

INTRODUCTION

A set of chemical, biological, and engineering principles underlays the many stormwater treatment technologies. These principles derive from our knowledge and experience in: water and wastewater treatment engineering, chemical engineering, aquatic chemistry, soil science, and biological science. This book presents these principles, exploring their relationship to design criteria, performance, and the causes of performance variability of the various treatment technologies. Included are basic sizing procedures and design elements that maximize performance and reliability.

1.1 EVOLUTION OF TREATMENT SYSTEMS

Over the past 150 years the evolution of wastewater and water treatment systems, predecessors and sources of experience for stormwater treatment, is increasing sophistication. This sophistication is a reflection of the engineer's increasing understanding of the water being treated and the underlying biological, chemical and engineering principles that define how the different treatment processes function. The outcome of this understanding is engineered systems capable of cost-effectively meeting increasingly stringent environmental requirements. With stormwater treatment the engineer faces an increasing number of choices, alternative design criteria, and expectations of performance. Understanding underlying principles enhances the engineer's ability to make cost-effective choices and designs. Today, choices (highlighted in Table 1.1) have expanded greatly since the dawn of stormwater treatment over two decades ago. Furthermore, manufactured or pre-engineered systems now complement the public-domain treatment systems, a healthy sign that the market has grown sufficiently to interest the entrepreneur.

TABLE 1.1
Treatment technologies

Public-domain technologies

bioswale...wet swale...dry swale...filter strip...wet pond...wet vault...extended detention pond...
wet extended detention pond...extended detention wetland...shallow wetland...hummock wetland
...pocket wetland...subsurface flow wetland...combined flood control detention/wet basin...oil/grit
separator...oil/water separator... infiltration trench...infiltration basin... bioretention...bioinfiltration
swale... sand filter... amended sand filter... organic filter...alum precipitation...

Pre-engineered technologies

AquaFilter™...AquaLogic™...Aqual Swirl™...BaySaver™...CDS™...CDS Filter™...Downstream
Defender™...DrainPac™...DualVortex™...EcoStorm™...EcoSep™...FlowGuard™...Hydro-
Kleen™...StreamGuard™... Stormvault™...Stormceptor®...StormFilter™...Storm Treat™...Ultra-
Urban Filter™...V2B1™...VortFilter™...Vortechs™...VortSentry™...

1.2 TREATMENT TECHNOLOGIES

The focus of this book is with passive treatment: no pumps, mixers, or electrical systems. Provided below is an introduction to these technologies. Other current publications provide design procedures,^{25,77,78,377,620,1088,1157,1173,1199,1913} and comparisons of performance.^{26,31,175,988,990,1008,1250} Occasionally mechanically complex technologies akin to wastewater treatment are used.¹⁵⁹ The treated water may be recycled for non-potable uses. For these complex technologies the engineer is referred to texts on wastewater treatment.^{47,66,114,256,747,1068}

Vegetated swales and strips

For this book, swales are defined as broad shallow vegetated channels, typically covered by grass. Stormwater enters the upper end, passing through to the outlet at the lower end. With strips, water enters as sheet flow from the pavement along the strip edge. Infiltration varies from little to substantial, in which case the device is more correctly considered an infiltration system. Although swales and strips are typically referred to as biofilters, it is likely that the primary removal mechanism is sedimentation rather than filtration.

Some systems called swales are more appropriately grouped elsewhere: the “dry swale” which is essentially an infiltration system; and the “wet swale”, which is essentially a shallow extended detention basin. These are volume-based systems, sized to store and treat the volume of a design event. In this book, swales are flow rate-based, sized to treat to a specified peak flow rate.

Dry basins

Dry basins temporarily store stormwater during and immediately following each storm, and are dry between storms. Water is contained by berms, an open excavation, or by a sub-surface vault. To enhance settling the discharge rate is controlled: “extended detention.” Settleable solids and attached pollutants are removed. Dissolved pollutant removal is modest because of short residence time and minimal contact with the soil. Variants include a shallow wet pool (wet extended) or small (micro) pools at the inlet and/or outlet.

Wet basins

Wet basins have a permanent pool during and between storms. Like dry basins, water is contained by berms, in an open excavation, or in a vault. Suspended solids and attached pollutants are removed as well as dissolved pollutants by surface wet basins. Assuming little or no rooted vegetation, removal of dissolved pollutants is with protista (algae and bacteria) and soil if earthen-lined.

Normally the discharge is not constrained. An extended detention layer may be placed atop the wet pool. A wet basin that includes an extended detention layer is essentially the same as a dry extended detention basin that includes a wet pool described previously. Where flood control is required, both objectives are commonly met with one basin. Pre-engineered products such as BaySaver, Stormceptor, and Stormvault are wet vaults. The latter includes an extended detention layer atop the wet pool by restricting the discharge.

Constructed wetlands

Wetlands are essentially shallow wet ponds. Shallowness allows rooted wetland plants to flourish. Suspended solids and attached pollutants settle. Plants, algae, bacteria, and the soil remove dissolved pollutants. There are many variants as indicated in Table 1.1. Although constructed wetlands may use more area than wet ponds, they provide the additional benefits of aesthetics and wildlife habitat. Natural wetlands are not commonly used to treat stormwater because of the concern for adverse effects. StormTreat is a pre-engineered wetland consisting of a standard module.

Vortex separators

A vortex separator can be viewed as a wet vault “in-the-round.” Stormwater enters tangentially, imparting circular movement. Through circular movement, the device removes settleable solids and attached pollutants. Vortex separators may achieve performance similar to wet vaults, but in a smaller space. Several manufacturers exploit vortex separation. Pre-engineered products include CDS, V2B1, Downstream Defender, Vortechs, Dual-Vortex, and AquaSwirl.

Oil/water separators

An oil/water separator is a wet vault that employs gravity separation but the pollutant moves upward. The most common configuration is a wet vault with closely spaced plates within which the oil coalesces into larger droplets as it rises. An undersized variant is the oil/grit separator which is a simple vault with vertical baffles. Some pre-engineered separators employ sorptive media, in some cases without the coalescing plates.

Inert media filters

These are filters that remove suspended solids and attached pollutants. The term “inert” indicates the media does not remove dissolved pollutants, although chemical precipitation may occur within the filter as well as biological activity. The flatbed configuration is common: a layer of the media such as sand over underdrain pipes. Water flows downward through the sand. Pretreatment precedes the inert media filter, thereby extending the maintenance cycle of the filter. Pretreatment is commonly by an extended detention or wet basin. Other inert media are perlite, crushed recycled glass, and geofabrics. Several pre-engineered products use a vertical cartridge containing media. Stormwater flows radially into the cartridge to a center well, exiting the cartridge. Examples are the StormFilter and VortFilter.

Sorptive media filters

These filters remove dissolved pollutants. Suspended solids with attached pollutants are also removed. The configurations are typically the same as inert media filters. Sorption media include leaf compost, activated carbon, peat, iron-amended resin, zeolite, surface-modified sand, and polypropylene. Pre-engineered products noted above are available with sorptive media.

Drain inlet devices

A large number of pre-engineered products are configured to be placed directly into vertical or side drain inlets. Some inserts are placed at the entrance of the drain inlet. Others are housed deeper within the inlet. The latter configuration allows the inlet sump to serve its func-

tion of removing sediments. Many products use sorptive media, generally to remove petroleum compounds. These devices are considered sorptive media filters. Example products in Table 1.1 include UltraUrban, HydroKleen, and StreamGuard.

Infiltration systems

Discharge into and through the soil is the primary means of treatment and disposal. Infiltration systems are essentially granular sorptive media filters in which the soil is the media and the underdrain system is the groundwater aquifer. There are many configurations including open basins, sub-surface vaults and rock filled trenches, and various forms of porous pavement. Bioretention is an infiltration system that incorporates vegetation such as trees, shrubs and grass. Coarse soils require pretreatment to protect groundwater quality.

1.3 MANAGEMENT APPROACH TO STORMWATER TREATMENT

Three decisions drive the selection and sizing of stormwater treatment systems: how much water to treat, which pollutants to remove, and the desired performance.

Volume goal

The frequently stated volume goal is 90 percent of the stormwater generated over all storms; that is, the treatment system is sized so as to effectively treat 90 percent of the stormwater occurring over time. The common approach is to specify a storm runoff depth. This depth defines either the volume or flow rate to be treated, for volume-based and rate-based systems, respectively.

Specified storm depths range from 0.5 to 1.2 inches (1.25 to 2.5 cms).^{77,1173} The volume of a volume-based system is the product of the specified flow depth, drainage area, and runoff coefficient. To size a rate-based system, a storm distribution is assumed. Alternatively, a storm intensity is defined such as 0.2 inches/hour, to calculate the peak rate. A less common approach is to use a single design storm event.¹¹⁹⁶ A specified hydrologic