Chapter 8 - Storm Drain Structures

Storm drain structures provide the connections between the ground surface and the storm drain system and between storm drain conduits. These structures include inlets, access holes, and junction chambers. Other miscellaneous storm drain components include transitions, flow splitters, siphons, and flap gates.

Most State DOTs develop their own design standards for commonly used structures resulting in variations in the design details of even the simplest storm drain structures. Recognizing that design details vary, this chapter describes common features and functions of storm drain structures.

8.1 Inlet Structures

Inlet structures, sometimes referred to as catch basins, allow surface water to enter the storm drainage system. Inlet structures also provide access points for cleaning and inspection.

8.1.1 Configuration and Materials

Figure 8.1 illustrates several typical box-shaped inlet structures including a standard drop inlet, inlet with a sump, curb inlet, and combination inlet. Chapter 7 covers the hydraulic design of surface inlets.

The inlet illustrated in Figure 8.1b captures surface flow in a similar way to a drop inlet but also has a sump that retains sediment and debris transported by stormwater into the storm drainage system. To be effective and to avoid becoming an odor and mosquito nuisance, inlet sumps involve periodic cleaning. However, in areas with site constraints that place storm drains on relatively flat slopes, and where the DOT follows a strict maintenance plan, inlets can serve to collect sediment and debris. Chapter 11 discusses storm drain inlets designed specifically to remove sediment, oil, and debris.

DOTs most commonly use cast-in-place concrete and pre-cast concrete for inlet construction.

8.1.2 Location

Chapter 7 describes inlet spacing based on where they are needed to capture surface flow. Below ground, designers locate inlet structures at the upstream end and at intermediate points along a storm drain line. Designers generally use an iterative process to locate inlet structures to produce an economical and hydraulically effective system.

8.2 Access Holes

Access holes provide convenient access to the storm drainage system for inspection and maintenance. Access holes also serve as flow junctions and can provide ventilation and pressure relief for storm drainage systems. An access hole provides pressure relief if its access door is not water-tight and allows water to escape to the surface when the hydraulic grade line (HGL) reaches the surface. Designers may select water-tight access doors to prevent escape when warranted.

Access holes do not accept surface flows as inlets do. Where access and surface water interception are desirable, designer use inlets rather than access holes.

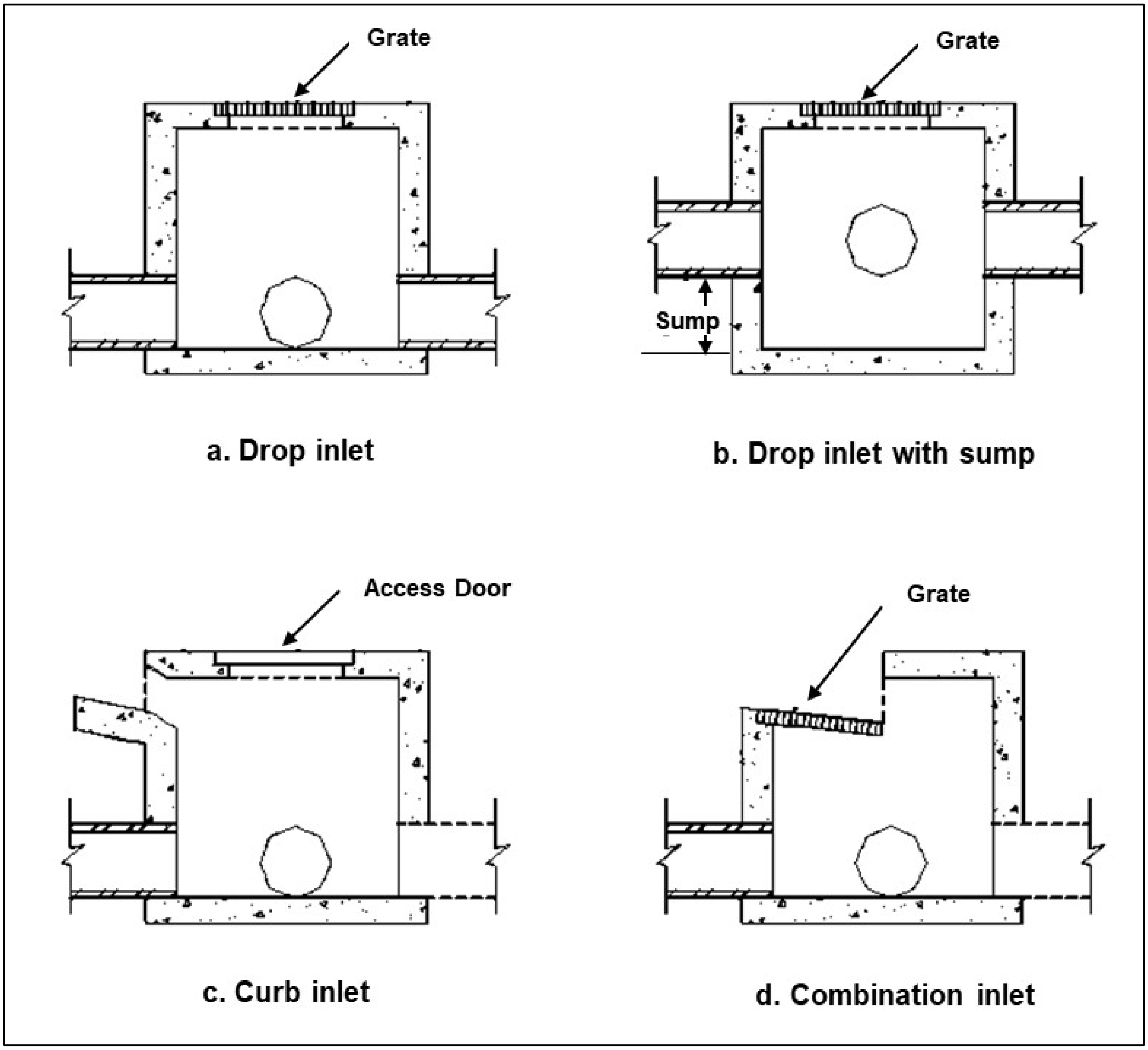

Figure 8.1. Inlet structures (elevation view).

8.2.1 Configuration and Materials

Designers use many configurations but orient the access hole so that workers can safely enter it while facing traffic if traffic exists. Access steps provide a means of convenient access and comply with applicable safety requirements. Using corrosion resistant materials for the steps (e.g., steps coated with neoprene or epoxy, or steps fabricated from rust-resistant material such as stainless steel or aluminum coated with bituminous paint), enhances safety and longevity.

Some access hole configurations do not include steps. Rather, maintenance personnel supply their own ladders to avoid safety issues associated with rust-damaged steps and to restrict access.

Typically, the access shaft (cone) provides a minimum horizontal clear opening of 24 inches. Most access holes are circular with the inside dimension of the bottom chamber being sufficient to perform inspection and cleaning operations without difficulty. Bottom chambers typically include a minimum inside diameter of 4 ft with a 5 ft inner diameter access hole being used with larger diameter connecting storm drain pipes.

In some cases, a smaller access shaft aligns concentrically with the bottom chamber. Figure 8.2a displays a constant diameter bottom chamber up to a conical section a short distance below the top. In other design configurations, the access shaft and bottom chamber align to provide a vertical series of steps for easier access. Figure 8.2b illustrates a practice that uses an eccentric cone for the access shaft.

Figure 8.2c shows an option that maintains the bottom chamber diameter to a height sufficient for adequate working space. This design tapers to 3 ft for the access shaft. The frame rests on the broad base of the access shaft. Because of the inward leaning angle of the steps in the access shaft, designers typically limit these configurations to bottom chambers 3 ft in diameter or less.

Figure 8.2d illustrates a design that minimizes the access shaft height and features a removable flat precast concrete slab that facilitates addressing more extensive maintenance needs. Designers prefer these tangent alignments for access holes with bottom chamber diameters 4 ft or greater.

The size of the bottom chamber limits the size of storm drain conduits that can connect to it. For larger storm drain conduits that are not readily accommodated by typical access hole structure configurations, designers could choose a vertical riser connected to the storm drain pipe with a "tee" unit as illustrated in Figure 8.3.

The configurations in Figure 8.2 represent variations of channels and benching at the bottom of the access hole. Many access holes do not include benching, which designers refer to as a "no benching" configuration. Flow channels provide a smooth, continuous path for the flow, reducing turbulence and, therefore, energy losses in the access hole. The bench elevates the bottom of the access hole on either side of the flow channel further increasing the hydraulic efficiency of the access hole. Because of the added cost associated with benching, designers use it when the HGL is relatively flat and there is no appreciable head available. Chapter 9 discusses energy losses and benching in greater detail.

Access hole frames and covers provide adequate strength to support superimposed loads, provide a fit between cover and frame, facilitate opening while providing resistance to unauthorized opening (especially from children), and prevent blowouts. To differentiate storm drain access holes from other underground utility access such as for sanitary sewers and communication conduits, good practice includes the words "STORM DRAIN" or equivalent cast into the top surface of the covers. Blowouts may occur during a flood event when the HGL in the access hole rises above the ground surface with sufficient pressure to move the cover from its normal position on the frame. To prevent blowouts, designers can provide openings to release surcharged flow or secure the cover in the frame with bolts or another type of locking mechanism.

Designers most commonly use pre-cast concrete and cast-in-place concrete when selecting materials for access holes. In most areas, the availability and competitive cost of pre-cast concrete access holes make them popular. They may include cast-in-place steps at the desired locations and special transition sections to reduce the diameter of the access hole at the top to accommodate the frame and cover. The transition sections are usually eccentric with one side vertical to accommodate access steps.

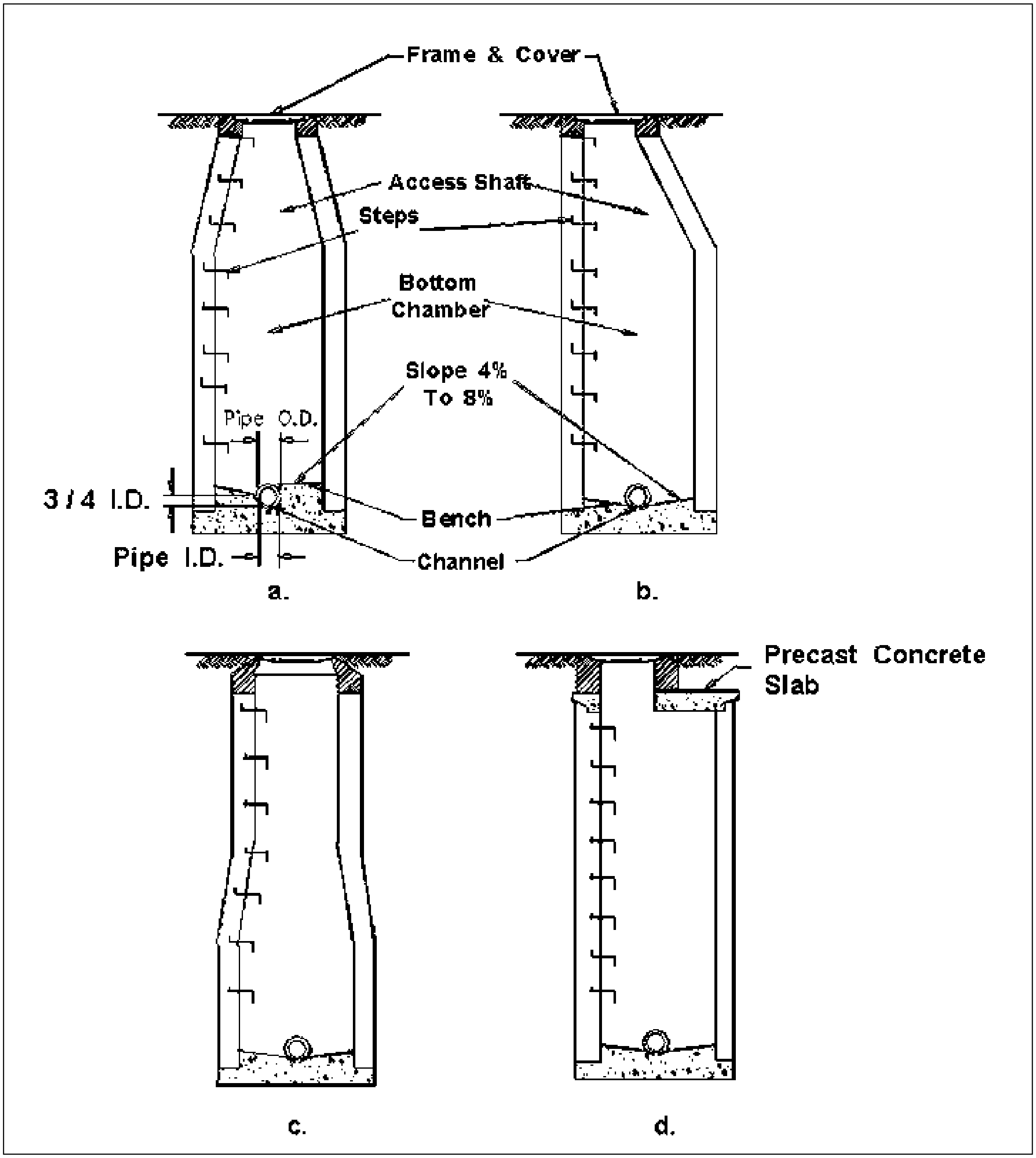

Figure 8.2. Typical access hole configurations.

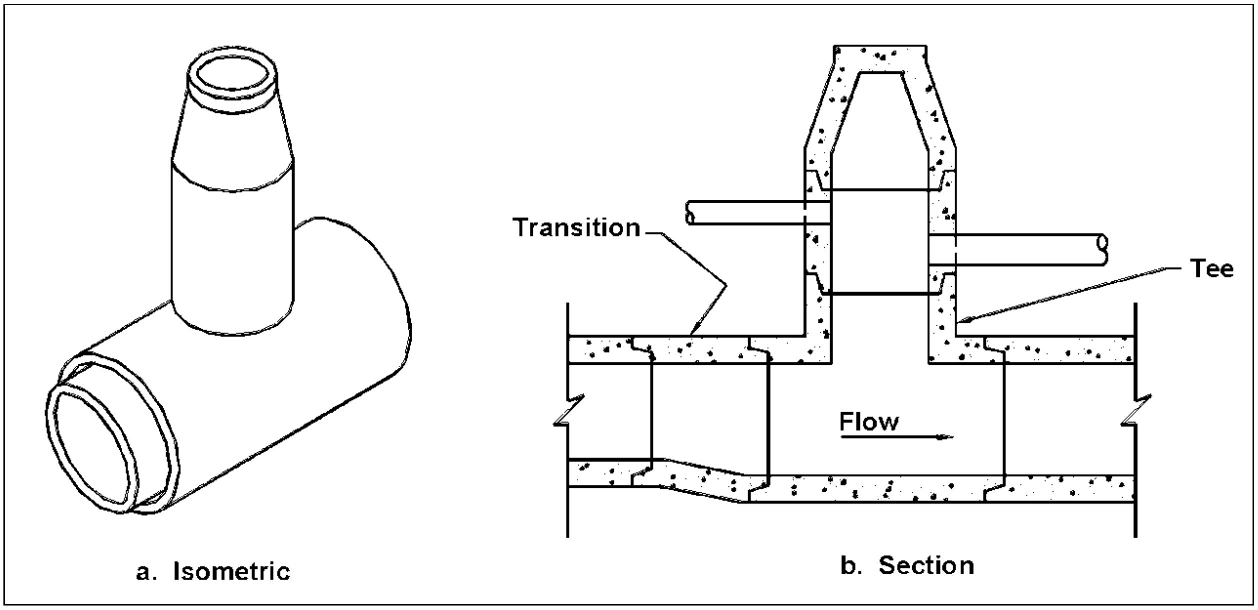

Figure 8.3. “Tee” access hole for large storm drains.

8.2.2 Depth, Location, and Spacing

Access hole depth, location, and spacing depend on design criteria related to hydraulic effectiveness, structural integrity, and maintenance. Chapter 9 (Storm Drain Conduits) describes many of these criteria and how they affect storm drain system design.

The storm drain profile and surface topography contribute to access hole depth. Typically, access hole depths range from 5 to 13 ft. In some circumstances, for example, to avoid other utilities, designers may specify access hole depths outside this range.

Irregular surface topography sometimes results in shallow access holes. When the depth to the invert is only 2 to 3 ft, all maintenance operations can be conducted from the surface. However, because maintenance activities are not comfortable from the surface, even at shallow depths, designers specify the same access hole widths used for bottom chambers of greater depths (4 to 5 ft). To enable a worker to stand in the access hole for maintenance operations, designers will include a large cover with a 2.5 to 3.0 ft opening. Access hole dimensions typically conform to applicable design standards which comply with pertinent safety requirements.

Structurally, access holes withstand soil pressure loads that increase with depth. In addition, access holes that extend below the water table withstand hydrostatic pressure and prevent excessive seepage. Since long portable ladders for deep access holes would be cumbersome and could be dangerous, designers provide access with either steps or built-in ladders that conform to applicable design standards and safety requirements.

Access hole location and spacing criteria consider maintenance access and equipment limitations. Although these criteria vary from jurisdiction to jurisdiction, designers often place access holes where:

- Two or more storm drains converge.
- Pipe sizes change.
- A change in horizontal alignment occurs.
- A change in vertical alignment occurs.

In addition, designers locate access holes at intermediate points along straight runs of storm drain in accordance with applicable spacing criteria. Table 8.1 shows example spacing criteria, but designers use the criteria from the jurisdiction within which they are working.

Table 8.1. Example access hole spacing criteria (AASHTO 2000).

Pipe Size (in)	Suggested Maximum Spacing (ft)
12 – 24	300
27 – 36	400
42 – 54	500
60 and up	1000

8.3 Junction Chambers

A junction chamber is an underground chamber used to join two or more large storm drain conduits. Designers commonly use this type of structure where storm drains are larger than the size that can be accommodated by standard access holes and may be rectangular, circular, or irregular in shape. Unlike access holes, junction chambers do not typically extend to the ground surface and can be completely buried. However, designers often include riser structures to provide surface access or to intercept surface runoff. Where junction chambers are used as access points for the storm drain system, designers follow the same criteria appropriate for access holes as discussed in Section 8.2.2.

To minimize flow turbulence and, therefore energy losses, in junction chambers, designers can include flow channels and benches in the bottom to guide flow through the chamber. Chapter 9 describes the use of benching and energy loss computations in more detail.

Designers commonly use pre-cast concrete and cast-in-place concrete for junction chamber construction materials. Storm drains constructed of corrugated metal may have junction chambers made of the same material.

8.4 Other Structural Components

In addition to inlet structures, access holes, and junction chambers, designers employ other structural components to connect elements of a storm drain system or to serve purposes not needed in many systems. These include transitions, flow splitters, siphons, and flap gates.

8.4.1 Transitions

In storm drainage systems, transitions from one pipe size to another typically occur in access holes or junction chambers. Where maintenance access is not needed, designers use transitions to avoid obstructions, to join different pipe sizes, and to join different conduit shapes. Figure 8.4 illustrates a transition where a rectangular pipe transition is used to avoid an obstruction. Figure 8.3 illustrates use of a transition upstream of tee type access holes.

Because abrupt transitions increase turbulence and energy loss, designers provide smooth, gradual transitions to minimize head losses whenever feasible. For example, when the flow velocity is less than 20 ft/s, designers typically use a 5:1 to 10:1 transition ratio for both expansion and contraction in the straight wall configuration shown in Figure 8.4a. For higher velocities, more gradual transition ratios of 10:1 to 20:1 reduce energy losses further.

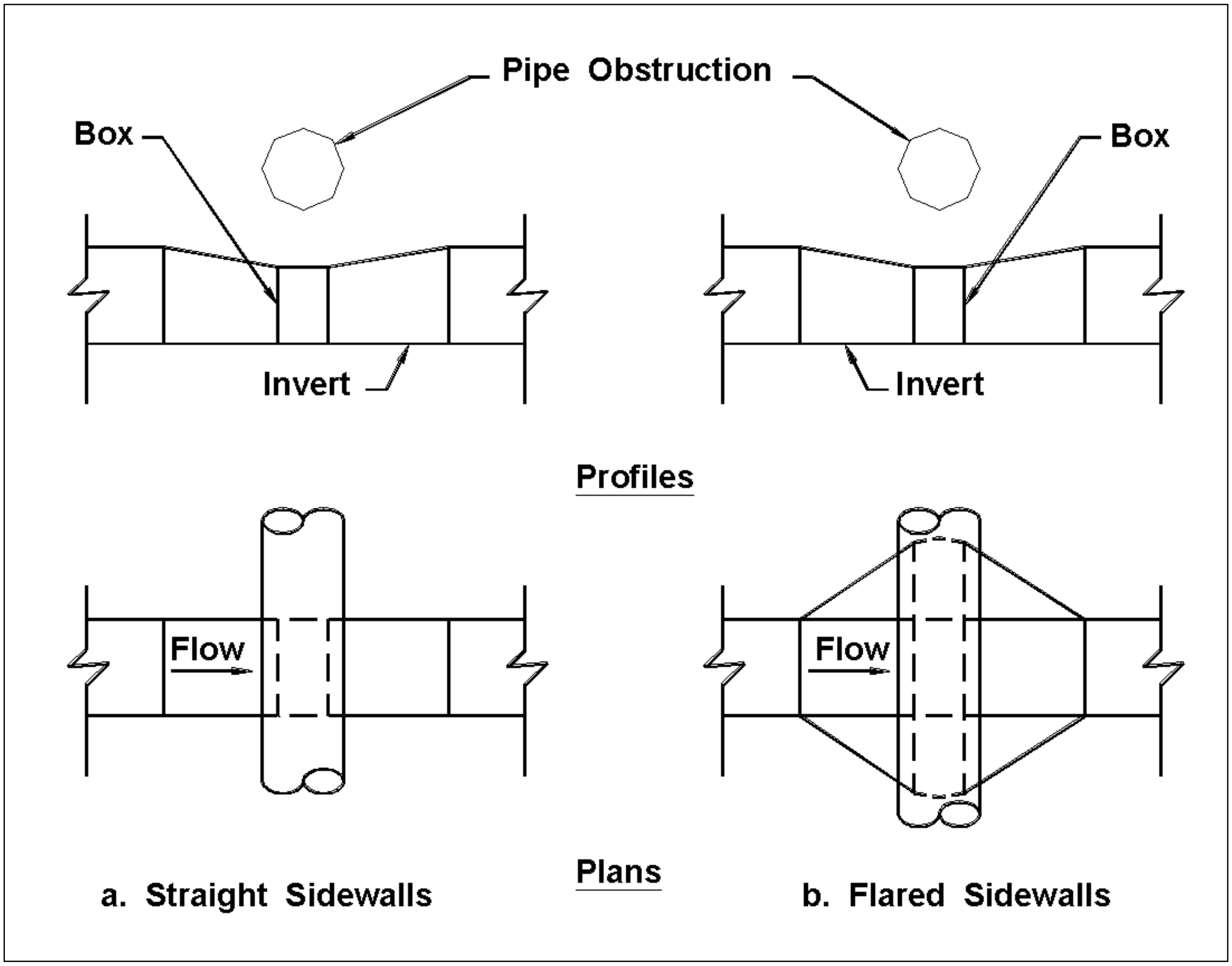

Figure 8.4. Transitions to avoid obstruction.

8.4.2 Flow Splitters

A flow splitter divides flow in an incoming storm drain conduit into two or more outgoing conduits for applications where high flows are diverted away from locations with limited capacity, e.g., water quality devices. As with other structures, designers consider how to minimize the unavoidable energy loss at the point of flow division and within the structure. Deflectors can guide flow through the structure and reduce energy losses. Where possible, designers avoid regions of flow velocity reduction that can cause deposition of material suspended in the stormwater flow.

Designers also seek to avoid capturing debris within the structure. If one of the outgoing conduits is smaller than the incoming conduit carrying debris, the debris can be captured by the outgoing conduit. Because of sediment deposition and debris capture, flow splitters can become maintenance intensive. Although flow splitters can be designed without maintenance access like junction chambers, designers generally provide for maintenance access.

8.4.3 Inverted Siphons

An inverted siphon or depressed pipe carries flow under an obstruction such as a utility conduit, stream, or depressed highway minimizing the energy loss. Figure 8.5 depicts a twin-barrel inverted siphon carrying flow under a river. Inverted siphons can consist of single or multiple barrels; however, the American Association of State Highway and Transportation Officials (AASHTO)suggests a minimum of two barrels (AASHTO 2014). Multiple barrels allow one barrel to operate for lower flows with additional barrels becoming active with higher flows. Regardless of the number of barrels, the lowered section of the inverted siphon does not drain by gravity when the flow stops, and the designer may wish to consider means for draining this section after each storm.

Designers can avoid sediment deposits in the lowered section by designing for sufficiently high velocities over a range of flows to flush any deposits. Designers can also facilitate flushing of sediment deposits by limiting the slope of the rising portion of the lowered section to a maximum of 15 percent or jurisdictionally specified value. Designers may include a sump in the inlet chamber to collect sediment prior to entering the siphon.

To minimize energy losses, debris capture, and sedimentation, designers avoid sharp bends and maintain a constant conduit section throughout the lowered section. Because inverted siphons are generally not maintenance free, designers plan for cleaning and maintenance.

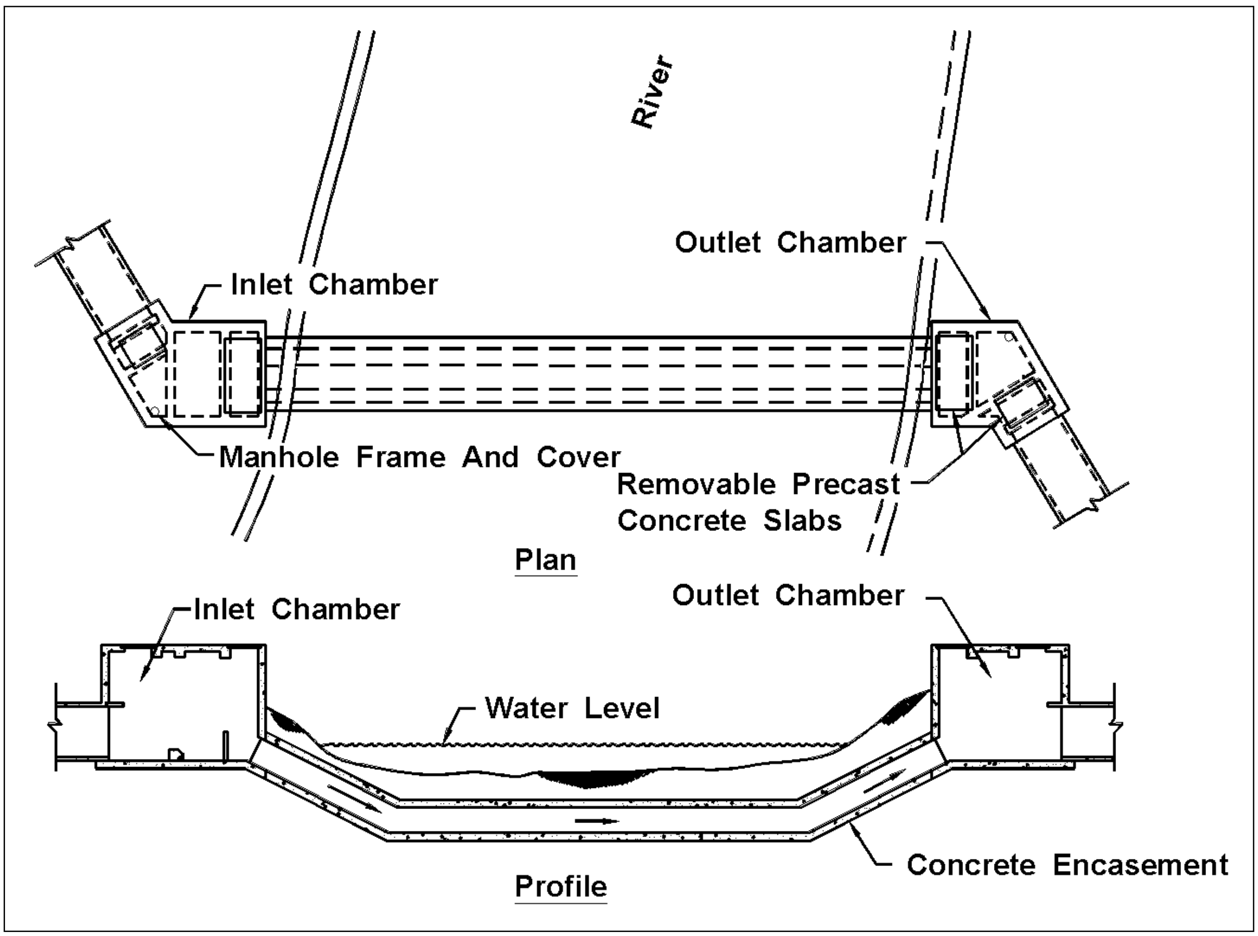

Figure 8.5. Twin-barrel inverted siphon.

8.4.4 Flap Gates

Designers use flap gates to prevent back-flooding of a drainage system outlet in the presence of high tides or high stages in receiving waters. During rainstorms, properly functioning flap gates open in response to the hydrostatic pressure from the stormwater in the conduit allowing discharge to the receiving waters. With high receiving water levels, the hydrostatic pressure from the receiving water keeps the flap gate in a closed position for the purpose of preventing water from entering the storm drain system. When rainstorms and high receiving water levels occur simultaneously, the dominant hydrostatic force, combined with the weight of the flap gate, determines whether the flap gate opens or closes. To avoid storm drain backups, the designer considers the probability and consequences of the situation where the receiving water hydrostatic force dominates and restricts discharge during a rainstorm.

Sediment, organic materials, and trash can impair the functioning of outlet conduits with flap gates by reducing the conveyance of the conduit. The reduction of flow velocity behind a closed or partially open flap gate may also cause sediment deposition in the storm drain near the outlet. Organic materials and trash from the storm drain system or the receiving waters can collect between the flap and seat preventing full closure of the flap gate. In addition, where a flap gate is mounted on a pipe projecting into a stream, the designer considers how to protect the conduit and flap gate from damage by woody material or ice during high flows. Flap gate installations depend on regular inspection and removal of accumulated sediment, organic materials, and trash to serve their intended function.

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