Chapter 7 Stormwater Management Calculations and Methodology

7.1 Overview

There are five primary components of better stormwater management that the designer must document for stormwater permitting requirements:

1. **Reduction of runoff quantities and pollutant loads** through source control and other non-structural practices (site protection and restoration BMPs).
2. **Capture and retention of the SOV** (in cubic feet of runoff).
3. Implementation of **water quality management** to achieve 80 percent reduction in TSS (in percent reduction).
4. Sufficient **conveyance capacity** of all stormwater structures to safely convey or direct peak flow rates (in cubic feet per second or feet per second as appropriate).
5. Mitigation of the **peak flow rate** (in cubic feet per second).

Several methodologies are available to estimate total runoff volume and peak runoff rate, as well as different approaches for estimating water quality improvement. This chapter describes the calculation methodologies required to comply with stormwater management regulations in the City of Chattanooga. Certain project types and sites may not be required to meet all stormwater calculation components as described in Chapter 3 and later sections of this chapter.

7.2 Step 1 − Runoff Reduction through Site Protection and Restoration

Rethinking the site design to reduce the hydrologic impacts of development is one of the most important and effective stormwater practices. Implementing better stormwater management begins by reducing unnecessary site disturbance, protecting important natural features and functions (protective BMPs), and employing practices that restore or recreate the functions of natural features (restorative BMPs).

<u>Damage Prevention and Site Protection BMP Credits (Protective BMPs)</u>

Protective BMPs are practices that protect and maintain areas of water quality and ecological benefit, and protect areas that are more susceptible to erosion and pollutant generation when disturbed. For the purpose of calculations and methodologies for specific protective BMPs, **the project area that incorporates protective BMPs is excluded from the project area used to calculate the SOV and water quality**. In other words, if a site area is protected and undisturbed as described in the protective BMPs, it is assumed that the protective BMPs provide water quality benefits and reduce runoff volumes. The area protected by the following "protective BMPs" in this manual may be excluded from SOV calculations:

5.2.1 Protect Undisturbed and Healthy Soils
- 5.2.1.1 Preserving Landforms
- 5.2.1.2 Protect Highly Erodible Soils on Steep Slopes

5.2.2 Protect and Incorporate Natural Flow Paths
5.2.3 Protect and Preserve Riparian Corridors
5.2.4 Protect and Preserve Natural Vegetation
- 5.2.4.1 Protect Historic or Specimen Trees

In order for these BMPs to be credited, they must be properly documented and implemented during construction. Chapter 5 provides specific guidance for each BMP, along with a checklist for compliance for each protective BMP. Essentially, for a project intended to protect a portion of a site both during and after construction, certain practices and measures must be implemented and documented on the plan sheets.

For example, tree protection fencing must be installed and maintained during construction, but if the area under a canopy tree is protected, it may be subtracted from the SOV and water quality area. The Protect Undisturbed and Healthy Soils BMP (Section 5.2.1) may be widely applied to new and redevelopment projects to reduce SOV. Portions of the site that can be protected from disturbance and from the movement of equipment and vehicles during and after construction can be considered undisturbed and excluded from the SOV and water quality requirements.

Excluding the area of protective BMPs in the SOV and water quality calculations is intended as an incentive to applicants/owners to reduce site disturbance and maintain the water quality benefits of important natural features. Reducing the site disturbance footprint will directly reduce the SOV. It should be noted that the drainage area of protective BMPs is **not** excluded from peak flow rate and safe conveyance calculations. This includes safe conveyance of flows originating offsite. These areas will contribute stormwater runoff in larger storm events, and this runoff must be safely managed to prevent localized or regional flooding conditions.

Additionally, the protective BMPs include BMP 5.2.4.2, Soil and Plant Salvage. This BMP will not reduce SOV, but the reuse of soils and plants can maintain ecological function and may reduce construction costs for the applicant/owner.

Protective practices allow a developer to exclude areas needing SOV management by implementing protective practices that maintain a site's ability to self-manage stormwater. By preventing the possibility for damage to a site's natural features, a developer is able to avoid building stormwater infrastructure for protected areas in a good, natural condition.

Restorative Practices and BMP Credits (Restorative BMPs)

A number of BMPs are presented in Chapter 5 that improve water quality by restoring the health and function of natural systems, and correspondingly reduce runoff volumes and pollutant loads. These are referred to as restorative BMPs and include:

5.4.1 Recreate Natural Flow Patterns
    5.4.1.1 Naturalize Swales and Drainage Channels
5.4.2 Improve Native Landscape Cover Types
    5.4.2.1 Change Cover Type
5.4.3 Amend and Restore Disturbed Soils

For the purpose of calculations and methodologies, **each of these restorative BMPs provides a specific volume credit (based on size/extent of BMP). These credits can be used to directly reduce the project SOV.**

Specific guidance for each restorative BMP, along with a checklist for compliance for each restorative BMP, is provided in Chapter 5. Section 7.7 provides “Credit Calculations and Worksheets.”

Inclusion of these restorative practices allows for a credit to be applied to the SOV that a developer is required to manage. By implementing these practices, up to 25 percent of the required SOV can be excluded from management, thus decreasing the size of BMPs needed to manage a disturbed area’s SOV. This credit can help a developer save time, effort, and capital on the implementation of stormwater BMPs because the necessary SOV to be managed is reduced. The developer receives value from the implementation of restorative practices while stormwater runoff volumes are reduced as a result of improved site management.

Green Roofs, Pervious Pavement, and Tree Planting Incentives

In addition to protective BMPs and restorative BMPs, certain practices also serve to reduce runoff, and correspondingly, can be excluded from the area used to quantify the required SOV:

- Pervious Pavement that Is Exclusively “Self-Managing”

  Pervious pavement is described in BMP 5.3.1. A pervious pavement area that **only** receives direct rainfall (that lands on the pavement or drains onto the pavement) can be excluded from the area used to calculate SOV. That is, the footprint of self-managing pervious pavement can be excluded from the area used to calculate SOV. Typical areas that may be eligible for this incentive include pervious paths, plazas, sidewalks, and parking areas.

In many applications, a pervious pavement area may be constructed over a stormwater bed that is intended to receive and manage runoff from other areas. (For example, the designer may elect to convey additional runoff from other areas into the stormwater bed, as discussed in Chapter 5.) In this situation, where the pervious pavement area is managing a larger project area, the pervious pavement is **not** eligible for exclusion from the area used to calculate SOV. Instead, the storage capacity of the stormwater bed is used to meet site SOV requirements, and the pavement is considered to have the same runoff coefficients as impervious pavement (since all rainfall will directly enter the stormwater bed and must be accounted for).

- Green Roofs

  Green roofs can be used to manage SOV onsite. Designs and supporting calculations should be submitted to the City for approval during the concept level of the application process. Guidance on green roof design can be found in BMP 5.3.6.

  Tree canopy serves to intercept and slow rainfall, and tree root systems help to maintain a more permeable ground surface. New trees planted with the center of the trunk within 10 feet of connected impervious surfaces may be eligible for SOV reduction credit. Deciduous trees may qualify for 10 cubic feet of SOV credit, and coniferous trees may qualify for 6 cubic feet of SOV credit. All trees must be planted in accordance with the City's ordinances, including landscape requirements.

The Non-Structural BMP Credits Worksheet (see Section 7.7) can be used to quantify the stormwater benefits of protective BMPs, restorative BMPs, and incentives. Current worksheets can be accessed at *(http://www.chattanooga.gov/public-works/city-engineering-a-water-quality-program).*

7.3 Step 2 – Manage Stay-on-Volume

The City's NPDES MS4 Permit requires applicants/owners to manage the first inch of rainfall with no discharge to surface waters. This volume of stormwater is defined as the SOV in Chapter 3 and is determined based on the runoff potential from the land uses within the project area. Calculation of the SOV is performed using the Small Storm Hydrology Method.

Project Area for SOV

As described above, the SOV is calculated based on the disturbed area of a project site. Areas that are undisturbed in accordance with the protective BMPs, as well as offsite drainage areas that are beyond the project property boundary, may be excluded from the SOV. This is shown diagrammatically on Figure 7-1. The applicant/owner is responsible for the SOV associated with the footprint of disturbance for a project site.

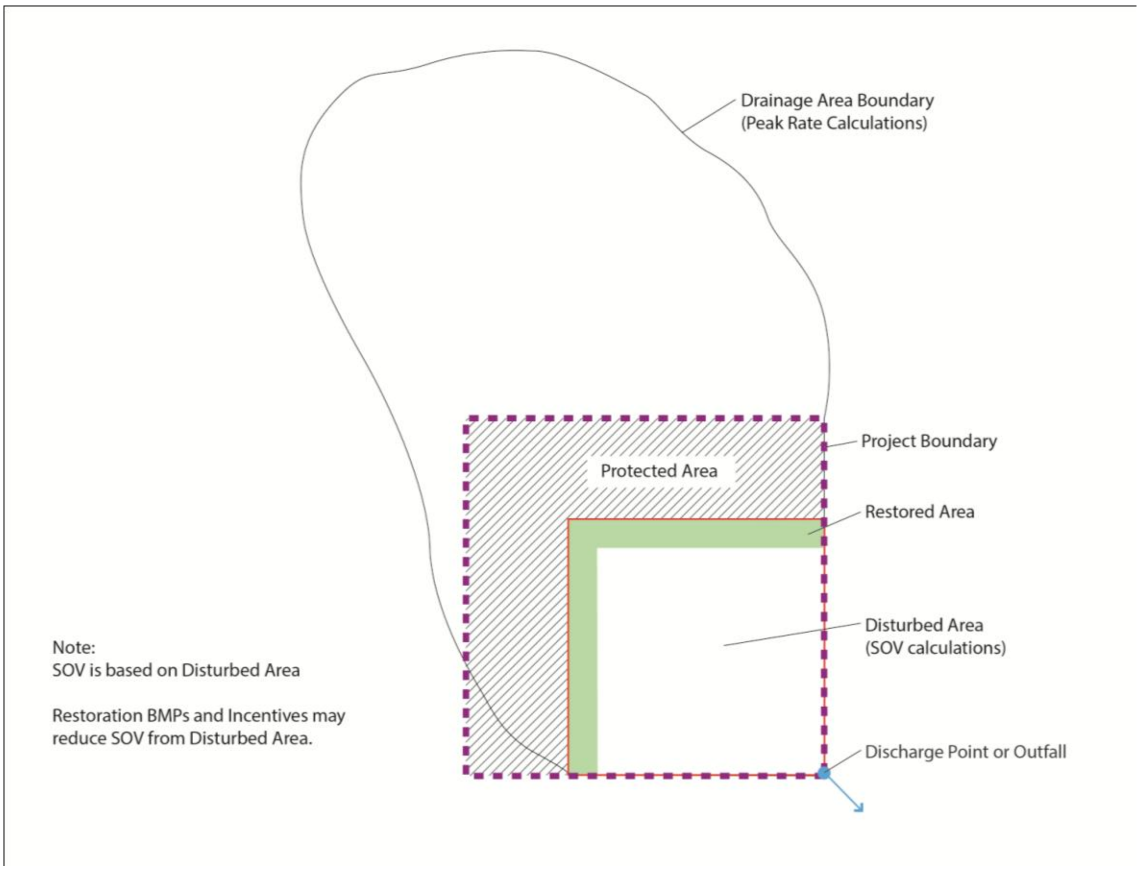

Figure 7-1. The SOV is calculated based on the disturbed area of a project. Protective BMPs and incentives may further reduce the SOV.

Small Storm Hydrology

The Small Storm Hydrology Method (SSHM) was developed to estimate the runoff volume from urban and suburban land uses for relatively small storm events (generally no more than 1.6 inches). Other common procedures, such as the runoff curve number method, are less accurate for small storms. The CN methodology can significantly underestimate the runoff generated from smaller storm events (Claytor and Schueler 1996 and Pitt 2003). The SSHM is a straightforward procedure in which runoff is calculated using volumetric runoff coefficients based on both land use type and rainfall. The runoff coefficients (Rv) are based on extensive field research from the Midwest and the southeastern United States, and Ontario, Canada, over a wide range of land uses and storm events. The coefficients have also been tested and verified for numerous other U.S. locations. Runoff coefficients for individual land uses generally vary with the rainfall amount – larger storms have higher coefficients. The runoff coefficients (Rv) for seven urban land use scenarios for the ½-inch, 1.0-inch, and 1.6-inch storms are provided in Table 7-1.

Table 7-1. Small Storm Hydrology Coefficients (Rv)

Small Storm Hydrology Coefficients (Rv) for Urban Land Uses

	Rv for 0.5"	Rv for1.0"	Rv for 1.6"	Rv for 2.1"
Flat Roof	0.79	0.85	0.88	0.90
Pitched Roof	0.95	0.97	0.99	0.99
Large Impervious Areas	0.97	0.98	0.99	0.99
Small Impervious Areas	0.64	0.70	0.79	0.85
Sandy Soils	0.02	0.03	0.05	0.08
Typical Urban Soils	0.10	0.12	0.15	0.18
Clayey Soils	0.19	0.21	0.24	0.27

Source: Pitt. 2003

Note:
- Soils mapped as "Urban" must use Rv values for urban soils.
- Soils mapped as Hydrologic Group A may use Rv values for sandy soils if soil group is described as sand. Otherwise, urban Rv values apply.
- Soils mapped as Hydrologic Group B must use Rv values for typical urban soils.
- Soils mapped as Hydrologic Group C or D must use Rv values for clayey soils.

See below for definitions.

The SSHM uses only those seven land area categories shown in Table 7.1. Based on field observation and detailed monitoring of specific source area runoff, several of these categories may be further defined as follows (Pitt 2003):

- ***Flat Roofs*** – This category also includes large unpaved parking areas located on typical urban soils. Large unpaved parking areas on sandy soils may apply the sandy soil runoff coefficients. In this context, "large" means an area of unpaved parking with an average dimension greater than 24 feet in any direction.

- ***Large Impervious Area*** – This category describes impervious areas with an average dimension greater than 24 feet in any direction. Examples of large impervious areas include parking lots with curbs, roads with curbs, highways, etc.

- ***Small impervious Areas*** – This category describes impervious areas with an average dimension no greater than 24 feet in any direction. Examples of small impervious areas include roads without curbs, small parking lots without curbs, and sidewalks.

For each land use type, SOV is calculated based on land use area, land use coefficient, and rainfall volume using the following equation:

SOV = P/12 * Rv * Area, where:

SOV = Stay-on-Volume (ft^3)
P = Rainfall depth (in)
Rv = Small Storm Hydrology Method runoff coefficient (Table 7-1)
A = area of land use (ft^2)

The Rainfall Depth P is based on project watershed location and type, and can be found in Table 3-2.

For a site with multiple land uses, SOV is calculated as follows:

$$SOV = \sum_{i=1}^{n}\left[\left(\frac{P}{12} * Rv_i * A_i\right) + \left(\frac{P}{12} * Rv_{i+1} * A_{i+1}\right) + \cdots + \left(\frac{P}{12} * Rv_n * A_n\right)\right]$$

For example, a small commercial building project that includes a single building structure with a pitched roof approximately 2,131 ft^2 in area, a large driveway/parking area approximately 12,258 ft^2 in size, and lawn areas (clayey soils) approximately 17,141 ft^2 in size would typically require management of 1,473 ft^3 SOV for a 1.0-inch rainfall depth, as calculated below:

$$SOV = \left[\left(\frac{1.0}{12} * 0.98 * 12{,}258\right) + \left(\frac{1.0}{12} * 0.21 * 17{,}141\right) + \left(\frac{1.0}{12} * 0.97 * 2{,}131\right)\right]$$
$$SOV = [1001 + 300 + 172]$$
$$SOV = 1473\ ft^3$$

A similar project located within the South Chickamauga watershed would require management of 2,448 ft^3 SOV for a 1.6-inch rainfall depth, per the calculations below:

$$SOV = \left[\left(\frac{1.6}{12} * 0.99 * 12{,}258\right) + \left(\frac{1.6}{12} * 0.24 * 17{,}141\right) + \left(\frac{1.6}{12} * 0.99 * 2{,}131\right)\right]$$
$$SOV = [1618 + 549 + 281]$$
$$SOV = 2{,}448\ ft^3$$

Managing SOV may be accomplished using one or a combination of BMPs, including restorative BMPs. As discussed previously, SOV may also be decreased by reducing site disturbance and implementing protective BMPs.

BMPs that infiltrate or capture and reuse runoff can be used to manage SOV. Many BMPs will also manage SOV via evapotranspiration (ET). ET is addressed in the BMP design by the volume credit assigned to soil storage (generally 20 percent of soil volume).

In practice, ET is a complex process by which plants, soils, and climatological processes interact. ET is a viable and important component for achieving SOV, but is difficult to quantify on a single rainfall event basis since ET occurs primarily during non-storm periods. Modeling ET involves dynamic simulation of multiple parameters over extended periods of time, including soil type, soil porosity, field moisture capacity, plant type, root depth, cover condition, and wilting point, as well as rainfall data, rainfall timing, and ambient temperature. Because of the complexity of determining ET quantities, applicants/owners wishing to take volume credit for ET must submit a detailed model analysis, such as WinSLAMM or similar model approved by the City of Chattanooga, that supports any additional reduction in SOV attained through ET.

<u>SOV Rainfall Depth and Credits</u>

The rainfall depth requirements for the calculation of SOV are described in Chapter 3, Table 3.2. These values (P = 1.6 inches for new development projects in the South Chickamauga watershed and 1 inch for all other new development; P = 1 inch for all redevelopment projects) are applied to calculated SOVs.

As described in Chapter 3, the City's NPDES MS4 Permit allows incentive standards for redeveloped sites. The City may allow a 10 percent reduction in the volume of rainfall to be managed (SOV) for the following types of development:

- Redevelopment in specific areas identified by the City
- Brownfield redevelopment
- High density (>7 units per acre)
- Vertical density (floor to area ratio of 2 or >18 units per acre)
- Mixed-use and transit-oriented development (within ½ mile of transit)

The 10 percent volume management reduction may be cumulative up to 50 percent for sites that meet multiple incentives. The project must meet the development type definition as defined by the City. The additional 10 percent reduction for redevelopment applies only to redevelopment locations or types specifically identified by the City as being eligible for the additional credit (i.e., redevelopment incentive areas).

The approval of any incentive reduction is at the discretion of the City to determine if the site meets the intent of the incentives. The applicant/owner must demonstrate that the proposed project meets the intent of the incentives.

For example, a commercial project located in the South Chickamauga watershed that meets City-defined criteria for both vertical density and transit-oriented development, and includes a 30,000-ft^2 building with a pitched roof and a 30,000-ft^2 parking garage with a flat roof (no parking on roof), would require management of 5,984 ft^3 of SOV, as calculated below:

$$SOV = \left[\left(\frac{1.6}{12} * 0.99 * 30{,}000\right) + \left(\frac{1.6}{12} * 0.88 * 30{,}000\right)\right] * (1.0 - 0.10 - 0.10)$$

$$SOV = [3{,}960 + 3{,}520] * 0.80$$

$$SOV = 5{,}984\ ft^3$$

<u>SOV and Multiple BMPs for LID Design</u>

Low-impact development is the practice of managing stormwater volume through soil and vegetative practices **close to the source of runoff**. This means that a site may include multiple BMPs, each located close to a source of runoff and managing a “sub-area” of a larger drainage area. This is shown diagrammatically on Figure 7-2 – Scenario 1. **The disturbed drainage area tributary to each structural BMP must be delineated, and each BMP sized to capture the SOV from the sub-drainage area.** If a BMP cannot manage the required SOV, it may discharge to a downstream area and BMP designed to accommodate the additional, unmanaged volume. This is shown diagrammatically on Figure 7-2 – Scenario 3. Designers may use Worksheet 3 of the LID Calculation Tool to appropriately size each BMP. **The sub-drainage areas used to calculate SOV may not necessarily correspond to areas required for peak rate calculations. Flow rate capacity calculations for structures such as inlets, pipes, etc. must consider all drainage to that structure, including offsite contributions.**

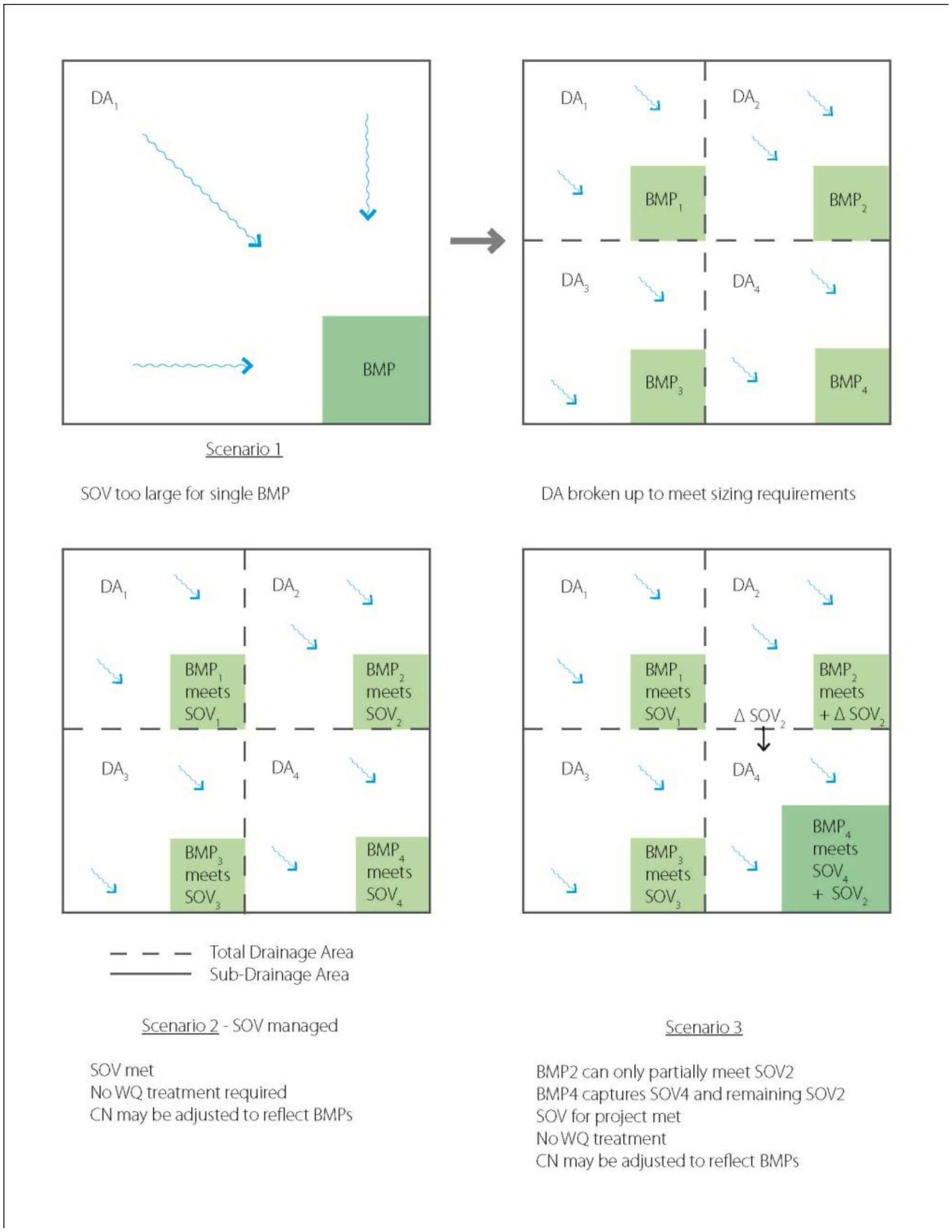

Figure 7-2. SOV and multiple BMPs for LID design.

Partial SOV Capture and "Swap" Areas

In certain instances, a project site may achieve only partial SOV capture. In such instances, the applicant/owner has several options:

1. The applicant/owner may elect to apply the water quality requirement. However, the water quality treatment volume requirements are based on a higher rainfall amount than the SOV rainfall amounts, as described in Section 7.3, and generally require volume capture, treatment, and, depending on the BMP, extended release over not less than 48 hours. The water quality rainfall may be reduced by the portion of the SOV rainfall managed as follows:

   Water Quality Rainfall − SOV Rainfall Managed = Adjusted Water Quality Rainfall

   For example, if the rainfall depth for calculation of the water quality volume is 2.1 inches, and the project has successfully achieved the SOV for a ½-inch rainfall, the adjusted water quality rainfall is:

   2.1 inches − 0.5 inches = 1.6 inches rainfall for water quality calculations

2. Alternatively, the applicant/owner may elect to manage an existing developed portion of the site (that currently does not have stormwater management), in lieu of managing the stormwater from the new construction. In other words, existing developed areas may be "swapped" to meet SOV requirements for the new development. The managed area must be part of the same property/location and under the control of the same applicant/owner. For example, the applicant/owner may elect to capture runoff from an existing building in lieu of managing an area of new construction. This is often a very cost-effective approach, especially in dense urban situations, brownfield sites, CSO areas, etc. The "swapping" of management areas must be approved by the City, and should be identified during the concept permit phase.

7.4 Step 3 – Water Quality Improvement

For projects that cannot manage 100 percent of the SOV, the City's MS4 Permit requires that "….the remainder of the stipulated amount of rainfall must be treated prior to discharge with a technology documented to remove 80% total suspended solids (TSS). The treatment technology must be designed, installed and maintained to continue to meet this performance standard" (3.2.5.2.3 of the permit). Applicants/owners must demonstrate reduction of TSS by implementing treatment BMPs that are designed, installed, and maintained to continuously meet this water quality standard.

Water quality in stormwater runoff can vary greatly, affected primarily by land use and geographic location. For meeting stormwater management requirements, applicants/owners can demonstrate water quality improvement with one of the following approaches:

1. Capture, treatment, and slow release of the defined water quality volume of the runoff from the water quality rainfall. WQv is defined as the runoff resulting from the 1-year, 24-hour type II rainfall event for BMPs that treat flow rates and 2.1-inch rainfall for BMPs that treat volumes. Runoff must be captured by appropriately designed BMPs and remove 80 percent of the TSS. BMPs (e.g., 5.3.4, 5.3.11, etc.) that function by treating volume must slow release between 48 and 72 hours to allow adequate settling and treatment time and not dry out.

   or

2. Demonstration of the percent reduction of TSS achieved on an annual basis using a continuous simulation model, such as WinSLAMM or a previously approved equal.

   or

3. Percent reduction of TSS by BMP type based on the International BMP Database (http://www.bmpdatabase.org). (Note: The database indicates a range of effectiveness for various BMPs; the 96 percent confidence level is to be applied). The applicant/owner will be responsible for demonstrating to the City that the BMPs are designed to achieve the proposed percent reductions for TSS, based on estimated pollutant loadings from land use types and designed performance of BMPs.

<u>Option 1: Capture, Treatment, and Slow Release of the Water Quality Volume</u>

Project sites that are unable to manage 100 percent of the SOV must design, install, and maintain BMPs to improve the quality of stormwater runoff discharge in accordance with the City's MS4 Permit. Based on analysis of the City's existing land uses, the chart on Figure 7-3 shows that most of the accumulative (total) solids are associated with runoff resulting from rainfall depths of approximately 2.1 inches. As a baseline, project sites that are unable to manage 100 percent of the SOV must design, install, and maintain water quality BMPs to treat the first 2.1 inches of rainfall, less any partial SOV achieved, prior to discharging from the site.

For other than flow rate controlled manufactured BMPs, to provide sufficient time for water quality treatment to occur and to reduce the impacts of hydro-modification from unmitigated volume increases, the water quality runoff volume must be detained and slowly released between 48 and 72 hours. In other words, the water quality volume should be released at a low flow rate such that full (100 percent of stored volume) release does not occur until between 48 and 72 hours after the beginning of rainfall.

For project sites that must meet peak rate controls, this requirement may increase the size of detention storage. Therefore, applicants/owners are encouraged to achieve as high a SOV as feasible.

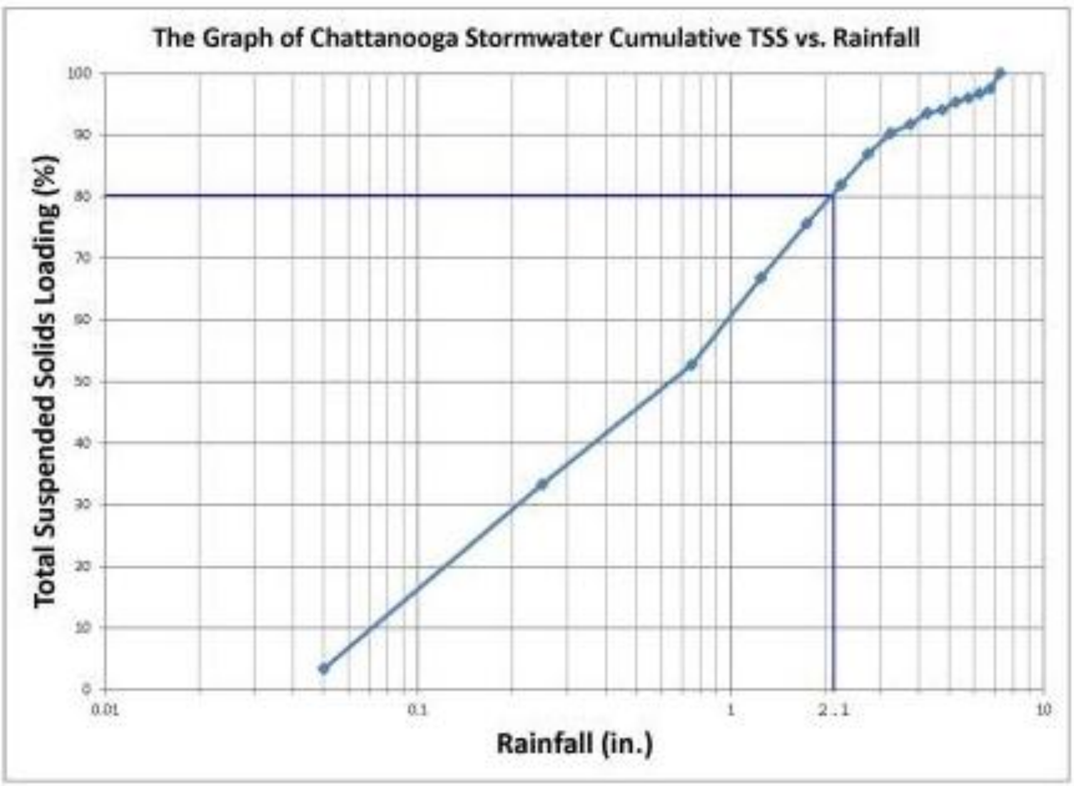

Figure 7-3. Rainfall capture and treatment for 80 percent TSS.

<u>Option 2: Calculate the Percent TSS Reduction on an Annual Basis Using a Continuous Simulation Model that Incorporates Water Quality, such as WinSLAMM or Previously Approved Equal</u>

Applicants/owners may provide a detailed model analysis, such as WinSLAMM, demonstrating achievement of an 80 percent reduction in TSS for different design storm depths. Submission of a WinSLAMM model does not in any way constitute approval from the City to manage a lesser storm. The City reserves the right to require management of runoff from the first 2.1 inches of rainfall regardless of submitted modeling.

Option 3: Percent Reduction of TSS by BMP Type Based on the International BMP Database (http://www.bmpdatabase.org/)

Alternatively, the City may allow the applicant to rely on assumed percent reduction values as provided in the International BMP Database. Many BMPs do not achieve 80 percent TSS reduction, and therefore, several BMPs may be required to achieve the targeted pollutant reduction. This approach does not consider different pollutant land use loadings, and therefore may result in areas where water quality BMPs are "over-applied" or "under-applied." To avoid this, the applicant is required to estimate pollutant loadings from land use types based on event mean concentration (EMC) values as provided in the International BMP Database or other documented sources. Providing the estimated effluent concentration and TSS loading for a specific rainfall event will allow the City to evaluate the performance of the proposed BMPs. The applicant should evaluate pollutant loadings and reductions based on the water quality rain event of 2.1 inches.

While the use of assumed percent reduction is widely accepted in other stormwater management programs, there is little supporting scientific evidence to substantiate performance in accordance with the assumed values. The applicant/owner should be prepared to support and substantiate any claimed TSS reduction values to the satisfaction of the City. Submission of documentation supporting an assumed percent reduction does not in any way constitute approval from the City. The City reserves the right to require additional management to meet water quality goals based on project location, type, and proposed BMP design.

One example where percent reduction may apply is when an applicant/owner proposes a hydrodynamic separation device from a certain manufacturer to treat runoff from a 10,000-square-foot parking area to achieve 80 percent TSS reduction.

First, the design runoff rate from the parking area must be computed, using the Rational Method for a 1-year design storm, as described below.

$$Qp = C * i * A$$

$$Qp = 0.98\ cfs$$

where:

Qp = peak rate of runoff (ft^3/sec)

C = 0.95, for impervious asphalt

i = 4.5 (in/hr), for a 1-year design storm assuming a 5-minute time of concentration across the parking area

A = 0.23 (ac)

A manufactured device is selected that has a design treatment capacity capable of handling an inflow velocity of 0.98 cubic feet per second (cfs). In this example, a manufactured device with a capacity range of 0.1 to 2 cfs was selected. See Section 5.3.12 for additional information regarding manufactured devices, including long-term operational monitoring requirements.

BMP Treatment Trains

A stormwater management BMP treatment train is a system of interconnected stormwater management BMPs constructed in series and designed to treat stormwater management to meet volume and rate reduction and water quality requirements. Studies have shown that incorporating treatment trains into traditionally developed projects significantly reduces pollutant loadings and volumetric runoff, and slows the rate at which stormwater leaves the project site. Treatment trains, however, rely primarily on appropriately sized source controls to achieve these benefits. While treatment trains promote green infrastructure and more closely mimic natural, undeveloped hydrologic conditions, it is important to realize the challenges and limitations when incorporating stormwater management BMP treatment trains into any site design. In particular, treatment trains rely on highly variable, assumed percent reductions to demonstrate compliance with intended water quality goals without considering the pollutant loading from contributing drainage areas. As such, stormwater management BMP treatment trains must provide a detailed model analysis, such as WinSLAMM or other City approved model, to document achievement of water quality goals prior to City approval.

Water quality BMPs, such as filter strips, and restorative BMPs, such as riparian buffers and restored soils, are important components of a treatment train approach. These practices reduce pollutants and also slow and reduce runoff. Designers are encouraged to incorporate such practices when SOV cannot be met, rather than relying on a single BMP to improve water quality.

Other Pollutants of Concern

The City of Chattanooga's NPDES MS4 Permit requires the City to reduce TSS concentrations from all new and redevelopment sites. However, TSS is not necessarily the only pollutant of concern; phosphorous, nitrogen, bacteria, and even temperature are pollutants commonly attributed to the various land uses found in Chattanooga.

Phosphorous is a chemical nutrient that can find its way into stormwater runoff from fertilized lawn areas, pet waste, road salts, and accumulated sediments. Increased levels of phosphorous in stormwater runoff may cause eutrophication and other water quality impairments that impact potability and recreational uses of affected water bodies (phosphorus is often the limiting nutrient in freshwater systems). Phosphorus is often bound to sediment such that TSS reduction can also reduce phosphorus loads.

Nitrogen is a chemical nutrient that may occur in several forms. Its primary contributing land use is agricultural sources, such as manure, and other natural sources; however, overuse of landscape fertilizers can impact nitrogen loads. Atmospheric deposition onto impervious surfaces can also contribute to nitrogen loads. Increased levels of nitrogen may cause algae and bacteria blooms that rapidly degrade water quality. Nitrogen is generally found in stormwater in a dissolved form that is not easily treated or removed. Vegetative BMPs must be maintained (i.e., vegetation removed at the end of the growing season) to prevent the release of nitrogen.

Bacteria, including E. coli, may be transported into stormwater runoff from pet waste or sanitary overflows during wet weather events. Livestock, wildlife, and septic systems can also affect bacteria levels. Bacteria and other pathogenic microorganisms create potentially devastating effects on human health and safety, not just from drinking contaminated water, but often merely from physical contact.

Finally, temperature plays a key role in the overall health and quality of waters receiving stormwater runoff. Any increase or decrease in temperature in a receiving water body, such as a stream, river, or lake, impacts the ability of that water body to sustain an environment suitable for its native species. For example, trout are primarily a cold water species; significant variations above the temperatures they can normally withstand may result in large-scale fish kills that impact both the health and recreational use of the affected water body. More commonly, alterations in stream temperature ranges will alter the microbial community in a water body, initiating species changes throughout the food chain.

Although the City's current NPDES MS4 Permit does not specifically require compliance with reduction requirements for any other pollutants of concern, Table 7-2 may be used as a general guide in determining which BMPs may improve water quality being degraded by the pollutants (other than TSS) described above.

Table 7-2. BMP Applicability Matrix for Water Quality Improvement for Specific Pollutants of Concern

BMP POLLUTANT REDUCTION POTENTIAL								
	Total Suspended Solids (TSS)		Total Phosphorus (TP)		Total Nitrogen (TN)		Bacteria E. Coli	
BMP	% Reduction	Performance Rating	% Reduction	Performance Rating	% Reduction	Performance Rating	% Reduction	Performance Rating
Pervious Pavement 5.3.1	80	H	40	L	18	L	--	--
Infiltration Bed 5.3.2	--	--	--	--	--	--	--	--
Infiltration Trench 5.3.3	--	--	--	--	--	--	--	--
Bioretention 5.3.4	78	H	18	L	36	L	71	H
Vegetated Swales 5.3.5	37	L	N/A	N/A	14	L	--	--
Vegetated Filter Strips 5.3.6	36	M	N/A	N/A	16	L	--	--
Infiltration Berms 5.3.7	--	--	--	--	--	--	--	--
Green Roofs 5.3.8	72	H	N/A	N/A	N/A	N/A	93	H
Runoff Capture and Reuse 5.3.9	--	--	--	--	--	--	--	--
Disconnection of Impervious Area 5.3.10	--	--	--	--	--	--	--	--
Stormwater Planter Box 5.3.11	--	--	--	--	--	--	--	--
Manufactured Devices 5.3.12	47	L	84	L	17	L	--	--

Key: H = High M = Medium L = Low N/A = Not Applicable

Pollutant reduction potential was adapted from performance summaries published in July 2012 by the International Stormwater BMP Database.

Notes:
1. Values for manufactured devices were taken as an average across the types specified in the IBD 2012 report.
2. Any device that returned a negative % reduction (increase) in any pollutant was marked with N/A.
3. Any % reduction over 70% was rated “H,” over 50% was rated “M,” below 50% was rated “L.”
4. Blank values indicate no data available.
5. Naturalized basin data (BMP 5.3.13) are not available and subject to design variables. Values can approximate bioretention.

7.5 Step 4 – Capacity Calculations

As defined in Chapter 3, stormwater designs must control peak discharge rates and demonstrate that all pipes, inlets, swales, trenches, and other stormwater conveyance structures have the capacity for the 10-year storm event. The designer should also consider conditions during large storm events onsite so as not to flood roads, buildings, etc.

Conveyance structures, such as pipes, swales, and inlets, that are designed only to transport runoff from project sites less than 25 acres may be sized for capacity using the Rational Method. Rational Method coefficients are provided in Table 7-3.The Rational Method has been used extensively to estimate peak runoff rates from relatively small (25 acres or less), highly impervious drainage areas using the following equation:

$$Qp = C * i * A$$

where:

- Qp = peak rate of runoff (ft^3/sec)
- C = rational method runoff coefficient
- i = average rainfall intensity (in/hr) for a storm with duration equal to the time of concentration of the area
- A = drainage area (ac)

The Rational Method may **not** be used to calculate water quality, infiltration, or SOV. The Rational Method may not be used to analyze peak rate mitigation in accordance with Section 7.6 below nor may it be used to calculate detention pond volumes.

Table 7-3. Rational Method Coefficients (C)

Rational Runoff Coefficients			
Land Cover	Rational Runoff Coefficient, C		
	slope <2%	slope 2%-7%	slope >7%
Flat Roofs	0.90	0.90	0.90
Pitched Roofs	1.00	1.00	1.00
Asphalt	0.95	0.95	0.95
Concrete	0.95	0.95	0.95
Brick	0.85	0.85	0.85
Unimproved Areas	0.35	0.35	0.35
Lawns, sandy soils	0.10	0.15	0.20
Lawns, urban and clayey soils	0.15	0.20	0.30
Meadow Areas	0.30	0.30	0.30
Wooded Areas	0.15	0.15	0.15

Adapted from Viessman, W. and M. Hammer, 1993

Average rainfall intensity in inches per hour (for the duration equal to the time of concentration) can be obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 interactive application at: http://dipper.nws.noaa.gov/hdsc/pfds/.

7.6 Step 5 – Peak Rate

The City requires applicants/owners to manage the peak flow rate at which all stormwater runoff leaving a project site is discharged. The post-development peak rate must not exceed the pre-developed peak rate of discharge for the 2-, 5-, 10, and 25-year storm events and check for the safe passage of the 100-year storm event.

Table 7-4. 24-hour Design Storm Rainfall Events for Chattanooga (reference: http://www.nws.noaa.gov/oh/hdsc)

24-HR Design Storm Rainfall Events for Chattanooga	
Rainfall Return Period (yr)	24-HR Rainfall Amount (in)
1	3.1
2	3.7
5	4.5
10	5.1
25	6.0
100	7.4

NRCS Unit Hydrograph Method for Peak Rate Calculation (Cover Complex Method)

NRCS developed a system to estimate peak runoff rates and runoff hydrographs using a dimensionless unit hydrograph derived from many natural unit hydrographs from diverse watersheds throughout the country (NRCS Chapter 16, 1972). As discussed below, the NRCS methodologies are available in several public domain computer models, including the TR-55 (WinTR-55) computer model (2003).

Runoff is calculated using this method with only a curve number (based on land cover type and hydrologic soil group) and rainfall depth. Curve numbers and additional information on the development of the method may be found in "Urban Hydrology for Small Watersheds" published by the Soil Conservation Service, now NRCS, in 1986. Recommended CN values for use in Chattanooga are provided in Table 7-5. Additionally, the recommended CN for pervious pavement is 75; green roofs may apply a CN of 72. **This methodology is commonly referred to as the "Cover Complex Method" and is the accepted methodology for peak rate calculation in Chattanooga.**

Table 7-5. Recommended NRCS Cover Complex Curve Numbers for Chattanooga Land Uses

Runoff curve numbers for urban areas [1]					
Cover Description		**Curve numbers for hydrologic soil group**			
Cover Type and hydrologic condition	Hydrologic condition	A	B	C	D
Impervious Areas:					
Paved parking lots, roof, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and Roads					
Paved: curbs and storm sewers (exclude right-of-way)		98	98	98	98
Paved, open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Meadow - continuous grass, protected from grazing and generally mowed for hay		30	58	71	78
Dirt (including right-of-way)		72	82	87	89
Pasture, grassland, or range - continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Brush - brush -weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Open Spaces (parks, golf courses, cemeteries, etc.)[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Woods-grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77

[1] Average runoff condition, and $I_a = 0.2S$.
[2] Poor: <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed
[3] Poor: < 50% ground cover
Fair: 50 to 75% ground cover
Good: > 75% ground cover
[4] Actual curve number is less than 30; use CN=30 for runoff computations
[5] CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods for pasture
[6] Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning
Fair: Woods are grazed but not burned, and some forest litter covers the soil
Good: Woods are protected from grazing , and litter and brush adequately cover the soil.

Technical Release 55 (TR-55) was originally published in 1975 as a simple procedure to estimate runoff volume, peak rate, hydrographs, and storage volumes required for peak rate control (NRCS 2002). TR-55 was released as a computer program in 1986 and work began on a modernized Windows version in 1998.

WinTR-55 generates hydrographs from urban and agricultural areas and routes them downstream through channels and/or reservoirs. WinTR-55 uses the TR-55 model for all of its hydrograph procedures and is an acceptable method to determine peak flow rate (NRCS 2002). WinTR-55 Version 1 was officially released in 2002 and can be downloaded at:
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/quality/?&cid=stelprdb1042901.

WinTR-55 or other tools (e.g., HEC-HMS, HydroCAD) based on the Cover Complex Method may be used to estimate pre-development and post-development peak flow rates. There are also a number of proprietary software modeling tools that use the Cover Complex Method to calculate peak flow rates and may be used for stormwater calculation purposes.

Peak Rate and Simplified Method

Chapter 3, Section 3.3, Determining Applicability, specifies criteria based on impervious area and disturbed area that qualify projects for the Simplified Method and exemption from peak rate control. All projects in the CSO area regardless of size require peak rate attenuation coordinated with facility fixtures. SOV and water quality treatment requirements apply to all projects with 5,000 square feet or more of disturbed area. All projects seeking to use the Simplified Method must demonstrate safe conveyance of the 10-year event.

Peak Rate and Discharge Location or Outfall

A large project site may have multiple subareas and discharge points. The drainage areas of these subareas may be different between the pre- and post-development conditions. Projects have traditionally been evaluated for peak rate control "as a whole" such that the combined discharge rate at all discharge locations from the project site is not greater than the combined discharge rate before development.

The use of a "project discharge rate" is still acceptable with the following caveats:

- If a project site straddles two or more stream channel watersheds, the discharge rates must be evaluated on a sub-watershed basis. This is to discourage designs that alter the hydrology between two stream systems. This is especially important in headwater (first and second order) streams.

- The peak discharge to any specific site discharge location (to a discharge point from the property, to a surface discharge location, or to waters of the United States as defined at 40 CFR 122.2) cannot be greater after development than before development. This is to prevent localized stream channel erosion and alteration.

The Ten-Percent Rule

While retention of the SOV onsite reduces downstream volume, post-development discharges can nonetheless increase the total volume of runoff. This increased volume combined with other downstream tributaries may increase the peak flows. The “ten-percent” rule criterion has been adopted to improve the effectiveness of onsite detention in maintaining pre-development peak flows in the downstream system.

The ten-percent rule recognizes that onsite detention has a “zone of influence” downstream where its effectiveness can be felt. Beyond the zone of influence, the detention control becomes insignificant compared to the runoff from the total drainage area at that point. That zone of influence is considered to be the point where the drainage area controlled by onsite detention comprises 10 percent of the total drainage area. For example, if the site facility controls 10 acres, the zone of influence ends at the point where the total drainage area is 100 acres or greater.

Application of the ten-percent rule requires the design professional to:

- Determine the target peak flow for the site for pre-development conditions.
- Determine the lower limit of the zone of influence (10 percent point).
- Determine the pre-development peak flows and timing of those peaks at each tributary junction beginning at the pond outlet and ending at the next tributary junction beyond the 10 percent point.
- Change the land use on the site to post-development and rerun the model.
- Designed the onsite control facility such that the discharge from the site for the 25-year post-development storm event does not increase the peak flows at the outlet and the determined tributary junctions.

If downstream peak flow cannot be attenuated, one of the following options may be considered:

- Control of downstream impacts of the 25-year storm event volume may be waived by the City, saving the developer the cost of sizing a detention basin for downstream peak flow control. In this case, the City may require a mitigation fee from the developer for alleviating downstream flooding or making conveyance improvements.
- Work with the local government to reduce the flow elevation through the channel or flow conveyance structure improvements downstream.

- Obtain a flow easement from downstream property owners to the 10 percent point.

  Example:

  Site A is a development of 10 acres, all draining to an extended detention stormwater pond. The overbank flooding and extreme flood portions of the design are going to incorporate the ten-percent rule. Looking downstream at each tributary in turn, it is determined that the analysis should end at the tributary marked “80 acres.” The 100-acre (10 percent) point is between the 80-acre and 120-acre tributary junction points.

  The assumption is that if there is no peak flow increase at the 80-acre point, there will be no increase through the next stream reach downstream through the 10 percent point (100 acres) to the 120-acre point. The designer constructs a simple HEC-1 model of the 80-acre areas using single existing condition sub-watersheds for each tributary. Key detention structures existing in other tributaries must be modeled. An approximate curve number is used since the *actual* peak flow is not key for initial analysis; only the increase or decrease is important. The accuracy in curve number determination is not as significant as an accurate estimate of the time of concentration. Since flooding is an issue downstream, the pond is designed (through several iterations) until the peak flow does not increase at junction points downstream to the 80-acre point.

  Site B is located downstream at the point where the total drainage area is 190 acres. The site itself is only 6 acres. The first tributary junction downstream from the 10 percent point is the junction of the site outlet with the stream. The total 190 acres is modeled as one basin with care taken to estimate the time of concentration for input into the model of the watershed. The model shows that a detention facility at site B, in this case, will actually increase the peak flow in the stream.

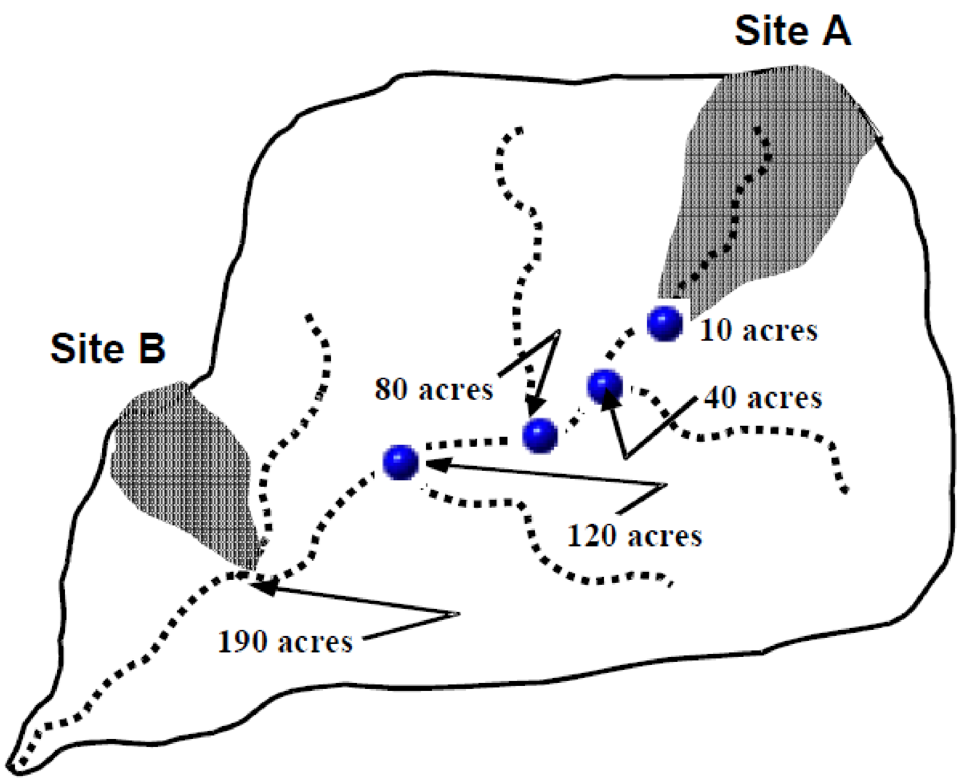

Figure 7-4. Example of Application of 10-Percent Rule (Source: Knox County, TN Stormwater Management Manual, Volume 2, 2008)

The 50-Acre Rule

Because of the potential flood hazard on property adjacent to an unmapped watercourse draining 50 acres or more above a property under construction, the City of Chattanooga may require that each unmapped watercourse draining 50 or more acres be investigated by a professional engineer and the elevation of adjacent structures with setbacks from the centerline of the unmapped watercourse marked on the design drawings and/or subdivision plat. The minimum elevation of the proposed structure shall be determined on the basis of a 100-year flood level on framed floor systems. The engineer shall use an accepted national method of calculation (e.g., USDA Technical Release No. 55 “Urban Hydrology for Small Watersheds”; American Society of Civil Engineers [ASCE] Manual of Practice No. 37 “Design and Construction of Sanitary and Storm Sewers”). The minimum setback shall be determined by an elevation of the unmapped watercourse based on the erosion potential of the watercourse and lot elevation as determined by the engineer. All projects adjacent to an unmapped watercourse draining 50 or more acres and for which 100-

year storm elevation calculations are required shall have a certification by a professional engineer that reads as follows:

> *I have made a flood hazard study of the project shown hereon and the drainage area above it and all affected proposed structures and/or lots within this project area are marked with a minimum building elevation. An elevation benchmark of public record for reference is noted on the drawings and/or plat, and established on the project with a minimum building elevation. Any unmarked proposed buildings and/or lots have been determined be above the required elevation and do not require a minimum building elevation due to their location and the existing drainage structure design.*
>
> *SEAL*
>
> *Name* ________________________
>
> *P.E. #*________________

Such certification will be provided on the final plan submittal

Peak Rate and CN Adjustment to Reflect SOV Capture

To account for the impacts on peak rate reduction through the application of LID measures on a project site, an adjustment may be made to the CN assigned to disturbed areas managed by a BMP. The CN value is adjusted to reflect both the volume captured in various BMPs (SOV) as well as any infiltration that occurs over a defined time period during a large storm.

CN adjustment, part of the Runoff Reduction Method (Battiata et al. 2010), combines the NRCS runoff equations 2-1 through 2-4 in “Urban Hydrology for Small Watersheds” (USDA 1986) to develop an adjusted CN that accounts for the reduced runoff volume from implementing volume reduction BMPs. This modification of the standard computational procedure starts with a combination of TR-55 Runoff Equations 2-1 and 2-2 in order to show runoff depth in terms of rainfall and potential retention, producing Equation 2-3. In addition, the potential retention, S, is related to soil and cover conditions of the watershed through the designation of a runoff CN as shown in Equation 2-4.

TR-55 Eqn. 2-1:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S}$$

TR-55 Eqn. 2-2

$$Ia = 0.2S$$

TR-55 Eqn. 2-3:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

TR-55 Eqn. 2-4:

$$S = \frac{1000}{CN} - 10$$

where:
- Q = Runoff volume (inches)
- P = rainfall depth (inches)
- Ia = Initial abstraction (inches)
- S = potential maximum retention after runoff begins (inches)
- CN = Runoff curve number
- R = Retention storage in inches (SOV provided by structural runoff reduction practices + allowable infiltration, see below)

In the CN adjustment method, the runoff depth (Q) is reduced to reflect the volume captured or infiltrated. The retention storage depth retained onsite (equivalent to the storage provided on the site through various structural BMPs and infiltration) is reflected in terms of R and is subtracted from the total runoff depth, Q in inches. A new modified S value (S_{mod}) is then calculated using Modified Eqn. 2-3. The S_{mod} value can be determined by reorganizing the modified Eqn. 2-3 to solve directly for S_{mod}.

Modified Eqn. 2-3:

$$Q - R = \frac{(P - 0.2S_{mod})^2}{(P + 0.8S_{mod})}$$

S_{mod} = potential maximum retention after runoff begins (inches) reflecting volume captured or infiltrated

For example, if Q = 4.19 inches, R = 1.01 inches, and P = 5.1 inches, modified equation 2-3 above can be solved for S_{mod} using the Quadratic Formula.

Standard Quadratic Equation:

$$ax^2 + bx + c = 0$$

Substituting values for Q, R, and P yields and combining like terms yields:

$$4.19 - 1.01 = (5.1 - 0.2S_{\text{mod}})^2 \div (5.1 - 0.2S_{\text{mod}})$$

Converting the equation to the standard Quadratic Equation form:

$$3.18 \text{ x } (5.1 + 0.8S_{\text{mod}}) = (5.1 - 0.2S_{\text{mod}}) \text{ x } (5.1 - 0.2S_{\text{mod}})$$

Completing the multiplication yields:

$$16.218 + 2.544S_{\text{mod}} = 26.01 - 2.04S_{\text{mod}} + 0.04\,(S_{\text{mod}})^2$$

Then combining and collecting like terms:

$$0.04 \text{ x } S_{\text{mod}}^2 - 4.584 \text{ x } S_{\text{mod}} + 9.792 = 0$$

This is now in the standard Quadratic Equation form where:

a = 0.04, b = 4.584, and c = 9.792

Solving the Quadratic Formula:

$$x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

$$S_{mod} = \frac{-(-4.584) \pm \sqrt{[(-4.584)^2 - 4(0.04)(9.792)]}}{2(0.04)}$$

Therefore, S_{mod} = 2.186 inches or 112 inches. Use S_{mod} = 2.186 inches.

Using the value found by solving for S_{mod}, a new adjusted CN may be calculated after rearranging Equation 2-4 as shown below (Battiata et al. 2010).

$$CN_{adj} = \frac{1000}{S_{mod} + 10}$$

For the purposes of site peak rate control, designers may adjust the CN value based on the volume managed by the SOV as well as the infiltration volume that occurs during a portion of the 24-hour design storm event. Designers may also adjust the CN value based solely on the water quality volume when proposing slow-release LID BMPs for water quality treatment. This will allow designers to account for runoff captured by applying LID and to develop a lower CN as described above.

When adjusting the CN, the infiltration volume may be estimated as the infiltration that occurs during 12 hours of a 14-hour design storm to ensure that credited infiltration volumes are not greater than the actual volume captured within each BMP. Infiltration volume may be estimated using the following equation:

Infiltration Volume (ft^3) = Infiltration BMP Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

Retention storage (R) in inches may be calculated by adding the SOV captured (by all BMPs) plus the infiltration volume (provided by all BMPs) and dividing by the drainage area managed as follows:

R (inches) = (SOV + Infiltration Volume) (ft^3) / Drainage Area Managed (ft^2) x 1/12

For example, if a BMP is sized to capture a SOV of 1,260 ft^3, infiltrate 1,400 ft^3, and has a managed drainage area of 31,530 ft^2, the retention storage (R) is calculated as follows:

$$R\ (inches) = \left(\frac{1260 + 1400}{31{,}530}\right) \times \frac{12\ in.}{1\ ft.}$$

$$R = 1.01\ in.$$

Implementing this process for CN adjustment allows applicants/owners to illustrate the effect of LID components on the ability to attenuate peak rate increases seen as a result of traditional development. It is important to note, however, that the values for P are unique to each design storm. As such, a unique adjusted CN must be calculated for each design storm required.

Depending on conditions and the extent of LID, the adjusted post-development CN may be lower than the pre-development CN. However, the designer must confirm that the time of concentration (Tc in hours) is not shorter after development than before, assuming that peak rates have not been altered.

The CN value should **only** be adjusted for the disturbed area (or area managed by a volume managing BMP). If the outfall for peak flow rates includes other drainage areas (such as protected areas and/or any applicable offsite areas), the adjusted CN value should **not** include those areas. Protected areas and offsite areas should be evaluated as separate sub-areas for peak rate evaluation.

Worksheet 4 of the LID Calculation Tool includes the Quadratic Formula and may be used to adjust the CN value.

7.7 Credit Calculations and Worksheets

Restorative BMPs may qualify for up to a 25 percent SOV volume credit, whereas areas served by protective BMPs are not excluded from runoff determination.

Design and volume credits are available for the following non-structural BMPs:

Non-Structural BMP Credits Worksheet

<u>Protective Practices Credits</u>

5.2.1 Protect Undisturbed and Healthy Soils
- 5.2.1.1 Preserving Landforms
- 5.2.1.2 Protect Highly Erodible Soils on Steep Slopes

5.2.2 Protect and Incorporate Natural Flow Paths

5.2.3 Protect and Preserve Riparian Corridors

5.2.4 Protect and Preserve Natural Vegetation
- 5.2.4.1 Protect Historic or Specimen Trees
- 5.2.4.2 Soil and Plant Salvage

<u>Restorative Practices Credits (Volume Credits)</u>

5.4.1 Recreate Natural Flow Patterns
- 5.4.1.1 Naturalize Swales and Drainage Channels

5.4.2 Improve Native Landscape Cover Types
- 5.4.2.1 Change Cover Type

5.4.3 Amend and Restore Disturbed Soils

Non-Structural BMP Credits Worksheet

Protective Practices Credits

5.2.1 Area of Protected Undisturbed and Healthy Soils	________	ac.
5.2.1.1 Area of Minimized Land Disturbance	________	ac.
5.2.1.2 Area of Protected Soils/Steep Slopes	________	ac.
5.2.2 Area of Protected Natural Flow Paths	________	ac.
5.2.3 Area of Protected/Enhanced Riparian Corridors	________	ac.
5.2.4 Area of Protected/Preserved Vegetation	________	ac.
Total Protected Area	________	ac.

$$Site\ Area - Protected\ Area = Stormwater\ Management\ Area$$

	-		=	

Restorative Practices Credits (**Maximum 25% of SOV**)

Volume Credits*

5.4.1 Recreate Natural Flow Patterns

Vegetated Area of Natural Flow Path	________	ft^2	x	$^{1}/_{4}$"	x	$^{1}/_{12}$	=	________	ft^3

5.4.1.1 Naturalize Swales and Drainage Channels

Vegetated Area of Naturalized Swale/Ditch	________	ft^2	x	$^{1}/_{4}$"	x	$^{1}/_{12}$	=	________	ft^3

5.4.2 Enhance Native Cover Types

Area of Enhanced Native Cover Type	________	ft^2	x	$^{1}/_{4}$"	x	$^{1}/_{12}$	=	________	ft^3

5.4.2.1 Change Cover Type

Area of Cover Changed to Meadow or other cover type (per BMP 5.4.2.1)	________	ft^2	x	$^{1}/_{4}$"	x	$^{1}/_{12}$	=		ft^3
Area of Cover Changed to Forest	________	ft^2	x	$^{1}/_{2}$"	x	$^{1}/_{12}$	=	________	ft^3

5.4.3 Amend and Restore Disturbed Soils

Area of Amended/Restored Soils	________	ft^2	x	$^{1}/_{4}$"	x	$^{1}/_{12}$	=	________	ft^3

Tree Planting (2-inch caliper minimum)

Deciduous	________	trees	x	10	ft^3	/tree	=	________	ft^3
Evergreen	________	trees	x	6	ft^3	/tree	=	________	ft^3

Total Non-Structural Volume Reduction: ________ ft^3

7.8 Calculation Submittal Requirements

Applicants/owners must submit the following to the City prior to approval of any stormwater management plan:

1. All applicable worksheets in electronic format
2. All applicable Excel tools in electronic format
3. All modeling packages (TR-55, WinSLAMM) in original electronic format, including all applicable input/output files, land use files, rain files, and parameter files
4. Any hand calculations in paper format, to include the preparer and reviewer's initials and the date of calculation. All submissions must be legible.