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. Outlets into forebay sedimentation traps of water quality basins are discussed in Chapter 14, Stormwater Quality.

10.0.1 Design Considerations. 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 of the City 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 of the City 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 and roadway design safety requirements. Handrails shall be required in areas frequented by pedestrians or bicycles (including in areas that are also fenced). The height of the handrail shall be 42-inches for pedestrian walkways or open areas and 54-inches for bicycle traffic. 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 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 2:1 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). See Figure 10-1 for an acceptable toe wall configuration.

A minimum of three joints, including the joint 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.

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 1- to 2- feet (2-feet for wetland channels) above the natural channel bottom 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 Section 3.5 of the Hydraulic Structures chapter in the UDFCD Manual. Final design criteria is also available in the UDFCD Manual.

TABLE 10-1
EROSION PROTECTION AT CONDUIT OUTLETS

Erosion Protection Guidelines	UDFCD Manual Section	Use For	Do Not Use For
1. Riprap Lining (Section 10.3.1)	Section 7.0 of Major Drainage Volume 1	▪ Receiving channel on same line and grade ▪ Storm sewer and culvert outlets ▪ Velocities from 0-15 fps ▪ High tailwater ▪ Fish passage	▪ Velocities above 15 fps ▪ Wetland channels
2. Low Tailwater Stilling Basin (Section 10.3.2)	Section 3.4 of 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
3. Concrete Impact Stilling Basin (Section 10.3.3)	Section 3.2 of Hydraulic Structures Volume 2	▪ Storm sewer outlets ▪ Velocities over 15 fps ▪ Low tailwater	▪ In-line culvert outlets ▪ High visibility areas
4. Concrete Baffle Chute (Section 10.3.4)	Section 3.3 of Hydraulic Structures Volume 2	▪ Storm sewer outlets ▪ Velocities over 5 fps ▪ Low tailwater ▪ Degrading channel	▪ In-line culvert outlets ▪ High debris potential ▪ High visibility areas
5. Drop Structures	Section 2.0 of Hydraulic Structures Volume 2	▪ Wetland channels ▪ Low rise box culverts or small diameter pipes where plugging is possible	▪ Confined receiving area ▪ Fish passage

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, it is highly recommended that the designer 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.

10.3 Design Criteria for Culvert and Storm Sewer Outlet Erosion Protection

10.3.1 Riprap Lining. The procedure for designing riprap for culvert outlet erosion protection is provided in Section 7.0 of the Major Drainage 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 in the City discharge into open drainageways, where the receiving channel may have little or no flow 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 Section 3.4 of the Hydraulic Structures Chapter of the UDFCD Manual.

10.3.3 Concrete Impact Stilling Basin. The use of concrete 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 Section 3.2 and 3.3 of the Hydraulic Structures Section of the UDFCD Manual. Design standards for an impact stilling basin are based on the United States Bureau of Reclamation Type VI basin, a relatively small structure that produces highly efficient energy dissipation characteristics without tailwater control. Energy dissipation is accomplished through the turbulence created by loss of momentum as flow entering the basin impacts a large overhanging baffle. Additional dissipation is produced as water builds up behind the baffle to form a highly turbulent backwater zone. Flow is then redirected under the baffle to the open basin and out to the receiving channel. A check at the basin end reduces exit velocities by breaking up the flow across the basin floor and improves the stilling action at low to moderate flow rates.

The generalized design configuration consists of an open concrete box attached directly to the conduit outlet. Figure HS-14 from the Hydraulic Structures Section of Volume 2 of the UDFCD Manual provides an example of the general design for the impact stilling basin.

The standard United States Bureau of Reclamation design above will retain a standing pool of water in the basin bottom that is generally undesirable from an environmental and maintenance standpoint. Section 3.2.1 of the Hydraulic Structures section of Volume 2 of the UDFCD Manual provides modifications to the United States Bureau of Reclamation standard design to allow drainage of the basin bottom during dry periods. Figure HS-16 from the Hydraulic Structures Section of Volume 2 of the UDFCD Manual provides an example of the modified end wall design to allow basin drainage for urban applications.

Figure HS-16 also provides details of a “mini” impact basin that can be used for small pipe diameters less than or equal to 36-inches.

10.3.4 Concrete Baffle Chute. The use of concrete baffle chutes 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 baffle chutes shall be designed in accordance with Section 3.2 and 3.3 of the Hydraulic Structures Section of the UDFCD Manual.

A concrete baffle chute is normally used in situations where there is a very large conduit outfall, future channel degradation is expected, and there is a drop in grade between the culvert outlet and the channel invert. The original design (United States Bureau of Reclamation Type IX baffled apron) has been modified slightly by UDFCD so it can be used with a conduit instead of an open channel. Section 3.3 of the Hydraulic Structures Chapter of the UDFCD Manual provides some design and construction details for this type of basin. Figure HS-17 from the Hydraulic Structures Section of the UDFCD Manual provides an example of the general design for the baffle chute pipe outlet.

This outlet dissipates energy along the slope, but scour holes can form at the base of the structure. These scour holes can undermine adjacent banks, particularly where development encroaches close to the channel. The designer shall provide riprap erosion protection along the downstream channel where a scour hole is undesirable.

FIGURE 10-1
CONCEPTUAL TOEWALL DETAIL

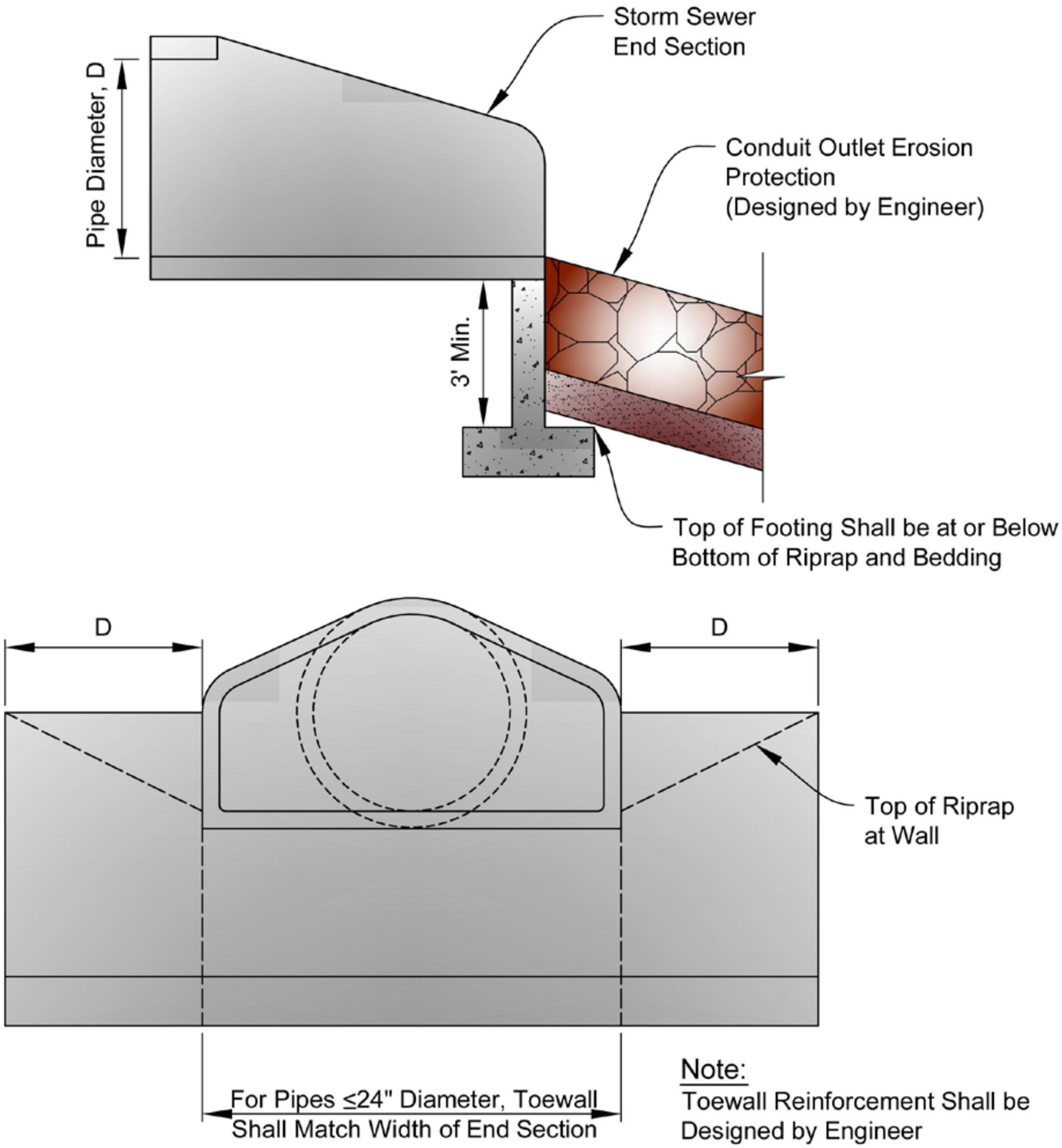

FIGURE 10-2
PIPE OUTFALL JOINT RESTRAINT REQUIREMENTS