Chapter 11 - Urban Stormwater Quality

This chapter provides an overview of urban stormwater quality practices specific to roadway applications. The purpose of an urban best management practice (BMP) is to mitigate the adverse impacts of development activity. BMPs can provide stormwater control benefits and pollutant removal capabilities. Evaluation of the available BMP options considers site-specific conditions and overall watershed management objectives. Often, requirements for water quality practices derive from those for the National Pollution Discharge Elimination System (NPDES) Program under the Clean Water Act as discussed in Chapter 2. [33 U.S.C. § 1342]. Local ordinances and regulations vary and may not require water quality practices in specific project locations. Early coordination with project environmental specialists assists in the recognition of water quality requirements and can facilitate identification and design of effective BMPs.

11.1 BMP Alternatives and Selection

Engineers consider several factors to determine the suitability of a particular BMP: physical conditions at the site, the watershed area, stormwater quantity objectives, and water quality objectives. Malhotra and Normann (1994) developed a matrix of site selection criteria for several BMPs and outlined site selection restrictions for each BMP. The Watershed-Based Stormwater Mitigation Toolbox (WBSMT), a spreadsheet-based planning level tool, uses nationally available geographic information systems (GIS) data to help State Departments of Transportation (DOTs) identify and prioritize potential stormwater runoff mitigation opportunities (NASEM 2017).

Schueler (1987) provided a comparative analysis of pollutant removal for various BMP designs. Generally, BMPs provide high pollutant removal for non-soluble particulate pollutants, such as suspended sediment and trace metals. BMPs typically achieve much lower rates for soluble pollutants, such as phosphorus and nitrogen.

Best Management Practices

In 1977, the Clean Water Act (CWA) introduced the concept and term, “best management practices” (BMPs) as an approach to controlling water pollution. BMPs manage stormwater by mitigating:

- Quantity – attenuate urbanized peak flows and store runoff volumes.
- Quality – reduce pollutant loads.
- Source – prevent or reduce the introduction of pollutants to stormwater with nonstructural measures.

An important parameter BMP designers consider is the runoff volume treated, often called the first flush volume or the water quality volume (WQ_V). This initial flush of runoff carries the most significant non-point pollutant loads. Methods to quantify the first flush or WQ_V vary. Most commonly, engineers estimate first flush volume as:

- The first 0.5 inch of runoff of impervious area.
- The first 0.5 inch of runoff of the entire catchment area.
- The first 1.0 inch of rainfall resulting in runoff from the entire catchment area.

In general terms, the greater the volume treated, the better the pollutant removal efficiency. However, treating volumes in excess of 1.0 inch of catchment area results in only minor improvements in pollutant removal efficiency (Schueler 1987).

In addition to Malhotra and Normann (1994) and Schueler (1987), researchers have created additional resources addressing BMP selection, performance, and evaluation of alternatives:

- *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring* (FHWA 2000).
- *State of the Practice in Data Collection and Performance Measurement* (FHWA 2014a).
- *Stochastic Empirical Loading and Dilution Model (SELDM)* for evaluating the adverse effects of runoff from highway projects (Granato 2013).

11.2 Pollutant Loads

Estimated pollutant loadings for both pre- and post-development scenarios indicate the impact of highway development activities in a watershed. Several methods and models employ algorithms for pollutant loading estimation. The aptly named, empirical Simple Method applies to sites of less than 1 mi^2 (Schueler 1987). To yield an average annual loading estimate, L, the following equation multiplies an average pollutant concentration by the annual runoff.

$$L = c\,R\,C\,A \tag{11.1}$$

where:

L	=	Average annual loading, lb (chemical constituents) or billion colonies (bacteria)
c	=	Unit conversion factor, 0.226 (chemical) or 103 (bacteria)
R	=	Annual runoff (inch)
C	=	Pollutant concentration (mg/l) for chemical constituents
	=	Bacteria concentration (1,000/ml) for bacteria
A	=	Area (ac)

The FHWA developed a computer model that characterizes stormwater runoff pollutant loads from highways and predicts impacts to receiving water, specifically lakes and streams. The four-volume FHWA report *Pollutant Loadings and Impacts from Highway Stormwater Runoff* (Driscoll 1990) contains more detail on the estimating procedures.

More recently, the FHWA, in cooperation with the U.S. Geological Survey (USGS), developed the highway runoff database (HRDB) (FHWA 2009) and the SELDM to estimate and simulate stormflow volumes, concentrations, and loads of highway and urban runoff constituents (Granato 2013, USGS 2020). HRDB and SELDM provide data, tools, and techniques to help transform complex scientific data into meaningful information about the risk of adverse effects of runoff on receiving waters, the potential need for mitigation measures, and the potential effectiveness of such management measures for reducing these risks (Granato 2013, Granato 2014, Granato and Jones 2019).

Several other stormwater management software applications and tools can generate pollutant loads and the fate and transport of the pollutants:

- Stormwater Management Model (SWMM) (USEPA 2020).
- Storage, Treatment, Overflow, Runoff Model (STORM) (USACE 1977).
- Hydrologic Simulation Program, Fortran (HSPF) (USEPA 2002).
- Spreadsheet Tool for Estimating Pollutant Loads (STEPL) (USEPA 2018).

11.3 Structural BMPs

Structural BMPs consist of stormwater management facilities, created by moving earth, planting vegetation, or construction, or a combination of these elements. Storage and infiltration BMPs represent the two categories of structural BMPs.

11.3.1 Storage BMPs

Storage BMPs include extended detention dry ponds or wet ponds. They function primarily to store stormwater runoff and remove pollutants by promoting settling.

11.3.1.1 Extended Detention Dry Ponds

Following a storm event, extended detention dry ponds temporarily store a portion of stormwater runoff in depressed basins. These facilities typically store water for up to 48 hours following a storm by means of a hydraulic control structure to restrict outlet discharge. The extended detention of the stormwater provides an opportunity for urban pollutants carried by the flow to settle out. The water quality benefits of a detention dry pond increase by extending the detention time. If the pond retains stormwater for 24 hours or more, it can remove as much as 90 percent of particulates. However, extended detention only slightly reduces levels of soluble phosphorus and nitrogen found in urban runoff. Extended detention dry ponds typically do not have a permanent water pool between storm events.

Figure 11.1 shows the plan and profile views of an extended detention facility. In addition to the storage area, such facilities may include a stabilized low flow channel, an extended detention control device (riser with hood), and an emergency spillway.

Extended detention dry ponds reduce the frequency of erosive floods downstream, depending on the quantity of stormwater detained and the time over which stormwater is released. A cost-effective BMP, extended detention rarely involves construction costs more than 10 percent above those for conventional dry ponds that have shorter detention times and are used as a flood control device.

Extended detention dry ponds benefits may include creation of local wetland and wildlife habitat, limited protection of downstream aquatic habitat, and recreational use opportunities in the infrequently inundated portion of the pond. Negative impacts may include occasional nuisance and aesthetic problems in the inundated portion of the pond (e.g., odor, debris, and weeds); moderate to high routine maintenance requirements; and the eventual need for sediment removal. Extended detention generally applies to most new development situations and presents an attractive option for retrofitting existing dry and wet ponds.

11.3.1.2 Wet Ponds

A wet pond, or retention pond, serves the dual purpose of controlling the volume of stormwater runoff and treating the runoff for pollutant removal. Wet ponds store a permanent pool during dry weather. Hydraulic outlet devices designed to discharge flows at various elevations and peak flow rates release overflow from wet ponds. Figure 11.2 shows a plan and profile view of a typical wet pond and its components.

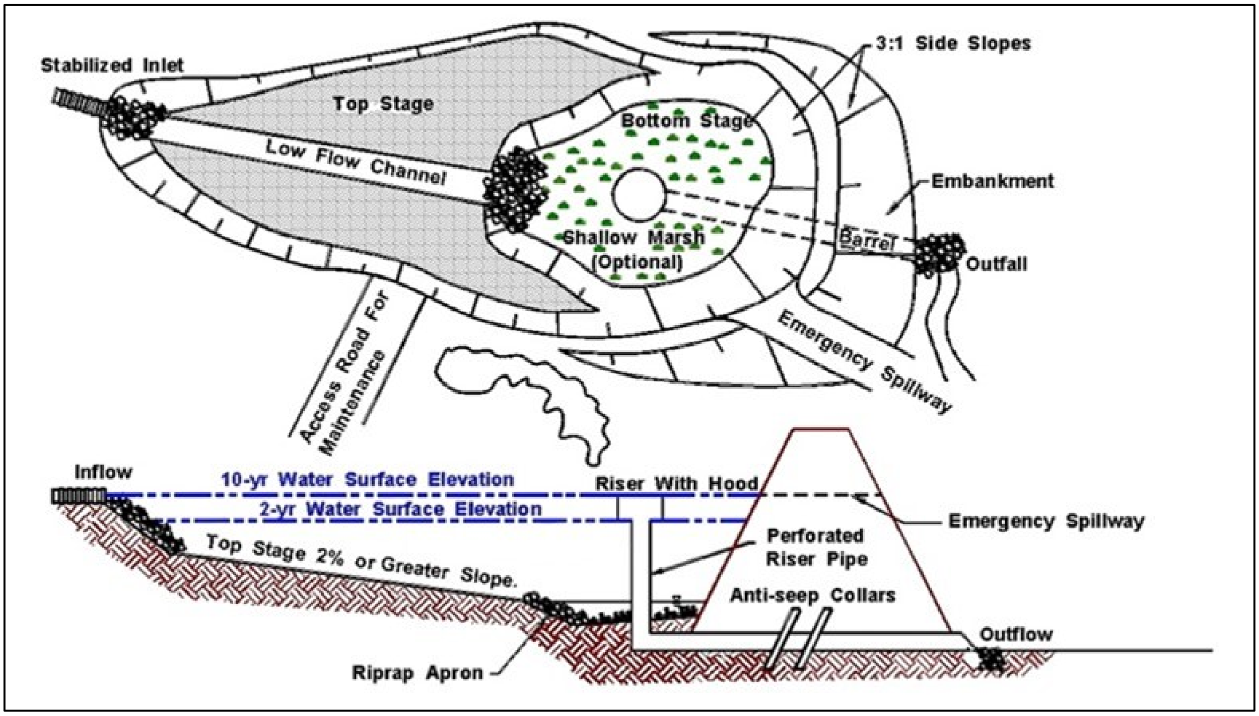


Figure 11.1. Extended detention pond.

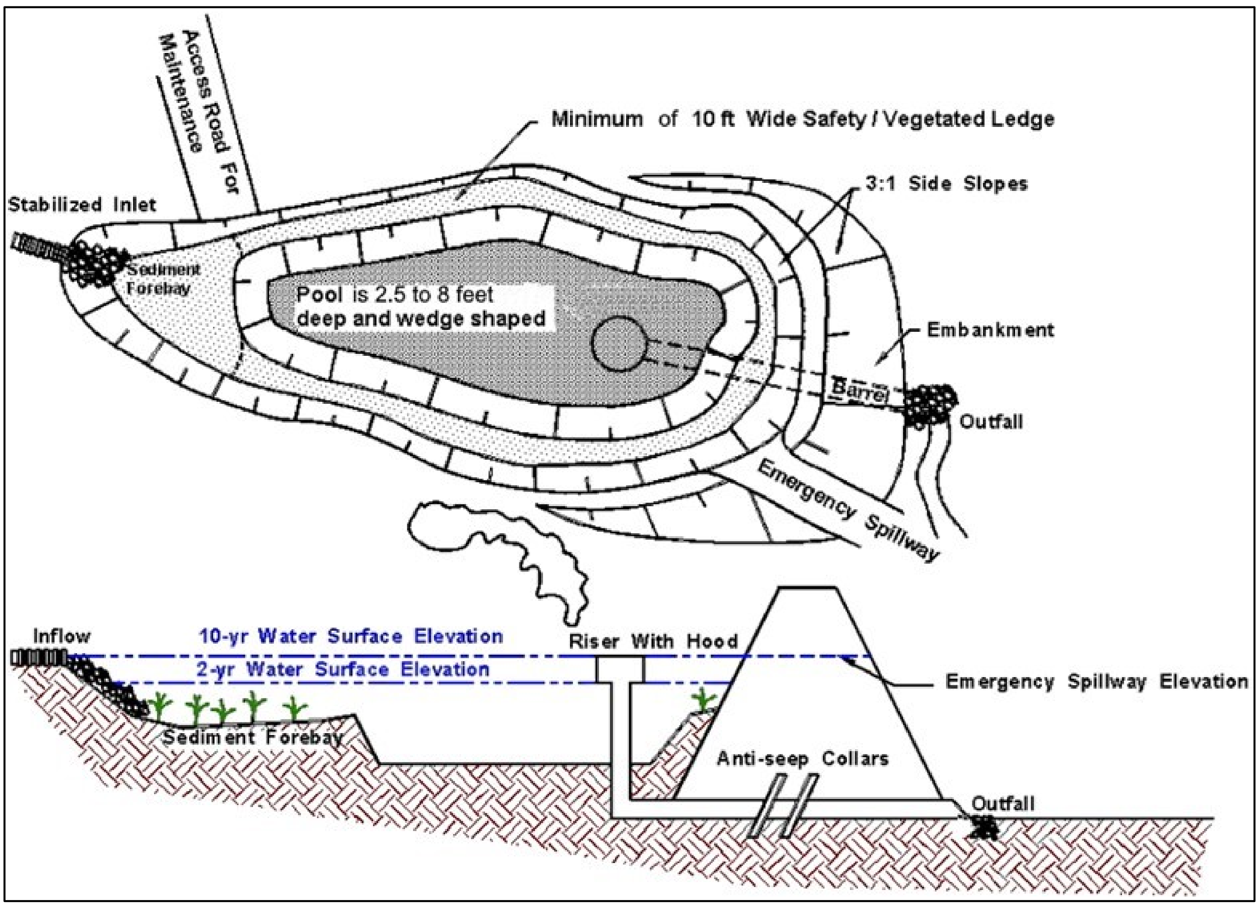


Figure 11.2. Typical wet pond schematic.

Wet ponds represent an effective water quality BMP. If properly sized and maintained, wet ponds can achieve a high removal rate of sediment, biological oxygen demand, organic nutrients, and trace metals. Biological processes within the pond also remove soluble nutrients (nitrate and ortho-phosphorus) that contribute to nutrient enrichment (eutrophication). Wet ponds are most cost-effective in larger, more intensively developed sites. Positive impacts of wet ponds can include creation of local wildlife habitat; higher property values; recreation; and landscape amenities. Negative impacts can include possible upstream and downstream habitat degradation; downstream sediment imbalance; potential safety hazards; occasional nuisance problems (e.g., odor, algae, and debris); and the eventual need for costly sediment removal.

11.3.2 Infiltration BMPs

Infiltration BMPs function primarily to remove pollutants by percolating stormwater runoff through soil strata. Common applications of infiltration BMPs include infiltration/exfiltration trenches, infiltration basins, and sand filters.

11.3.2.1 Infiltration/Exfiltration Trenches

Infiltration trenches are shallow excavations which have been backfilled with a coarse stone media. The trench forms an underground reservoir which collects runoff and either exfiltrates it to the subsoil or diverts it to an outflow facility. The trenches primarily serve as a BMP providing moderate to high removal of fine particulates and soluble pollutants, but they also serve to reduce peak flows. Infiltration trenches only work with permeable soils and where the seasonal groundwater table is below the bottom of the trench. Figure 11.3 shows an example of surface trench design (Schueler 1987). Engineers frequently use infiltration trenches for highway median strips and parking lot "islands" (depressions between two lots or adjacent sides of one lot). The components of an infiltration trench can include backfill material, observation wells, permeable filter, overflow pipes, emergency overflow berms, and a vegetated buffer strip.

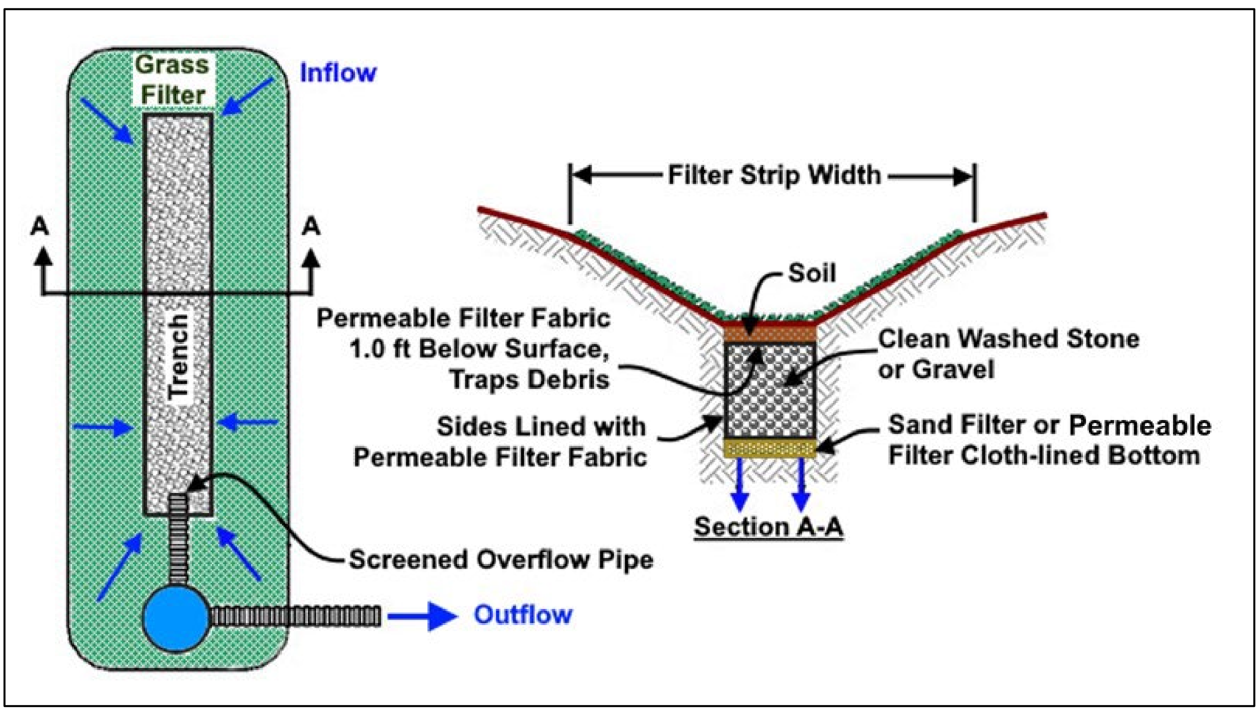


Figure 11.3. Median strip trench design.

Advantages of infiltration trenches include preservation of the natural groundwater recharge capabilities of a site and the relative ease of fitting them into the margins, perimeters, and other unused areas of a development site. Few other BMPs offer pollutant removal on small sites or infill developments.

The disadvantages associated with infiltration trenches include practical difficulties in keeping sediment out of the structure during site construction (particularly if development occurs in phases), the need for careful construction of the trench and regular maintenance thereafter, and a possible risk of groundwater contamination. Frequent clogging involves routine maintenance, which has a cost impact. Designers may wish to examine the limitations, risks, and benefits of infiltration BMPs in the context of the built and natural environments (e.g., surface water, groundwater, soils, and infrastructure) (NASEM 2019).

There are three basic trench systems: complete exfiltration, partial exfiltration, and water quality exfiltration. In a **complete exfiltration system**, water can exit the trench only by passing through the stone reservoir and into the underlying soils (i.e., it includes no positive pipe outlet from the trench). As a result, the stone reservoir must be large enough to accommodate the entire expected design runoff volume, less any runoff volume lost via exfiltration during the storm. The complete exfiltration system provides total peak flow, volume, and water quality control for all rainfall events less than or equal to the design storm. To handle any excess runoff from storms greater than the design storm, a rudimentary overflow channel, such as a shallow berm or dike, may be included.

A **partial exfiltration system** offers an alternative where complete reliance on exfiltration to dispose of runoff may not be possible or prudent. For example, designers may be concerned about the long-term permeability of the underlying soils, downstream seepage, or clogging at the interface between the filter fabric and subsoil. To address this, a partial exfiltration system includes a perforated pipe to collect water and direct it to an outlet.

If the designer locates the perforated pipe as an underdrain at the bottom of the trench, the underdrain will collect and convey a high percentage of the water that has not yet exfiltrated from the trench. As a result, these designs may only act as a short-term underground detention system. Together, the low exfiltration rates and short residence times can result in poor pollutant removal and hydrologic control.

Engineers can improve the performance of partial exfiltration systems during smaller storms by including a perforated pipe near the top of the trench. In this design, runoff will not exit the trench through the pipe until it rises to the level of the outlet pipe. Storms with less volume than the design storm may never fill the trench to this level and will be subject to complete exfiltration.

In either design, engineers can analyze the passage of the inflow hydrograph through the trench with hydrograph routing procedures to determine the appropriate sizing of the trench. Due to storage and timing effects, partial exfiltration trenches will be smaller in size than full exfiltration trenches serving the same site.

For a **Water Quality Exfiltration System**, engineers design the storage volume of a water quality trench to receive only the first flush of runoff volume during a storm. As discussed in Section 11.1, engineers quantify first flush volume variously according to local practice. The trench does not treat the remaining runoff volume, and instead conveys it to a conventional detention or retention facility downstream. Engineers estimate the water quality volume using:

$$WQ_V = Q\,A = (R_V\,P)A \qquad (11.2)$$

where:

WQ_v	=	Water quality volume
Q	=	Depth of runoff, inch (mm)
R_V	=	Volumetric runoff coefficient
P	=	Rainfall depth, inch (mm)
A	=	Drainage area, ac (ha)

While water quality exfiltration systems do not typically satisfy stormwater storage goals, they may result in smaller, less costly facilities downstream. The smaller size and area requirements of water quality exfiltration systems allows considerable flexibility in their placement within a development site, an important factor for “tight” sites. Additionally, if for some reason the water quality trench fails, a downstream stormwater management facility may still adequately control stormwater.

11.3.2.2 Infiltration Basins

An infiltration basin impounds stormwater flow and gradually exfiltrates it through the floor of an excavated area. Infiltration basins have a similar appearance and construction to conventional dry ponds. However, the detained runoff exfiltrates though permeable soils beneath the basin, removing both fine and soluble pollutants. Engineers may design infiltration basins as combined exfiltration/detention facilities or as simple infiltration basins. They can be adapted to provide stormwater management functions by attenuating peak flows from large design storms and can serve drainage areas up to 50 ac. Figure 11.4 shows a plan and profile schematic of an infiltration basin and its components.

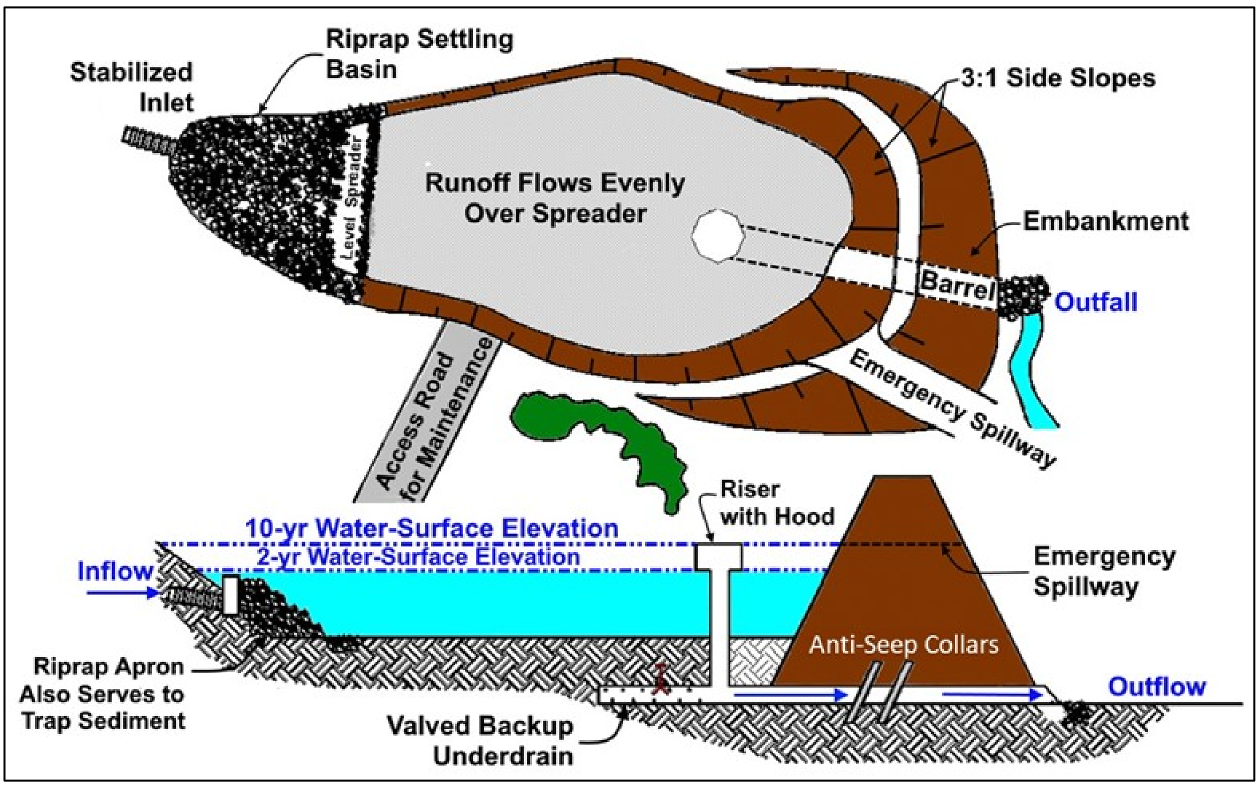


Figure 11.4. Infiltration basin schematic.

Infiltration basins present a feasible option where soils are permeable, and where the water table and bedrock are situated well below the soil surface. They have similar construction costs and maintenance requirements to those for conventional dry ponds. Experience to date indicates that infiltration basins have one of the highest failure rates of any BMP from plugging of the permeable soils, emphasizing the importance of regular inspection for standing water.

Advantages of infiltration basins include:

- Preserving the natural water balance of the site.
- Serving larger developments.
- Usefulness as sediment basins during the construction phase.
- Reasonable cost-effectiveness in comparison with other BMPs.

Disadvantages of infiltration basins include:

- High rate of failure due to unsuitable soils.
- Need for frequent maintenance.
- Frequent nuisance problems (e.g., odors, mosquitoes, soggy ground).

11.3.2.3 Sand Filters

Sand filters provide stormwater treatment for first flush runoff. Runoff filters through a sand bed before returning to a stream or channel. Engineers generally use sand filters in urban areas and for groundwater protection where infiltration into soils is not feasible. Alternative designs of sand filters use a top layer of peat or some form of grass cover through which runoff passes before being strained through the sand layer. This combination of layers increases pollutant removal. Effective BMPs such as bioretention and rain gardens include sand filters as a component (USEPA 2021).

Engineers use a variety of sand filter designs. Figure 11.5 and Figure 11.6 present examples of the two general types of filter systems. Figure 11.5 shows a cross-section schematic of a sand filter compartment (City of Alexandria 1992), and Figure 11.6 shows a cross-section schematic of a peat-sand filter (Galli 1990).

Sand filters have the advantage of being adaptable. They can be used on areas with thin soils, high evaporation rates, low soil infiltration rates, and limited space. Sand filters also have high removal rates for sediment and trace metals and have a very low failure rate. Disadvantages associated with sand filters include frequent maintenance to ensure proper operation, unattractive surfaces, and odor problems.

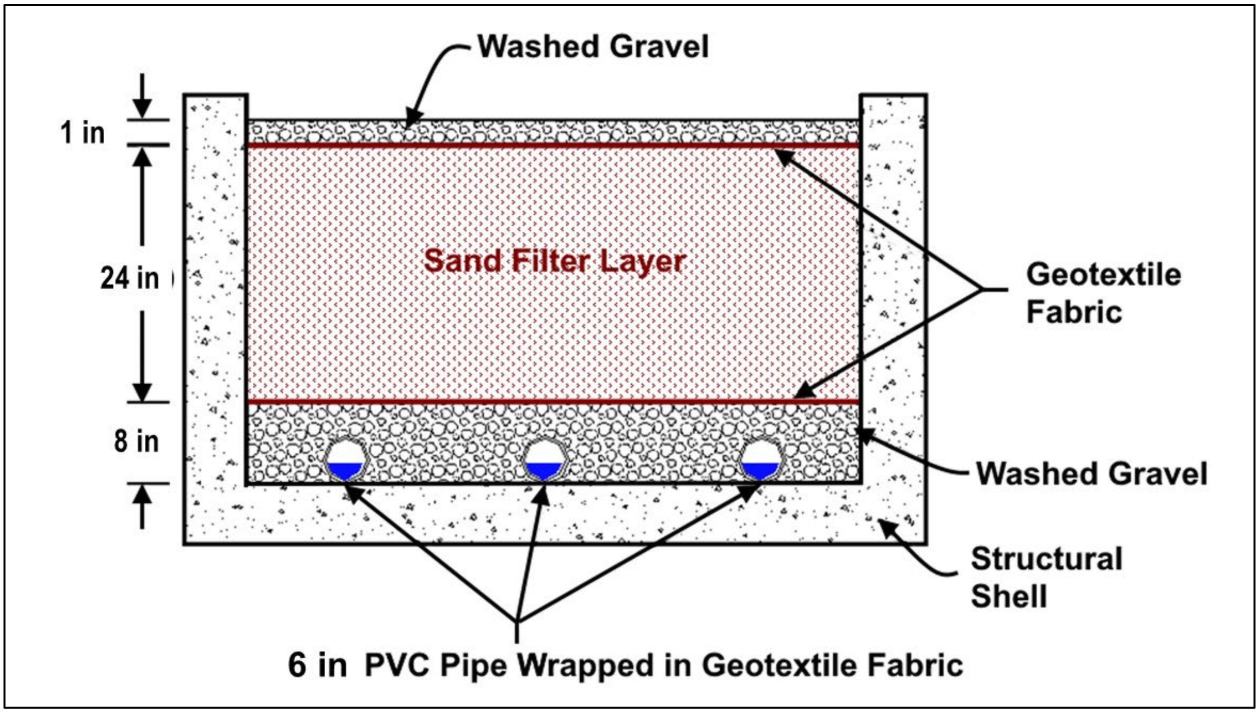


Figure 11.5. Cross-section schematic of sand filter compartment.

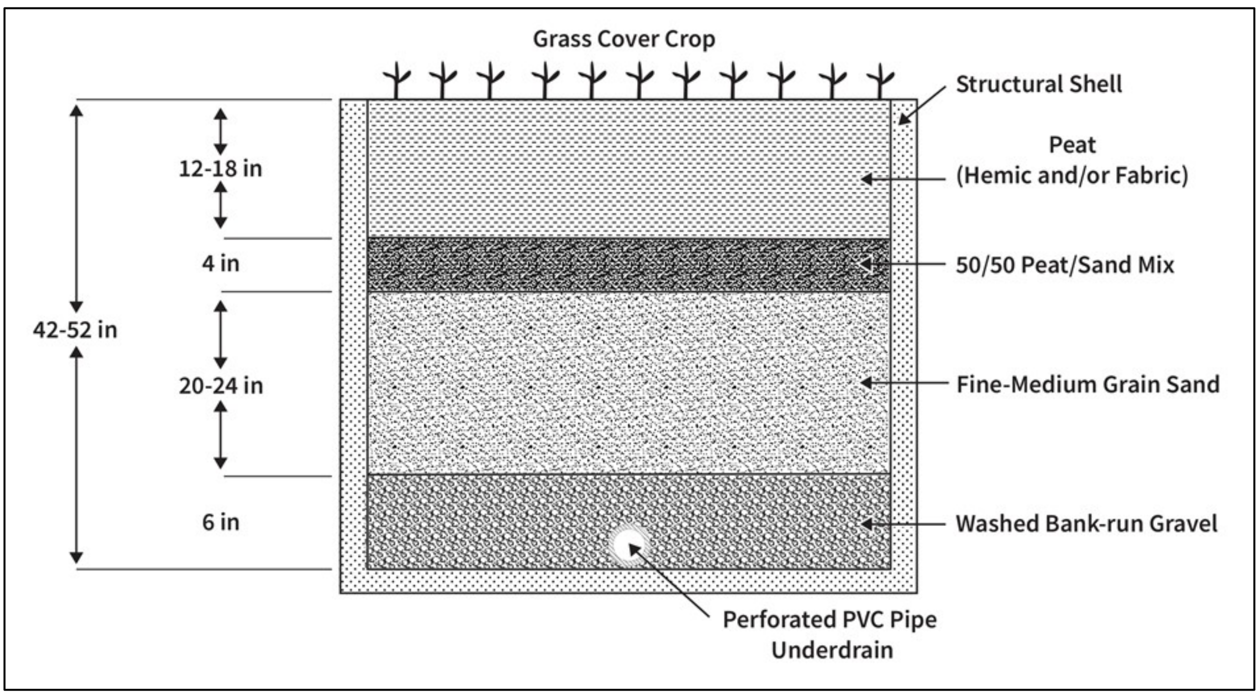


Figure 11.6. Cross-section schematic of peat-sand filter.

11.4 Green Infrastructure

Green infrastructure involves stormwater management designed to capture rainwater near where it falls, largely by slowing runoff and promoting infiltration in ways that mimic natural runoff and infiltration. Examples of green infrastructure include green roofs, rain gardens, grass paver parking lots, infiltration trenches, permeable pavements, bioswales, planter boxes and rainwater harvesting.

Gray Infrastructure

In contrast to green infrastructure, gray infrastructure includes approaches for stormwater collection, storage, and conveyance designed to move rainwater away from impervious surfaces, such as roadways, parking lots and rooftops, as quickly as possible. It may include curbs, gutters, drains, piping, and collection systems.

Green infrastructure represents a resilient nature-based solution that manages wet weather impacts and provide ecological, economic, and social benefits to the affected community. The International Union for Conservation of Nature (IUCN 2020) describes "nature-based solutions" (NBS) as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing for human well-being and biodiversity benefits."

Green infrastructure may also be called natural infrastructure. Section 11103 of BIL added a definition of natural infrastructure under Section 101 of Title 23 of U.S. Code as follows:

> The term "natural infrastructure" means infrastructure that uses, restores, or emulates natural ecological processes and —
>
> (A) is created through the action of natural physical, geological, biological, and chemical processes over time;
>
> (B) is created by human design, engineering, and construction to emulate or act in concert with natural processes; or
>
> (C) involves the use of plants, soils, and other natural features, including through the creation, restoration, or preservation of vegetated areas using materials appropriate to the region to manage stormwater and runoff, to attenuate flooding and storm surges, and for other related purposes.

Executive Order 13690 "Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input" also promotes such NBS and natural infrastructure by requiring agencies, where possible, to use natural systems, ecosystem processes, and nature-based approaches when developing alternatives for consideration.'' (80 FR 13690 (Jan. 30, 2015), revoked by EO 13807 (Aug. 15, 2017), but reinstated by EO 14030 (May 20, 2021)). Green infrastructure (NBS and natural infrastructure) is important to consider as FHWA and others seek to ensure the transportation network is resilient in the face of the risk associated with climate change.

11.4.1 Low Impact Development

Low impact development (LID) is a decentralized source and treatment control strategy for stormwater management (NASEM 2006). LID establishes a stormwater management system to prevent pollution resulting from development and urbanization. It mimics natural processes to maintain the hydrological processes of infiltration, interception, and evapotranspiration that existed before development. LID strategies come in many forms including:

- Bioretention area (rain garden): Retains, infiltrates, and filters runoff and pollutants using a shallow surface depression usually planted with native vegetation. See Figure 11.7.
- Bioretention swales: Also referred to as bioswales or vegetated swales, consist of typically parabolic or trapezoidal depressions that use bioretention soil media and vegetation to promote infiltration, water retention, and sedimentation and pollutant removal. See Figure 11.8.
- Stormwater curb extensions: Also called stormwater bump outs, extend the curb into the roadway to reduce traffic speed and capture stormwater runoff from roadways and sidewalks.
- Stormwater planters: Consist of narrow, flat-bottomed landscape areas, typically of rectangular shape with vertical walls.
- Stormwater tree systems (i.e., pits and trenches): Intercept and capture stormwater using a tree or shrub, bioretention soil media, and a gravel reservoir.
- Infiltration trenches: Excavated linear areas filled with layers of stone and sand wrapped in geotextile fabric. See Figure 11.9.
- Subsurface infiltration and detention practices: Underground storage that holds runoff and allows infiltration.
- Permeable pavements: Includes porous asphalt (pavement) and pavers that allow runoff to infiltrate through void space instead of becoming surface runoff. See Figure 11.10.

Figure 11.7. Green infrastructure practice: bioretention (rain garden). Source: Roger Kilgore.

Figure 11.8. Green infrastructure practice: bioswale (USEPA 2021).

Figure 11.9. Green infrastructure practice: infiltration trench (USEPA 2021).

Figure 11.10. Green infrastructure practice: permeable pavers (USEPA 2021).

Table 11.1 summarizes the relative effectiveness (based on pollutant removal efficiencies) of properly maintained green infrastructure practices for various water quality constituents that roadway runoff typically produces in high concentrations.

Table 11.1. Pollutant removal efficiencies of green infrastructure practices (USEPA 2021).

Green Infrastructure Practice	Pollutant Removal Efficiency *						
	Total Suspended Solids	Total Nitrogen	Total Phosphorus	Fecal Coliform	Total Zinc	Total Copper	Total Lead
Bioretention (Rain Garden)	●	○	●	–	●	–	◎
Bioswale	◎	○	○	○	–	–	–
Stormwater Curb Extension	●	○	●	–	●	–	◎
Stormwater Planter	●	○	●	–	●	–	◎
Street Trees	●	◎	◎	●	◎	◎	◎
Infiltration Trench	●	○	●	●	●	–	–
Subsurface Infiltration and Detention	●	◎	◎	●	●	●	●
Permeable Pavement	●	–	◎	–	●	◎	◎
Permeable Friction Course	●	–	–	–	●	◎	●

*○ = 0 – 30%; ◎ = 31 – 65%; ● = >65%; – = no data.

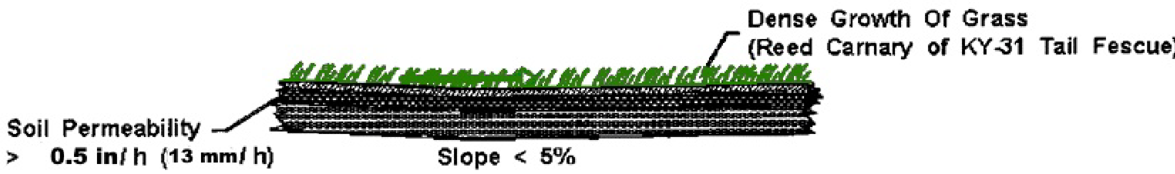
11.4.2 Grassed Swales

Engineers typically use grassed swales in developments and highway medians as an alternative to curb and gutter drainage systems. Swales have a limited capacity to accept runoff from large design storms, and often lead into storm drain inlets to prevent large, concentrated flows from gullying/eroding the swale. HEC-15 (FHWA 2005) provides information for the design of grassed swales.

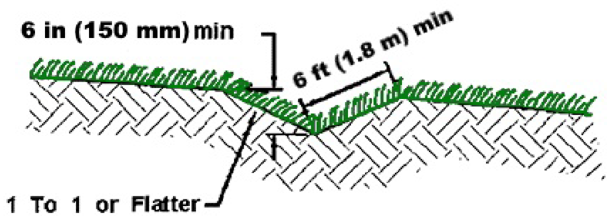
Grassed swales sometimes incorporate check dams and level spreaders. Level spreaders consist of excavated depressions running perpendicular across the swale. Engineers incorporate level spreaders and check dams into a swale design to reduce overland runoff velocities. Figure 11.11 shows a schematic of a grassed swale level spreader and check dam. Swales with check dams placed across the flow path can provide some stormwater management for small design storms by infiltration and flow attenuation. In most cases, however, engineers combine swales with other BMPs downstream to meet stormwater management requirements.

Swales can filter out particulate pollutants under certain site conditions. However, swales generally cannot remove soluble pollutants, such as nutrients. In some cases, trace metals leached from culverts and nutrients leached from lawn fertilization may increase the export of soluble pollutants. Grassed swales usually cost less than the curb and gutter.

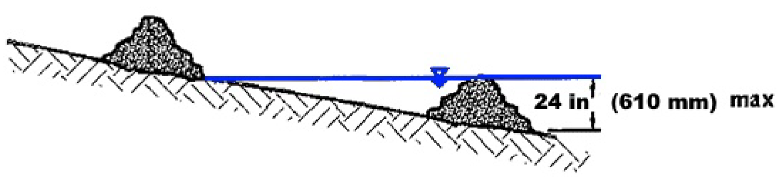
In addition to being conveyors of stormwater, grassed swales can also function as biofilters in the management of the quality of stormwater runoff from roads. Swales designed to increase hydraulic residence to promote biofiltration are known as biofiltration swales as discussed in the previous section. Biofiltration swales take advantage of filtration, infiltration, adsorption, and biological uptakes as runoff flows over and through vegetation. Removal of pollutants by a biofiltration swale depends on the time that water remains in the swale, or the hydraulic residence time, and the extent of its contact with vegetation and soil surfaces. The Washington State Department of Transportation *Highway Runoff Manual* contains information on biofiltration swales (WSDOT 2019).



a. Grassy Swale – Slows runoff; filters sediment; roots bind surface of soil and enhance infiltration; grass and leaves protect soil surface from rainfall impact; and litter layer improves porosity.



b. Level Spreader – Redistributes concentrated flow to sheet flow, increases infiltration.



c. Check Dam – Reduces erosive velocities.

Figure 11.11. Schematic of grassed swale level spreader and check dam.

11.4.3 Filter Strips

Filter strips have many similarities to grassed swales, but only accept overland sheet flow. To function, runoff from an adjacent impervious area must be evenly distributed across the filter strips. Runoff has a strong tendency to concentrate and form a channel, effectively "short-circuiting" the filter strip so that it does not perform as designed.

A properly functioning filter strip has: 1) some sort of level spreading device; 2) dense vegetation with a mix of erosion resistant plant species that effectively bind the soil; 3) grading to a uniform, even, and relatively low slope; and 4) length at least equal to the contributing runoff area. HEC-15 has information on permissible shear stresses (erosion resistance) of various types of vegetation (FHWA 2005). Filter strips built using HEC-15 can remove a high percentage of particulate pollutants. Little research exists on the capability of filter strips in removing soluble pollutants. Filter strips cost relatively little to establish and almost nothing if preserved before site development. A creatively landscaped filter strip can become a valuable community amenity, providing wildlife habitat, screening, and stream protection. Engineers also commonly use grass filter strips to protect surface infiltration trenches from clogging by sediment.

Filter strips do not provide storage or infiltration to effectively reduce peak flows. Typically, filter strips make up one part of an integrated stormwater management system. Thus, the strips can lower runoff velocity (and, consequently, the watershed time of concentration), slightly reduce both runoff volume and watershed imperviousness, and contribute to groundwater recharge. Filter strips also provide important benefits of preserving the riparian zone and stabilizing streambanks.

11.4.4 Constructed Wetlands

Wetlands can efficiently remove pollutants from highway and urban runoff. Engineers often use wetlands or shallow marshes in conjunction with other BMPs to achieve maximum pollutant removal. Studies on wetlands concluded that detention basins and wetlands appear to function comparably well in removing monitored pollutants (Strecker et al. 1992), but for some indicators wetlands perform better (NASEM 2017). An effective design of a wetland as a water quality measure would include the creation of a detention basin upstream of the wetland. The detention basin provides an area where heavy particulate matter can settle, thus minimizing disturbance of the wetland soils and vegetation.

Frequently, engineers design wetlands for BMP purposes in conjunction with wet pond sites, provided that the runoff passing through the vegetation does not dislodge the aquatic vegetation (AASHTO 2007). Vegetation systems may not be effective where the water's edge is extremely unstable or heavily used. Additionally, in flood-prone areas, the alteration of the hydraulic characteristics of the watercourse may cause some types of marsh vegetation to be ineffective as a BMP.

11.5 Ultra-Urban BMPs

Densely developed areas with very limited right-of-way, termed "ultra-urban" environments, present a unique challenge for the use of traditional treatment BMPs given the lack of available surface area. The term "ultra-urban BMPs" generally describes the use of treatment BMPs installed underground and resulting in small footprints (NASEM 2012). These methods capture runoff contaminants before they reach surface water and groundwater. They apply particularly well to retrofitting urban areas, as well as to new urban development.

These engineered devices are typically structural and are made on a production line in a factory. Engineers may design them to handle a range of pollutant and water quantity conditions and, because they have small footprints they may be dropped into the urban infrastructure or integrated into the streetscape of both private and public sector property. Others may be installed beneath parking lots and garages or on rooftops. Engineers design still others to remove pollutants before they are flushed into urban runoff collection systems.

Pre-cast storm drain inlets, or "water quality inlets," remove sediment, oil and grease, and large particulates from runoff originating from paved surfaces before it reaches storm drainage systems or infiltration BMPs. Water quality inlets typically serve highway storm drainage facilities adjacent to commercial sites generating large amounts of vehicle wastes, such as gas stations, vehicle repair facilities, and loading areas. They may pretreat runoff before it enters an underground filter system.

These inlets can include a three-chamber underground retention system designed to settle out grit and absorbed hydrocarbons as shown in Figure 11.12: a sediment trapping chamber, an oil separation chamber, and the final chamber attached to the outlet. The sediment trapping chamber settles out grit and sediment and traps floating debris in a permanent pool. An orifice protected by a trash rack connects this chamber to the oil separation chamber. The oil separation chamber also maintains a permanent pool of water. An inverted elbow connects the separation chamber to the third chamber.

Advantages of water quality inlets include compatibility with the storm drain network, easy to access, able to pretreat runoff before it enters infiltration BMPs, and unobtrusive. Disadvantages include their limited stormwater and pollutant removal capabilities, frequent cleaning (which cannot always be assured), the possible difficulties in disposing of accumulated sediments, and cost.

Other water quality ultra-urban applications, include filter inserts, hydrodynamic devices, and simple sumps. Bag or basket type filter inserts have small openings to allow low flows to seep through and larger flows to overflow without causing backwater to the inlet. Hydrodynamic devices typically include baffles, vortex mechanisms, or other settling components, or a combination of these elements. These devices separate sediment and pollutants from stormwater and commonly are inserted between inlets and storm drain pipes. Sumps placed at the bottom of access holes and below the storm drain pipe flow lines allow sediment and debris to deposit while releasing stormwater through weep holes.

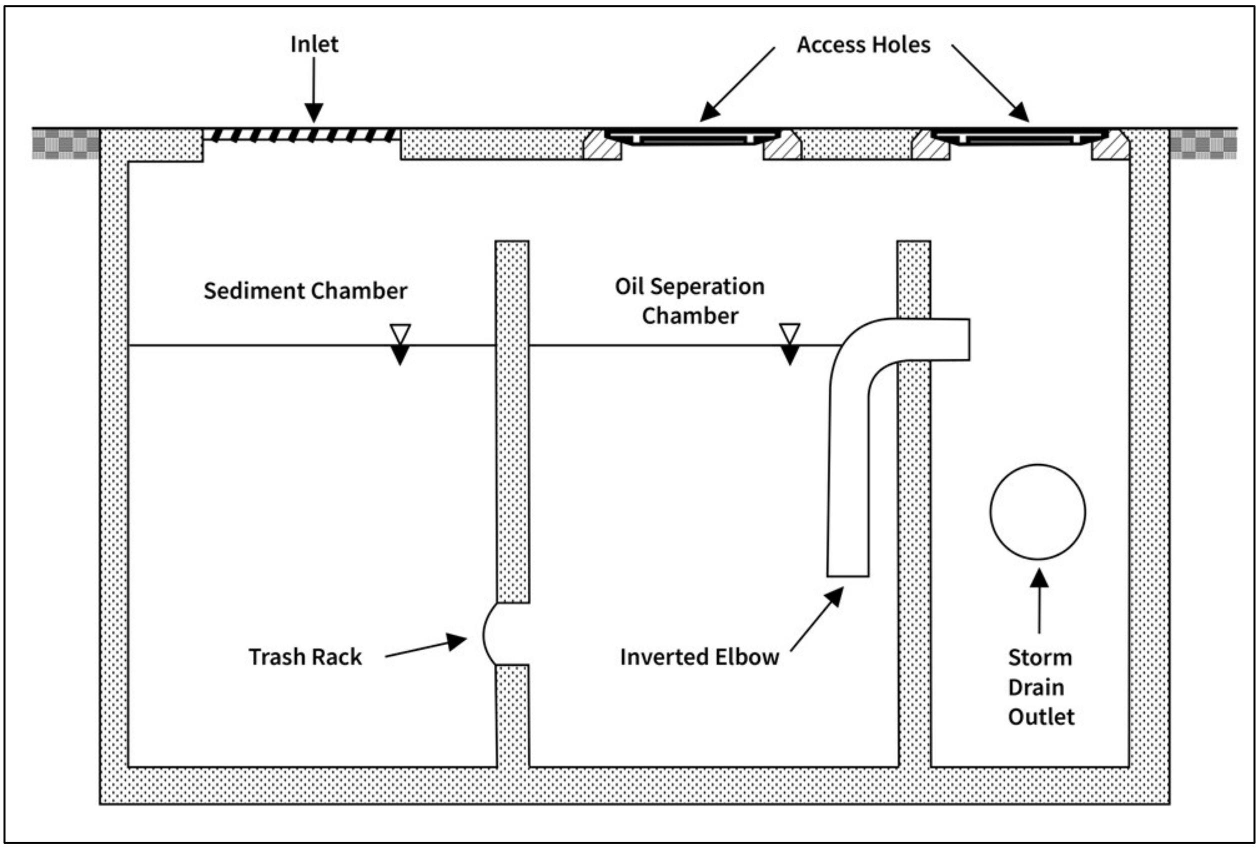


Figure 11.12. Cross-section detail of a typical oil/grit separator.

11.6 Non-Structural BMPs

Drainage engineers and planners commonly use non-structural BMPs in conjunction with structural BMPs, particularly as a means of pre-treating runoff before retention, detention, storage, or discharge. Non-structural BMPs do not involve grading or construction, and therefore cost significantly less than structural controls. In contrast to structural BMPs, which treat or remove pollutants, non-structural BMPs focus primarily on the avoidance of pollution. Governmental agencies and other organizations typically implement non-structural BMPs by establishing ordinances and administrative policies, and through watershed planning. Some of the most common non-structural BMPs are (NASEM 2014):

- **Storm drain cleaning**: Removal of sediment and debris from storm drain pipes and inlets. Has a minor effect on water quality improvement because most pollutants, notably nutrients, tend to pass through the drainage inlets and catch basins. This BMP most efficiently removes suspended solids.
- **Street sweeping**: Removal of sediment from paved surfaces. Has modest water quality benefits, in particular in the removal of sediment, debris, and trash/litter.
- **Efficient landscaping practices**: Minimizing or eliminating the use of pollutants in landscaping (e.g., fertilizers) and avoiding excessive irrigation.
- **Trash management practices**: Minimizing public littering and minimizing windblown trash from vehicles and landfills.
- **Elimination of groundwater inflow to storm drains**: Use of watertight joints and the elevation of pipes above the groundwater table. Storm drains that are below the groundwater table can perennially convey low flows with concentrations of pollutants.
- **Slope and channel stabilization**: Vegetating, lining, or reconfiguring embankment slopes and channels to reduce erosion.
- **Winter maintenance:** Proper use of deicing chemicals and abrasives to alleviate winter conditions and post-winter cleanup.
- **Irrigation runoff reduction practices**: Maintain landscaped areas and reduce overwatering of landscapes to mitigate excess runoff and associated high concentrations of pollutants, typically during the dry weather season.