to supplement the UDFCD Manual. Other outlet protection options, including many specialized types of concrete outlet structures are available and may be used if approved by SEMSWA. These types of structures are listed in the Hydraulic Structures chapter in the UDFCD Manual. Final design criteria are also available in the UDFCD Manual.

TABLE 10-1
EROSION PROTECTION AT CONDUIT OUTLETS

Erosion Protection Method	UDFCD Manual Section for Sizing and Details	Use For	Do Not Use For
Riprap Apron	Rock and Boulders Volume 1 & Hydraulic Structures Volume 2	▪ Receiving channel on same line and grade ▪ Storm sewer and culvert outlets ▪ Velocities[1] to 5 fps (non-cohesive soils) ▪ Velocities to 7 fps (erosion-resistant soils) ▪ Froude Number ≤ 2.5 ▪ High tailwater ▪ Fish passage	▪ Velocities above 7 fps ▪ Wetland channels
Low Tailwater Basin	Hydraulic Structures Volume 2	▪ Storm sewer and culvert outlets ▪ Velocities from 0-15 fps ▪ Low tailwater	▪ Velocities above 15 fps ▪ Confined receiving area ▪ Major drainage ▪ Areas where standing water is unacceptable
Impact Stilling Basin	Hydraulic Structures Volume 2	▪ Storm sewer outlets ▪ Velocities ≥ 18 fps ▪ Low tailwater	▪ In-line culvert outlets ▪ High visibility areas
Forebays	Hydraulic Structures Volume 2 Treatment BMP Fact Sheets Volume 3	▪ Storm sewer outlets into Extended Detention Basins and Sand Filter Basins	▪ Any other outlet that does not discharge into a Treatment BMP
Grouted Boulder Outfalls and Rundowns	Hydraulic Structures Volume 2	▪ Large river outfalls[2]	
Drop Structures	Hydraulic Structures Volume 2	▪ Wetland channels ▪ Low rise box culverts or small diameter pipes where plugging is possible	▪ Confined receiving area ▪ Fish passage

[1] – all velocities in this table refer to flows generated for the major design event (e.g. 100-year or as otherwise required by the facility design
[2] – refer to the Hydraulic Structures Chapter of the UDFCD Manual for selection criteria

10.2.2 Selecting Type of Erosion Protection. Riprap protection downstream of culverts is appropriate for most situations where moderate outlet hydraulics govern. Table 10-1 should be considered when determining the appropriate type of erosion protection for the outlet condition. Where a storm sewer enters a drainageway at an approximate right angle, the designer shall use a low tailwater basin. For in-line culvert outlets on major drainageways, drop structures or riprap lining are recommended.

Prior to the selection of a concrete structure, the design engineer should evaluate techniques which are available to decrease outlet velocities to the point where a concrete stilling basin may not be necessary. Steep, high velocity conduits can be modified by providing a drop in a manhole and designing a larger diameter, flatter slope pipe from the manhole to the channel. This technique may also be used to reduce outlet velocities and the corresponding extents of riprap erosion protection. The use of drop manholes for this purpose is discussed in Section 9.7.6.

In general, concrete outlet structures are large, uncharacteristic of the natural environment, and require special safety and maintenance considerations. The use of concrete structures should be avoided when possible, and must be approved by SEMSWA prior to their use. Concrete structures will not be approved in areas that are highly visible, and improvements are intended to complement the natural environment. If exit velocities are extremely high and turbulence at a conduit outlet is expected to be severe, and if space is especially limited, there are cases where a concrete stilling basin structure may be considered.

All extended detention basins and sand filter basins must include a concrete forebay that allows for routine maintenance.

10.3 Design Criteria for Culvert and Storm Sewer Outlet Erosion Protection

10.3.1 Riprap Apron. The procedure for designing riprap for conduit and culvert outlet erosion protection is provided in the Hydraulic Structures Chapter and Open Channels Chapter of the UDFCD Manual. The riprap protection is suggested for outlet Froude numbers up to 2.5 where the outlet of the conduit slope is parallel with the channel gradient and the conduit outlet invert is flush with the riprap channel protection. An additional thickness of riprap just downstream from the outlet is required to assure protection from extreme flow conditions that might precipitate rock movement in this region. Protection is required under the conduit barrel and an end slope is provided to accommodate degradation of the downstream channel.

10.3.2 Low Tailwater Riprap Basins. The majority of storm sewer pipes discharge into open drainageways, where the receiving channel may have little or no flow or tailwater when the conduit is discharging. Uncontrolled pipe velocities create erosion problems downstream of the outlet and in the channel. By providing a low tailwater basin at the end of a storm sewer conduit or culvert, the kinetic energy of the discharge is dissipated under controlled conditions without causing scour at the channel bottom.

Low tailwater is defined as being equal to or less than 1/3 of the storm sewer diameter/height. Design criteria for low tailwater riprap basins for circular and rectangular pipe are provided in the Hydraulic Structures Chapter of the UDFCD Manual.

10.3.3 Concrete Impact Stilling Basin. The use of concrete impact stilling basins is discouraged where moderate outlet conditions exist, and where there are other options available which better fit the natural characteristic of the drainageway. However, when accepted by SEMSWA, concrete impact stilling basins shall be designed in accordance with the Hydraulic Structures Section of the UDFCD Manual. Three types of impact still basin designs are included in the UDFCD Manual. One is applicable for outlets less than 18 inches diameter and less than 18 fps exit velocity, one is for outlets 18-48 inches diameter and less than 18 fps exit velocity, and the USBR Type VI basin is for exit velocities greater than 18 fps.

10.3.3 Forebays. Forebays are used at conduit outlets that discharge into extended detention basins and sand filter basins. They should generally follow the impact stilling basin design appropriate for the outlet size and exit velocities discussed above, but also must conform with maintenance access requirements as presented in the Treatment BMP Fact Sheet Chapter of the UDFCD Manual.

10.3.3 Grouted Boulder Outfalls and Rundowns. The use of grouted boulder outfalls are generally limited to outlets that discharge into large rivers where the need for low tailwater basins are not necessary. Grouted boulder outfalls shall be designed according to the design criteria in the Hydraulic Structures Section of the UDFCD Manual.

10.3.4 Drop Structures. The use of drop structures is appropriate for culverts in wetland channels and other discharges to wetland channels where wetland vegetation may clog outlets. Several types of drop structures may be used and must be approved by SEMSWA. Drop structure design shall be performed following the design criteria in the Hydraulic Structures Chapter of the UDFCD Manual.