

Chapter 10

Conduit Outlet Structures

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1.0 Introduction

This chapter addresses the design of culvert outlets, which are typically oriented in-line with the flow in a drainageway, and storm drain 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 Volume 3 of the UDFCD Manual.

Conduit outlet structures are necessary to dissipate energy at culvert and storm drain outlets and to provide a transition from the conduit to an open channel. A conduit outlet structure consists 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 Channels.

2.0 General Design

2.1 Inlet and Outlet Configuration

All conduits 54 inches in diameter and larger 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. Detailed grading plans showing proposed contours, spot elevations, and outlet erosion protection measures shall be included in the construction drawings at all conduit inlets and outlets.

2.2 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. 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.

2.3 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. 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. Joint fasteners shall be constructed consistent with the details provided in CDOT Standard Plan No. M-603-10.

2.4 Transition to Drainageways

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 appropriate erosion protection measures. The drop is to reduce backwater effects in the storm sewer due to sedimentation. When a storm sewer outfalls into a channel with an overbank between the bank toe of the main channel and the low-flow channel, outlet protection

shall be extended to the invert of the low-flow channel using the design flow for the storm sewer. However, protection extended into the main channel of the receiving channel must be evaluated for stability during the major storm event in the main channel.

In general, in-line culvert inlet and outlet elevations should match drainageway invert elevations upstream and downstream. Outlets shall be provided with erosion protection measures as discussed later in this chapter.

If the existing drainageway has experienced degradation and the channel is incised, channel 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 condition and 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.

3.0 Outlet Erosion Protection

3.1 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 intended to supplement the UDFCD Manual. Other outlet erosion protection options, including many specialized types of concrete outlet structures, are available and may be used if approved on a case-by-case basis. These types of structures are listed in the Hydraulic Structures Chapter of the UDFCD Manual.

3.2 Selecting Type of Erosion Protection

Riprap protection downstream of culverts is considered for most situations where moderate outlet hydraulics govern (i.e., culvert exit velocities < 15 ft/sec). It is highly recommended that the designer use a low tailwater basin when a storm drain enters a drainageway at an approximate right angle, and drop structures or riprap lining should be used to guard against erosion for in-line culvert outlets on major drainageways.

In general, concrete structures are large, uncharacteristic of the natural environment, and require special safety and maintenance considerations. Concrete structures will not be approved in areas that are intended to complement the natural environment when other alternatives are feasible. Cases where a concrete stilling basin structure may be considered include situations where exit velocities are extremely high, turbulence at a conduit outlet is expected to be severe, and/or where space is particularly limited.

Table 10-1. Erosion Protection at Conduit Outlets

Erosion Protection Types	UDFCD Manual Chapter	Use For	Do Not Use For
1. Riprap Lining (Section 4.1)	Major Drainage	<ul style="list-style-type: none"> ▪ Receiving channel on same line and grade ▪ Storm sewer and culvert outlets ▪ In-line culvert outlets ▪ Velocities < 15 ft/sec ▪ High tailwater ▪ Fish passage 	<ul style="list-style-type: none"> ▪ Velocities > 15 ft/sec ▪ Wetland channels
2. Low Tailwater Stilling Basin (Section 4.2)	Hydraulic Structures	<ul style="list-style-type: none"> ▪ Storm sewer and culvert outlets ▪ Velocities < 15 ft/sec ▪ Low tailwater 	<ul style="list-style-type: none"> ▪ Velocities > 15 ft/sec ▪ Confined receiving area ▪ Major drainageways ▪ Areas where standing water is unacceptable
3. Concrete Impact Stilling Basin (Section 4.3)	Hydraulic Structures	<ul style="list-style-type: none"> ▪ Storm sewer outlets ▪ Velocities > 15 ft/sec ▪ Low tailwater 	<ul style="list-style-type: none"> ▪ In-line culvert outlets ▪ High visibility areas
4. Concrete Baffle Chute (Section 4.4)	Hydraulic Structures	<ul style="list-style-type: none"> ▪ Storm sewer outlets ▪ Velocities > 15 ft/sec ▪ Low tailwater ▪ Degrading channel 	<ul style="list-style-type: none"> ▪ In-line culvert outlets ▪ High debris potential ▪ High visibility areas
5. Drop Structures	Hydraulic Structures	<ul style="list-style-type: none"> ▪ Wetland channels ▪ Low rise box culverts or small diameter pipes where plugging is possible ▪ In-line culvert outlets 	<ul style="list-style-type: none"> ▪ Confined receiving area ▪ Fish passage

4.0 Design of Outlet Erosion Protection

4.1 Riprap Lining

The procedure for designing riprap for culvert outlet erosion protection is provided in 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 cause rock movement in this region. Protection is required under the conduit barrel and an end slope is necessary to accommodate degradation of the downstream channel.

4.2 Low Tailwater Stilling Basins

The majority of storm sewer pipes discharge into open drainageways, where the receiving channel may have little or no flow when the conduit is discharging. Uncontrolled pipe velocities have the potential to 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, minimizing scour at the channel bottom.

Low tailwater is defined as being equal to or less than one-third of the storm sewer diameter/height and is based on the depth of flow in the receiving channel during the minor design storm event. Design criteria for low tailwater riprap basins for circular and rectangular pipe are provided in the Hydraulic Structures Chapter of the UDFCD Manual.

4.3 Concrete Impact Stilling Basin

The use of concrete impact stilling basins is discouraged where moderate outlet conditions exist, but there are situations when the design engineer may have to consider using an impact stilling basin. Those situations are generally discussed in the Hydraulic Structures Chapter of the UDFCD Manual. Impact stilling basins shall be designed in accordance with the Hydraulic Structures Chapter of the UDFCD Manual.

Design standards for an impact stilling basin are based on the United States Bureau of Reclamation (USBR) 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.

Generally, the configuration consists of an open concrete box attached directly to the conduit outlet. The Hydraulic Structures Chapter of the UDFCD Manual provides a figure illustrating the general design for the impact stilling basin.

The standard USBR design above will retain a standing pool of water in the basin bottom that is generally undesirable from an environmental and maintenance standpoint. The Hydraulic Structures Chapter of Volume 2 of the UDFCD Manual modifies the standard USBR design to allow drainage of the basin bottom during dry periods. These modifications are shown in figures providing examples of the modified end wall design to allow basin drainage for urban applications and providing details of a “mini” impact basin that can be used for small pipe diameters from 18 inches to 36 inches.

4.4 Concrete Baffle Chute

The use of concrete baffle chutes is discouraged where moderate outlet conditions exist, but there are situations when the design engineer may have to consider using a concrete baffle chute. Those situations are generally discussed in the Hydraulic Structures Chapter 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 (USBR Type IX baffled apron) has been modified slightly by UDFCD so it can be used with a conduit instead of an open channel. The Hydraulic Structures Chapter of the UDFCD

Manual provides some design and construction details for this type of basin, along with a figure providing an example of the general design for the baffle chute pipe outlet. Although this outlet dissipates energy along the slope, 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.

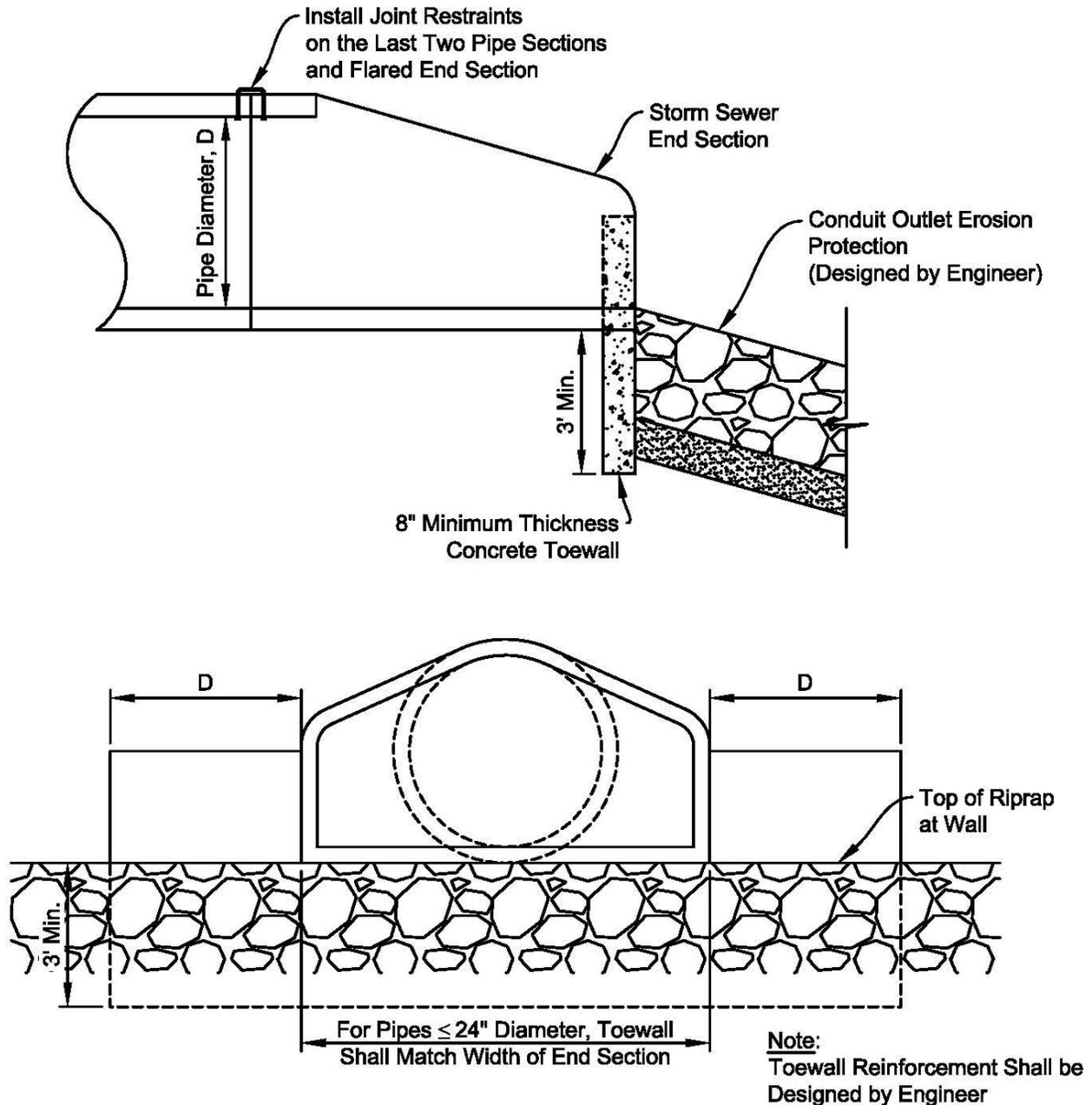


Figure 10-1. Conceptual Toewall Detail