1.0 Introduction

Stormwater management programs have been required in Maryland since the first stormwater management law was passed in 1982. Title 4, Subtitle 2 of the Environment Article of the Annotated Code of Maryland states that "…the management of stormwater runoff is necessary to reduce stream channel erosion, pollution, siltation and sedimentation, and local flooding, all of which have adverse impacts on the water and land resources of Maryland." Maryland's stormwater management law, regulations, and design standards are focused on managing the impacts of runoff from new development and redevelopment. The Maryland Department of the Environment (MDE) provides guidance and oversight of the State's program while counties and municipalities are responsible for administering effective local stormwater management programs that "…maintain after development, as nearly as possible the pre-development runoff characteristics…"

The "Maryland Stormwater Design Manual" (Manual) is incorporated by reference into the Code of Maryland Regulations (COMAR) Section 26.17.02.02. The law, regulations, and this Manual provide the minimum standards for stormwater management that every county and municipality must follow and that MDE must apply to State and federal projects.

Since the law was enacted in 1982, tens of thousands of stormwater best management practices (BMPs) have been constructed in Maryland. Maryland's Manual has evolved over the years, most notably in 2000 and 2010, to require stormwater controls that are more effective at mimicking natural runoff characteristics, protecting water quality, and reducing the risk of flooding. In 2010, Maryland updated its stormwater Manual to require better site design, and the use of smaller scale practices distributed throughout a development site. The 2010 Manual required the implementation of environmental site design (ESD) to the maximum extent practicable (MEP) to replicate the runoff hydrology of woods in good condition for the one year, 24-hour rainfall event.

This latest Manual incorporates the scientific advances and practical experiences gained by the State's stormwater community since its last update in 2010 and provides needed improvements for managing urban runoff. These updates to the design standards continue to advance the science of managing stormwater runoff, in particular to adapt to changing rainfall characteristics.

The purpose of this Manual is to:

- Provide the minimum criteria for managing stormwater runoff from development sites;
- Provide design criteria for the most effective structural and non-structural stormwater management practices for development sites; and
- Improve the performance of stormwater management practices that are constructed in the State, specifically regarding longevity, safety, ease of maintenance, community acceptance, and environmental benefit.

MDE encourages wise, environmentally sensitive, site designs that reduce the generation of polluted runoff. For stormwater runoff that is generated from new development sites, MDE has evaluated numerous stormwater BMPs and provided the acceptable design criteria for each. Additionally, the "General Performance Standards" outlined below shall be met to ensure that stormwater management for all development sites meet the Maryland minimum criteria.

Maryland's stormwater management requirements for redevelopment are established in the Code of Maryland Regulations (COMAR 26.17.02) and this Manual. While the BMPs listed in this Manual for new development are also appropriate for redevelopment, additional flexibility is provided for areas where a redevelopment site is constrained by size or existing infrastructure. The redevelopment policy specifies a 50% reduction of existing impervious surface area or that water quality treatment be provided for 50% of the reconstructed impervious area. Stormwater management for any net increases in impervious area and for any hydrologic or hydraulic changes shall be addressed according to new development requirements. This includes water quality treatment, Re_v, Cp_v, and q_{p10}, and includes q_f for interjurisdictional watersheds.

The BMPs contained in this Manual are by no means exclusive. MDE encourages the development of innovative practices that meet the intent of Maryland's stormwater management law and regulations and can perform according to the General Performance Standards. The approval of new control technologies, modifications to the practices contained in this Manual, and alternative policies regarding stormwater management for new development is the responsibility of MDE. To obtain new or alternative practice approval, information on the practice and monitoring data demonstrating that the performance standards in this Manual are achieved shall be submitted to MDE for review and approval. MDE will determine whether the proposed practice is appropriate for use on new development or redevelopment projects.

1.1 Why Stormwater Matters: Impact of Runoff on Maryland's Watersheds

Stormwater runoff from land development can have a profound influence on the quality of Maryland's waters. Land development alters the local hydrologic cycle (see Figure 1.1). The hydrology of a site changes during the initial clearing and grading that occur during construction. Trees, meadow grasses, and agricultural crops that intercept and absorb rainfall are removed and natural depressions that temporarily pond water are graded to a uniform slope. Cleared and graded sites erode, and the soils are often severely compacted, resulting in rainfall being rapidly converted into stormwater runoff.

Impacts to the natural hydrologic cycle are exacerbated in post-development conditions. Roof tops, roads, parking lots, driveways and other impervious surfaces no longer allow rainfall to soak into the ground. Consequently, most rainfall is converted directly to stormwater runoff. The volume of stormwater runoff increases sharply with impervious cover. For example, a one-acre parking lot can produce 16 times more stormwater runoff each year than a one-acre meadow (Schueler, 1994).

The increase in stormwater runoff can overwhelm the existing natural drainage system which is often "improved" to rapidly collect runoff and quickly convey it away (using curb and gutter, enclosed storm drain inlets and pipes, and lined channels). The stormwater runoff is subsequently discharged to downstream waters such as streams, reservoirs, lakes or estuaries.

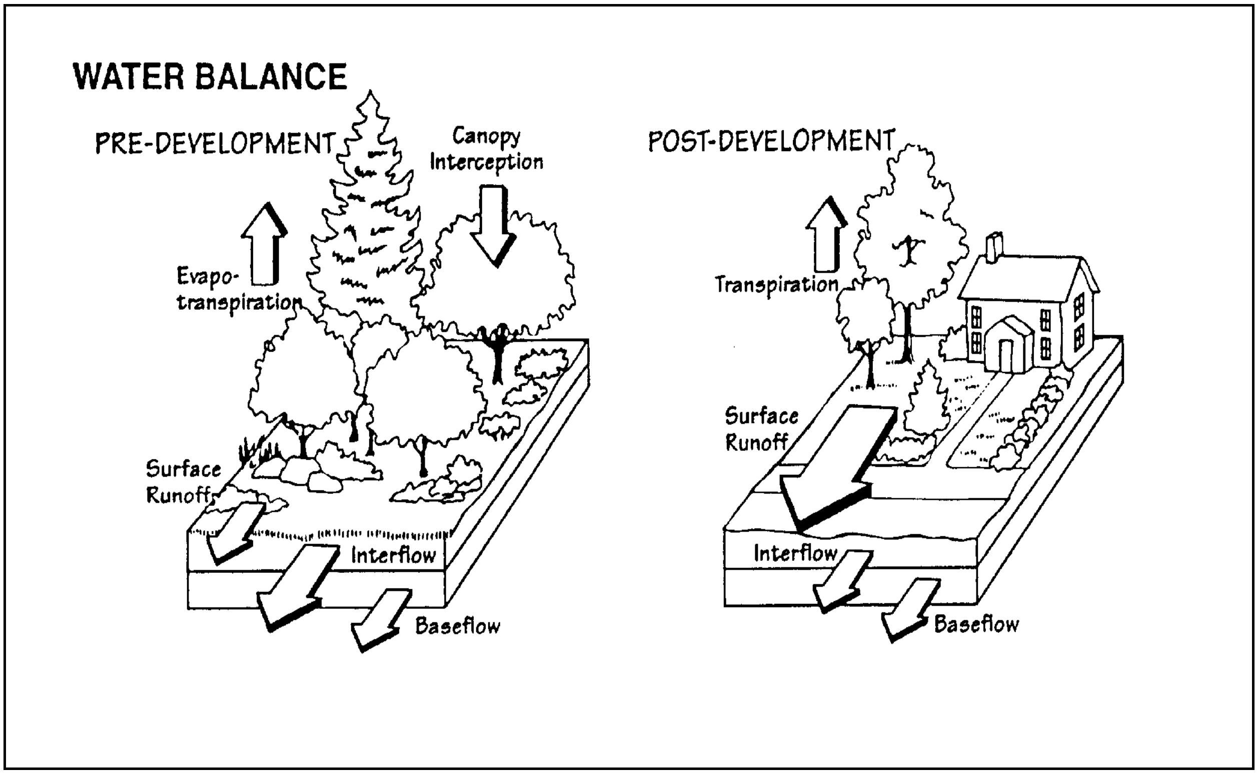

Figure 1.1 Water Balance at a Developed and Undeveloped Site

(Source: Schueler, 1987)

1.1.1 Declining Water Quality

Impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles, or windblown from adjacent areas. During storm events, these pollutants quickly wash off and are rapidly delivered to downstream waters. Some common pollutants found in urban stormwater runoff are listed in Table 1.1 and include:

Nutrients. Urban stormwater runoff has elevated concentrations of both phosphorus and nitrogen, which can enrich streams, lakes, reservoirs and estuaries (known as eutrophication). Excess nutrients have been documented to be a major factor in the decline of Chesapeake Bay. Excess nutrients promote algal growth that blocks sunlight from reaching underwater grasses and depletes oxygen in bottom waters.

Suspended solids. Sources of sediment include wash off of particles that are deposited on impervious surfaces and the erosion of streambanks and construction sites. Both suspended and deposited sediments can have adverse effects on aquatic life in streams, lakes and estuaries. Sediments also transport other attached pollutants (e.g., phosphorus, metals).

Organic Carbon. Organic matter, washed from impervious surfaces during storms, can present a problem in slower moving downstream waters. As organic matter decomposes, it can deplete dissolved oxygen in lakes and tidal waters. Low levels of oxygen in the water can have an adverse impact on aquatic life.

Bacteria. Bacteria levels in stormwater runoff routinely exceed public health standards for water contact recreation. Stormwater runoff can also lead to the closure of adjacent shellfish beds and swimming beaches and may increase the cost of treating drinking water at water supply reservoirs.

Hydrocarbons. Vehicles leak oil and grease that contain a wide array of hydrocarbon compounds, some of which can be toxic at low concentrations to aquatic life.

Trace Metals. Cadmium, copper, lead and zinc are routinely found in stormwater runoff. These metals can be toxic to aquatic life at certain concentrations and can also accumulate in the sediments of streams, lakes and Chesapeake Bay.

Pesticides. A modest number of currently used and recently banned insecticides and herbicides have been detected in streamflow at concentrations that approach or exceed toxicity thresholds for aquatic life.

Chlorides. Salts that are applied to roads and parking lots in the winter months appear in stormwater runoff and meltwater at much higher concentrations than many freshwater organisms can tolerate.

Thermal Impacts. Impervious surfaces may increase temperature in receiving waters, adversely impacting aquatic life that requires cold and cool water conditions (e.g., trout).

Trash and Debris. Considerable quantities of trash and debris are washed through storm drain systems. The trash and debris accumulate in streams and lakes and detract from their natural beauty.

Table 1.1 Typical Pollutant Concentrations Found in Stormwater Runoff

Typical Pollutants Found in Stormwater Runoff (Data Source)	**Units**	**Average Concentration (1)**
Total Suspended Solids (a)	mg/l	80
Total Phosphorus (b)	mg/l	0.30
Total Nitrogen (a)	mg/l	2.0
Total Organic Carbon (d)	mg/l	12.7
Fecal Coliform Bacteria (c)	MPN/100 ml	3600
E. coli Bacteria (c)	MPN/100 ml	1450
Petroleum Hydrocarbons (d)	mg/l	3.5
Cadmium (e)	ug/l	2
Copper (a)	ug/l	10
Lead (a)	ug/l	18
Zinc (e)	ug/l	140
Chlorides (f) (winter only)	mg/l	230
Insecticides (g)	ug/l	0.1 to 2.0
Herbicides (g)	ug/l	1 to 5.0

(1) These concentrations represent *mean or median* storm concentrations measured at typical sites and may be greater during individual storms. Also note that mean or median runoff concentrations from *stormwater hotspots* are 2 to 10 times higher than those shown here. Units = mg/l = milligrams/liter, g/l = micrograms/liter, MPN = Most Probable Number.

Data Sources: (a) Schueler (1987), (b) Schueler (1995), (c) Schueler (1997), (d) Rabanal and Grizzard (1996), (e) USEPA (1983), (f) Oberts (1995), (g) Schueler (1996)

1.1.2 Diminishing Groundwater Recharge and Quality

The slow infiltration of rainfall through the soil layer is essential for replenishing groundwater. The amount of rainfall that recharges groundwater varies, depending on the slope, soils, and vegetation. Some indications of the importance of recharge is depicted in Table 1.2 which shows Natural Resources Conservation Service (NRCS) regional estimates of average annual recharge volume based on soil type (Horsely, 1996).

Table 1.2 Estimates of Annual Recharge Rates Based on NRCS Soil Type

Hydrologic Soil Group (NRCS)	Average Annual Recharge Volume
"A" Soils	18 inches/year
"B" Soils	12 inches/year
"C" Soils	6 inches/year
"D" Soils	3 inches/year
Average annual rainfall is about 45 inches per year across Maryland.	

Groundwater is a critical water resource across the State. Not only do many residents depend on groundwater for their drinking water, but the health of many aquatic systems is also dependent on its steady discharge. For example, during periods of dry weather, groundwater sustains flows in streams and helps to maintain the hydrology of non-tidal wetlands (Figure 1.2). Because development creates impervious surfaces that can prevent natural recharge, a net decrease in groundwater recharge rates can be expected in urban watersheds. Thus, during prolonged periods of dry weather, stream flow sharply diminishes. In smaller headwater streams, the decline in stream flow can cause a perennial stream to become seasonally dry.

Urban land uses and activities can also degrade groundwater quality if stormwater runoff is directed into the soil without adequate treatment. Certain land uses and activities are known to produce higher loads of metals and toxic chemicals and are designated as stormwater hotspots. Soluble pollutants, such as chloride, nitrate, copper, dissolved solids and some polycyclic aromatic hydrocarbons (PAH's) can migrate into groundwater and potentially contaminate wells. Stormwater runoff should never be infiltrated into the soil if a site is a designated hotspot.

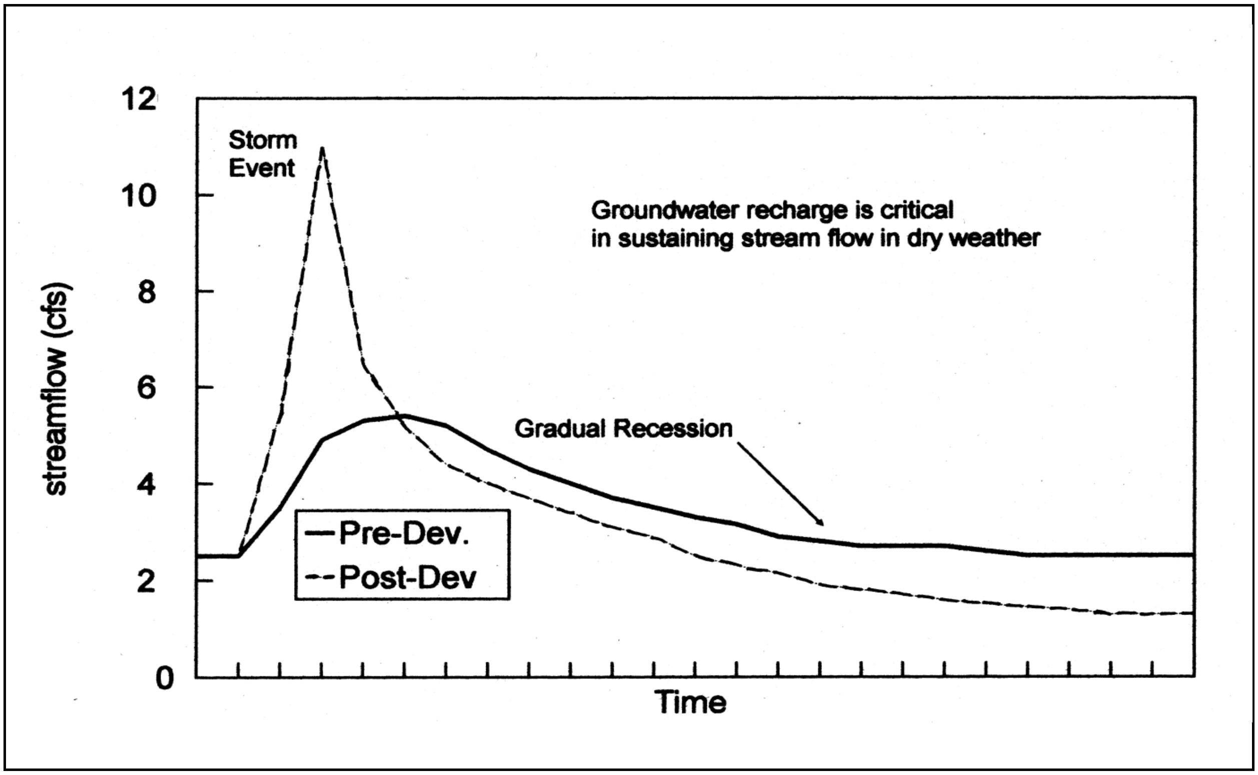

Figure 1.2 Decline in Stream Flow Due to Diminished Groundwater Recharge

1.1.3 Degradation of Stream Channels

Stormwater runoff is a powerful force that influences the geometry of streams. After development, both the frequency and magnitude of runoff increases dramatically. Consequently, urban stream channels are subject to a greater number of high flow volumes and velocities, with increased impacts to stream bank stability compared to pre-development conditions (see Figure 1.3).

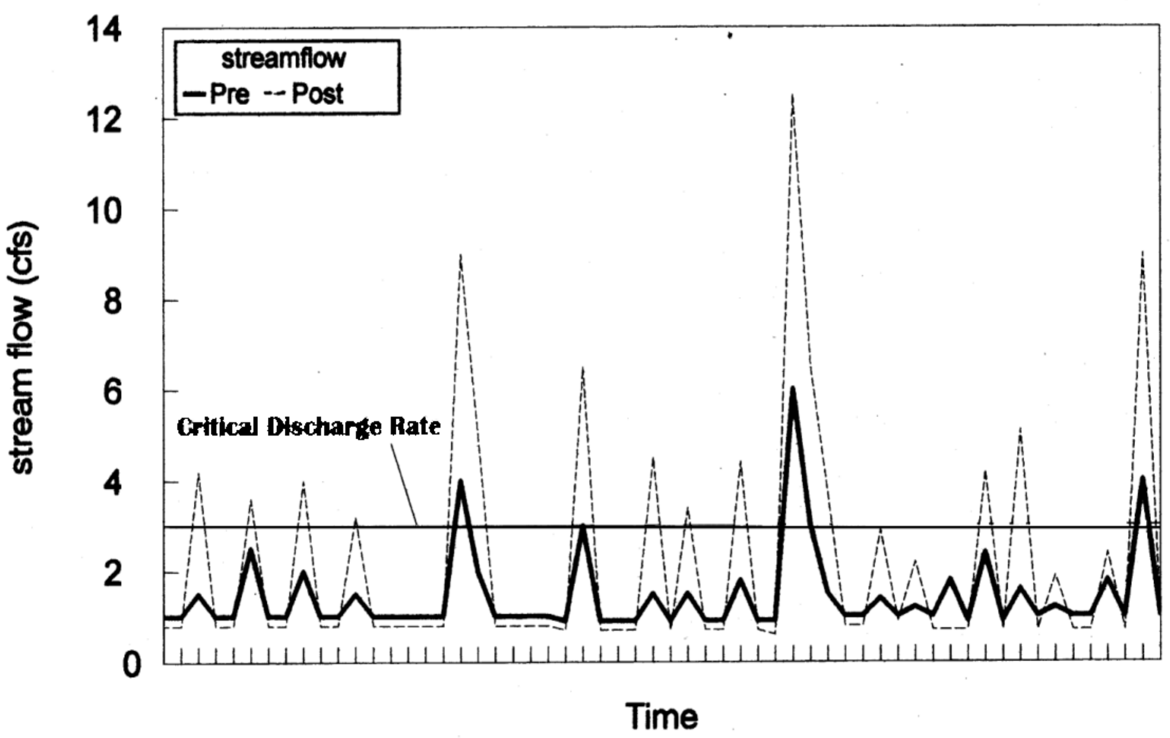

Figure 1.3 Increased Frequency of Erosive Flows in a Stream Channel After Development

As a result, the stream bed and banks are exposed to highly erosive flows more frequently and for longer periods. Streams typically respond to this change by increasing cross-sectional area to handle the more frequent and erosive flows either by channel widening or down cutting, or both. This results in a highly unstable phase where the stream experiences severe bank erosion and habitat degradation. In this phase, the stream often experiences some of the following changes:

- rapid stream widening or down cutting
- increased streambank and channel erosion
- decline in stream substrate quality (through sediment deposition and embedding of the substrate)
- loss of pool/riffle structure in the stream channel
- degradation of stream habitat structure

The decline in the physical habitat of the stream, coupled with lower base flows and higher stormwater pollutant loads, can have a severe impact on the aquatic community. Research has shown the following changes in stream ecology:

- decline in aquatic insect and freshwater mussel diversity

- decline in fish diversity
- degradation of aquatic habitat

In the early days of stormwater management, Maryland attempted to provide some measure of channel protection by imposing a design storm peak discharge control requirement. The criteria required that the discharge from the two-year post development peak discharge rates be reduced to pre-development levels. However, research and experience indicated that the two-year peak discharge criterion was not capable of protecting downstream channels from erosion. In some cases, controlling the two-year storm to pre-development peak levels may accelerate streambank erosion because it exposes the channel to a longer duration of erosive flows than during pre-development conditions.

Beginning in 2000, Maryland began requiring implementation of extended detention for the one-year, 24-hour storm for protecting stream channels. By capturing and slowly releasing the one-year storm, the frequency of erosive flows is greatly reduced resulting in a reduced impact to stream channel stability.

1.1.4 Increased Overbank Flooding

Urban development increases the peak discharge rate associated with a given design storm because impervious surfaces generate greater runoff volumes and conveyance systems deliver it more rapidly to a discharge point or stream. This is exacerbated by a decrease in infiltration into the ground due to soil compaction. The typical change in the stormwater runoff hydrograph is profiled in Figure 1.4.

Stormwater runoff from larger or more intense rain events can exceed the capacity of the conveyance system or the stream channel and spill out into adjacent lands or floodplains. These are termed "overbank" floods and can damage property and downstream drainage structures.

While some overbank flooding is inevitable and even desirable, the historical goal of conveyance design in most of Maryland has been to maintain pre-development peak discharge rates for the ten-year frequency storms after development, thus keeping the level of overbank or out of conveyance system flooding from increasing. This can reduce costly property damage and maintenance for culverts, drainage structures, and swales.

Rainfall events that can produce overbank floods are ranked in terms of their statistical return frequency. A rainfall event that has a 10% chance of occurring in any given year is termed a "ten-year storm." For Maryland, depending on local conditions, a ten-year, 24-hour storm occurs when a storm event produces between 3.64 to 5.34 inches of rain. Changing rainfall patterns indicate these values are predicted to increase over the next 75 years from 4.38 to 6.25 inches of rain in a 24-hour period. Under typical engineering practice in Maryland, most manmade conveyance systems such as channels and storm drain pipes are designed with enough capacity to safely pass the peak discharge from the ten-year, 24-hour storm. However, most of these existing systems were designed based on precipitation data that is now outdated. This and the likelihood thatfuture precipitation patterns will result in increased rainfall emphasize the importance of updating how these overbank flood events are managed.

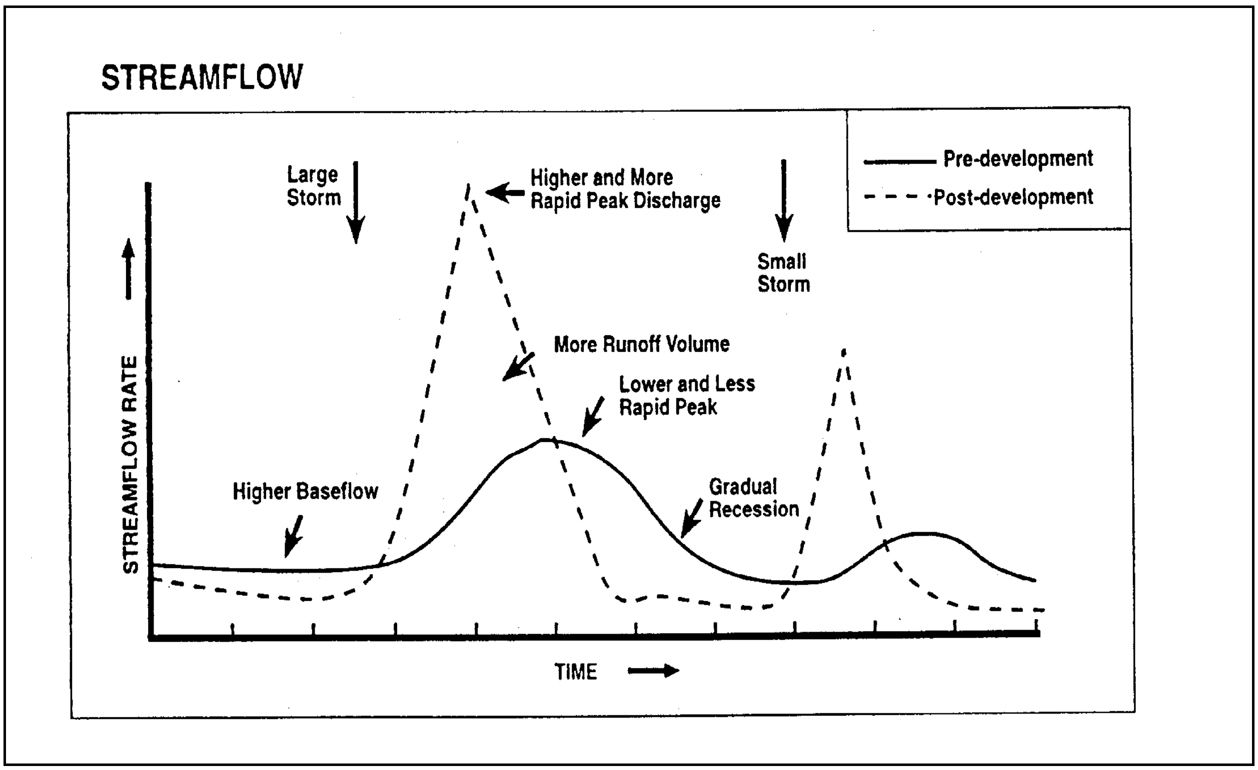

Figure 1.4 Change in Hydrograph following Development

(Source: Schueler, 1987)

1.1.5 Floodplain Expansion

The areas bordering streams and rivers are known as floodplains. The floodplain is usually defined as the land area within the limits of the 100-year storm flow water elevation. The 100-year storm has a 1% chance of occurring in any given year. For drainage areas greater than 640 acres, this storm and its resulting floodplain serve as the basis for establishing flood insurance rates by the Federal Emergency Management Agency. In Maryland, depending on local conditions, a 100-year, 24-hour storm occurs when a storm event produces between 5.96 to 9.23 inches of rain depending on location. Changing rainfall patterns indicate these values are predicted to increase over the next 75 years from 7.17 to 10.80 inches of rain in a 24-hour period. Unmanaged stormwater runoff from these storm events can be very destructive and can pose a threat to property and human life. Floodplains are intended to be protected flood storage areas that help to attenuate downstream flooding.

Floodplains can also be very important habitat areas, encompassing riparian forests, wetlands, and wildlife corridors. Consequently, many local jurisdictions in Maryland restrict or even prohibit new development within the 100-year floodplain to reduce increases in flood hazards and conserve habitats. Nevertheless, prior development that has occurred in the floodplain may be subject to periodic flooding during these storms.

As with other design storms, unmanaged runoff from development sharply increases the peak discharge rate associated with the 100-year design storm. Consequently, the elevation of the 100-year floodplain becomes higher, and the boundaries the floodplain expand (see Figure 1.5). In some instances, property and structures that had not previously been subject to flooding are now at risk. Additionally, such a shift in a floodplain's hydrology can degrade wetlands and forest habitats.

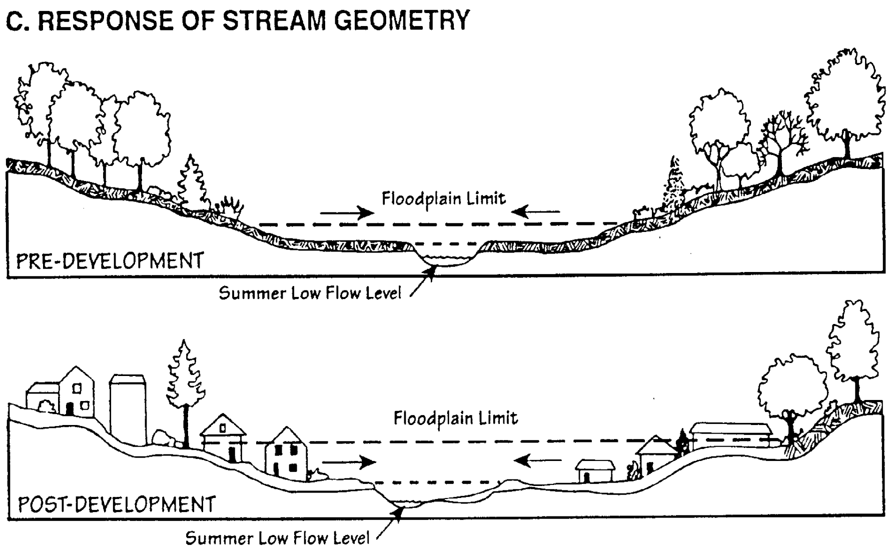

Figure 1.5 Change in Floodplain Elevations

(Source: Schueler, 1987)

1.2 Managing the Stormwater Impacts of Land Development - What's New

Urban flooding is a growing issue in Maryland that has been exacerbated by the increase in the number of extreme rainfall events that produce intense precipitation. Maryland's stormwater management law requires MDE to regularly evaluate and update Maryland's stormwater management standards as needed to ensure communities and stormwater management systems remain resilient. The average annual rainfall amount in Maryland has increased and may continue to increase due to changing weather patterns resulting in the need to manage more volume for groundwater recharge and water quality treatment. It has become clear that because of increasing prevalence of high intensity rainfall events, additional stream channel protection and flood mitigation is needed. Maryland's stormwater management regulations and the stormwater management practice design standards included in this Manual have been updated to adapt to these changing rainfall characteristics.

1.2.1 Precipitation and Design Storms

Precipitation and design storms are fundamental in the development of Maryland's stormwater management requirements and BMP standards. More specifically, stormwater management requirements and BMP designs are based upon 24-hour duration storms of different recurrence intervals. Beginning with the 2000 Manual, minimum runoff quantity design requirements were determined based on these design storms and are used today for managing the impacts of land development and sizing of conveyance systems. These design storms are based on county average rainfall depths for different recurrence intervals. For the 2000 Manual values were taken from the United States Department of Commerce, Weather Bureau's 1961 publication *Technical Paper or "TP" 40 "Rainfall Frequency Atlas of the United States* (USCD, 1961). Most of the rainfall data used to develop TP-40 was gathered from 1938 to 1957.

More recent precipitation data were incorporated into the *National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 2 Precipitation-Frequency Atlas of the United States, Ohio River Basin and Surrounding States,* published by the U.S. Department of Commerce, NOAA in 2004 and updated in 2006 (NOAA, 2006). NOAA Atlas 14 uses a much larger period of record, is based on a more robust statistical analysis method, and includes more rain stations and gauges (e.g., 93 in Maryland). NOAA Atlas 14 includes point-specific information and statistically robust mean values for each of Maryland's counties.

This Manual incorporates these updated design storm rainfall depths for each county, replacing the TP-40 based design storms with the county mean values from the 2006 NOAA Atlas 14. These updated design storms are presented in Chapter 2, Table 2.1.

i. Water Quality Treatment Design Storm

In Maryland, the water quality treatment design storm is based on the 90% capture rule introduced in *Design of Stormwater Wetland Systems* (Schueler, 1992). This rule requires that stormwater BMPs be designed to capture and treat a rainfall depth that produces 90% of the average annual runoff volume in Maryland based on a 40-year period of record. Rainfall frequency data for seven Maryland locations were compiled in 1996 as part of the *Technical Support Document for the State of Maryland Stormwater Design Manual* (Schueler and Claytor, 1996). An analysis of that information recommended that 1.0 inches of rainfall should be used as the design storm to treat 90% of average annual runoff volume for Maryland.

Recently, an updated analysis was performed of rainfall data from 1980 through 2023 from 44 weather stations located across the State, with at least one station from each of Maryland's counties. Weather stations were selected based on location and period of record. Except for one, the stations have at least 10 years of continuous daily rainfall data. To be consistent with the original 1997 analysis, all events less than 0.1 inch were removed from each station's rainfall record. The remaining events were sorted and ordered based on depth of rainfall. The rainfall depth needed to produce 90% of the average annual runoff volume in Maryland was determined by generating a cumulative rainfall distribution curve.

The results show that there are two distinct rainfall zones in Maryland. For the western region of the State, the 90% capture rainfall event in Washington, Allegany, and Garrett Counties varies from 0.9 inches to 1.1 inches with the median value of 1.0 inches. In the central and eastern regions of the State (including the Eastern Shore), the 90% capture rainfall event varies from 1.3 inches to 1.8 inches. The median value for the central and eastern region is 1.5 inches.

Based on these results, the State is separated into two rainfall zones for addressing the water quality treatment requirements. In the western rainfall zone (Washington, Allegany, and Garrett Counties), the rainfall depth (P) that must be captured and treated to meet the 90% capture rule is 1.0 inches. In the remaining counties, or the central/eastern rainfall zone, the rainfall depth (P) that must be captured and treated is 1.5 inches. These new water quality treatment design storms are incorporated into this Manual and are discussed further in Chapter 2.

ii. Channel Protection Design Storm

The 2000 edition of the Manual required that 24-hour extended detention of the one-year, 24-hour duration storm event as described in "*Design Procedures for Stormwater Management Extended Detention Structures*" (MDE, 1987) be used to protect stream channels from erosion. Rainfall depths for the one-year, 24-hour duration storm event are based on Table 2.2 of the 2000 Manual. This table, published in October 2000, provides the rainfall depths for each county in Maryland as found in TP-40.

Recently a consortium of universities and the RAND Corporation published future projected intensity-duration-frequency (IDF) curves for the Chesapeake Bay watershed based on the current NOAA Atlas 14 precipitation data with a range of predictions for future climate change. The data are presented in an online application tool developed by the Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) for three human greenhouse gas and aerosol emission scenarios with four confidence intervals and two time periods (2020-2070 and 2050-2100).

For a high emissions scenario projecting to the year 2100, the MARISA tool predicts an average increase for the two-year, 24-hour duration design storm rainfall of 13% will occur in Maryland. Design storms have been developed for each county based on Atlas 14 and the projected climate change design storm. This information is discussed in more detail in Chapter 2.

1.2.2 Stormwater Management Criteria

Maryland uses a unified approach and requires the implementation of Environmental Site Design to the Maximum Extent Practicable to manage stormwater runoff and size BMPs to meet pollutant removal goals, maintain groundwater recharge, reduce channel erosion, minimize the risk of overbank flooding, and safely pass extreme floods. The overall goal is to mimic pre-development hydrologic runoff characteristics and minimize the impact of land development on water resources. The criteria are described below and are summarized in Table 1.3.

i. Water Quality Treatment, Groundwater Recharge, and Channel Protection

The 2010 edition of the Manual established the minimum stormwater management requirement for new development to implement environmental site design (ESD) to the maximum extent practicable (MEP). For new development, the ESD to the MEP standard was met when ESD planning techniques were employed and the runoff volume from a rainfall event of a minimum of 1 inch up to 2.7 inches, was managed in an ESD practice to the MEP. The remaining runoff volume was required to be managed in a practice identified in Chapter 3. Management of the full volume of runoff from 2.4 to 3.0 inches of rain in ESD practices or a combination of ESD practices and Chapter 3 practices provided the minimum required water quality treatment, groundwater recharge, and channel protection.t

The 2010 Manual did not require a minimum level of quantity management statewide. Instead, management of the overbank protection volume was left to the local approval authority to require when downstream flooding existed, and the jurisdiction did not control the design of the downstream conveyance systems.

ESD practices were originally intended to provide groundwater recharge and both water quality treatment and channel protection for small drainage areas. These practices were intended to infiltrate and/or slowly release runoff from the one-year storm event. However, several factors have severely limited the ability of these ESD practices from functioning as originally intended. These factors include compaction of soils during the development process, locating ESD practices within the flow path of larger storm events, and changing rainfall patterns resulting in more frequent high intensity storms. Experience has shown that these factors may result in clogging and overflow, and ultimately failure of many ESD practices. ESD practices have also been used to reduce the runoff volume and discharge rate requirements for quantity management or flood control. Monitoring existing ESD practices has shown that they are not appropriate for managing peak discharge rates for extreme events (Hopkins, et. al., 2022). While these smaller scale distributed ESD practices have been shown to be effective and resilient for providing water quality treatment, their effectiveness in protecting stream channels from erosion is predicted to continue to decrease as the intensity and frequency of large storm events continues to increase with climate change (Butcher, 2020).

ESD practices are not resilient to high intensity storms because they become flooded, are not able to adequately infiltrate, or simply allow bypass of these larger intensity runoff events. A shift is needed that incorporates more resilient structural practices for channel protection and flood control. These larger structural practices have design features that are more resilient during higher intensity rain events. Therefore, in this Manual, new development is required to provide water quality treatment and ground water recharge in an ESD practice and provide channel protection volume in either an ESD practice or a structural practice. When a project meets these requirements and implements ESD planning techniques through a 3-phased review process it is considered to satisfy the ESD to the MEP standard described in Section 2.8 of Chapter 2.

To meet the ESD to the MEP Standard, the water quality treatment and Re_v shall be based on the runoff from an updated rainfall amount, i.e., 1.0 inch for western Maryland and 1.5 inches for the rest of the State. The water quality treatment and Re_v shall be managed in an ESD practice. The Cp_v is based on the volume of runoff from an updated one-year 24-hour storm adjusted for climate change. The Cp_v is required to be managed in either an ESD practice or a structural practice. This ESD to the MEP standard is discussed in detail in Chapter 2, Section 2.7.

ii. Local Flood Protection

Maryland's first statewide stormwater law in 1982 required quantity management for the two and ten-year 24-hour storm events for all new development projects with a land area disturbance of greater than 5,000 square feet. This required the capture and release of stormwater runoff not to exceed a peak-rate equal to pre-development conditions for each design storm. In 2007, new State stormwater management regulations required a water quality treatment focus. At that time the statewide two-year and ten-year quantity management requirement was modified from a statewide mandate to only being required in areas where a local jurisdiction determined it was necessary due to known flooding problems and where the downstream conveyance system design could not be controlled. Because local approval authorities made these quantity management decisions independently, except for in specifically identified interjurisdictional watersheds, there currently exist inconsistencies in the application of quantity management requirements across jurisdictional boundaries.

Maryland requires that approved stormwater management plans for new development projects shall not worsen flooding impacts to existing downstream properties under design storm conditions. In order to correct for inconsistencies in quantity management, this Manual now requires management of the ten-year 24-hour duration peak discharge for all new development, statewide.

Table 1.3 Summary of New Stormwater Management Criteria

Precipitation and design storms	Atlas 14 data with and without climate change factor; 90 % storm based on updated rainfall data through 2023
Water quality treatment and ground water recharge	Water quality treatment must be provided in ESD practice
	Water quality treatment for 90% of average annual rainfall for two regional values: Western region: 1.0 inches of rainfall. Central/Eastern region: 1.5 inches of rainfall
	Re_v must be provided for all new development projects.
Channel protection	Cp_v is required for all new development. Cp_v shall be provided in an ESD practice or a structural practice. Cp_v shall be provided for a new 1-year storm based on Atlas 14 county mean adjusted for climate change.
Flood risk	Q_{p10} required for all new development projects. Q_{p10} for post-development condition using 10-year climate change projection storm managed to pre-development condition 10-year storm based on Atlas 14 county average.
	Q_{f100} required for all new development projects located within an interjurisdictional watershed. Q_{f100} for post development condition using 100-year climate change projection storm managed to pre-development condition 100-year storm based on Atlas 14 county average. Qf_{100} may also be required locally by the appropriate reviewing authority in areas prone to flooding.

1.3 General Performance Standards for Stormwater Management in Maryland

To prevent adverse impacts of stormwater runoff, the State of Maryland has developed fourteen performance standards that must be met at all new development sites where stormwater management is required. These standards apply to any construction activity disturbing 5,000 or more square feet of earth. The following development activities are exempt from the requirement to meet these performance standards in Maryland:

1. Additions or modifications to existing single family structures;
2. Developments that do not disturb more than 5,000 square feet of land; or
3. Agricultural land management practices.

The minimum stormwater management requirements and BMP design criteria outlined in this Manual ensure that these performance standards are met at all development sites where stormwater management is required:

Standard No. 1 *Site designs shall minimize the generation of stormwater runoff and maximize pervious areas for stormwater treatment.*

Standard No. 2 *Stormwater runoff generated from development and discharged directly into a jurisdictional wetland or waters of the State of Maryland shall be adequately treated.*

Standard No. 3 *Annual groundwater recharge rates shall be maintained by promoting infiltration using structural and non-structural methods. At a minimum, the annual recharge from post-development site conditions shall mimic the annual recharge from pre-development site conditions.*

Standard No. 4 *Water quality treatment shall be provided using environmental site design practices.*

Standard No. 5 *Structural BMPs and ESD practices used for new development shall be designed to remove 80% of the average annual post development total suspended solids load (TSS) and 40% of the average annual post development total phosphorous load (TP). It is presumed that a BMP complies with this performance standard if it is:*

- *designed according to the criteria outlined in this manual,*
- *constructed properly, and*
- *maintained regularly.*

Standard No. 6 *Management of the ten-year, 24-hour frequency storm event is required for all new development projects. In addition, safe conveyance of the 100-year storm event shall be provided.*

Standard No. 7 *To protect stream channels from degradation, the channel protection storage volume (Cp_v) shall be based on the runoff from the one-year frequency storm event adjusted to reflect climate change. The Cp_v requirements may be addressed by using either environmental site design practices or structural practices to capture, treat, and slowly release the runoff from the one-year, 24-hour storm event.*

Standard No. 8 *Stormwater discharges to critical areas with sensitive resources [e.g., cold water fisheries, shellfish beds, swimming beaches, recharge areas, water supply reservoirs, Chesapeake Bay Critical Area] may be subject to additional performance criteria or may need to utilize or restrict certain BMPs.*

Standard No. 9 *All BMPs shall have an enforceable operation and maintenance agreement to ensure the system functions as designed.*

Standard No. 10 *Every BMP shall have an acceptable form of water quality pretreatment.*

Standard No. 11 *Redevelopment, defined as any construction, alteration or improvement exceeding five thousand square feet of land disturbance on development sites where existing land use is commercial, industrial, institutional or multi-family residential and existing impervious cover is 40%, is governed by special stormwater sizing criteria as outlined in this Manual*

Standard No. 12 *Certain industrial sites and all construction sites disturbing over one acre, are required to prepare and implement a stormwater pollution prevention plan and file a notice of intent (NOI) under the provisions of Maryland's National Pollutant Discharge Elimination System (NPDES) General Permit for Discharges from Stormwater Associated with Construction Activity. The requirements for the general discharge permit are available from MDE's website.*

Standard No. 13 *Stormwater discharges from land uses or activities with higher potential for pollutant loadings, defined as hotspots in Chapter 4, may require the use of specific structural BMPs and pollution prevention practices. In addition, stormwater from a hotspot land use may not be infiltrated without proper pretreatment.*

Standard No. 14 *In Maryland, local governments are usually responsible for most* *stormwater management review authority. Therefore, prior to design, applicants should always consult with their local reviewing agency to determine if they are subject to additional stormwater design requirements.*

1.4 Symbols and Acronyms

As an aid to the reader, the following table outlines the symbols and acronyms that are used throughout the text. In addition, a glossary is provided at the end of this volume that defines the terminology used in the text.

Table 1.4 Key Symbols and Acronyms Cited in Manual

A	drainage area	q_i	peak inflow discharge
A_f	filter bed area	Q_i	runoff depth for the impervious area
A_i	impervious area	q_o	peak outflow discharge
A_p	pervious area	Q_p	Runoff depth for the pervious area
A_{sf}	surface area, sedimentation basin full	q_p	overbank flood protection peak discharge
A_{sp}	surface area, sedimentation basin partial	q_u	unit peak discharge
BMP	best management practice	Q_w	weighted runoff depth
cfs	cubic feet per second	Re_v	recharge volume
Cp_v	channel protection storage volume	R_f	soil specific recharge factor
CMP	corrugated metal pipe	R/W	right of way
CN	curve number	SD	separation distance
d_f	depth of filter bed	t_c	time of concentration
du	dwelling units	t_f	time to drain filter bed
ED	24-hour drawdown of the water quality volume	TP	total phosphorous
ESD	environmental site design	t_t	time of travel
f	soil infiltration rate	TR-20	Technical Release No. 20 Project Formulation-Hydrology, computer program
fps	feet per second	TR-55	Technical Release No. 55 Urban Unit Hydrology for Small Watersheds
h_f	head above filter bed	TSS	total suspended solids
HSG	hydrologic soil group	V_f	filter bed volume
Ia	initial abstraction	V_r	volume of runoff
I	percent impervious cover	V_s	volume of storage
k	coefficient of permeability		
MEP	maximum extent practicable	V_t	total volume
P	rainfall depth	V_v	volume of voids
Q	direct runoff depth	WQ_v	water quality storage volume
q_f	extreme flood protection discharge	WSE	water surface elevation