Appendix H

Hydrologic
Methods
And
Models

H.1 Acceptable Hydrologic Methods and Models

The following are the acceptable methodologies and computer models for estimating runoff hydrographs before and after development. These methods are used to predict the runoff response from given rainfall information and site surface characteristic conditions. The design storm frequencies used in all of the hydrologic engineering calculations will be based on design storms required in this guidebook unless circumstances make consideration of another storm intensity criteria appropriate.

- Urban Hydrology for Small Watersheds TR-55 (TR-55)
- Storage-Indication Routing
- HEC-1, WinTR-55, TR-20, and SWMM Computer Models
- Rational Method & Modified Rational Method

These methods are given as valid in principle, and are applicable to most stormwater management design situations in the District. Other methods may be used when the District reviewing authority approves their application.

Note: Of the above methods, TR-55 and SWMM allow for the easiest correlation of the benefits of retention BMPs used to meet the SWRv with peak flow detention requirements, and are therefore strongly recommended. ***Appendix A*** includes more information on using the Stormwater Compliance Spreadsheet to account for retention BMPs in calculating peak flow detention requirements.

The following conditions should be assumed when developing pre-development, pre-project, and post-development hydrology, as applicable:

- Pre-development runoff conditions (used for the 2-year storm) shall be computed independent of existing developed land uses and conditions and shall be based on “Meadow in good condition” or better, assuming good hydrologic conditions and land with grass cover.

- Pre-project runoff conditions (used for the 15-year storm) shall be based on the existing condition of the site

- Post-development shall be computed for future land use assuming good hydrologic and appropriate land use conditions. If a NRCS CN Method-based approach, such as TR-55, is used, this curve number may be reduced based upon the application of retention BMPs, as indicated in the Stormwater Compliance Spreadsheet (See ***Appendix A***). This curve number reduction will reduce the required detention volume for a site, but it should not be used to reduce the size of conveyance infrastructure.

- The rainfall intensity - duration - frequency curve should be determined from the most recent version of the Hydrometeorological Design Studies Center's Precipitation Frequency Data Server (NOAA Atlas 14, Volume 2). http://hdsc.nws.noaa.gov/hdsc/pfds/index.html

- Pre-development time of concentration shall be based on the sum total of computed or estimated overland flow time and travel in natural swales, streams, creeks and rivers, but never less than six minutes.

- Post-development time of concentration shall be based on the sum total of the inlet time and travel time in improved channels or storm drains, but shall not be less than six minutes.

- Drainage areas exceeding 25 acres that are heterogeneous with respect to land use, RCN or Time of Concentration (T_c) shall require a separate hydrological analysis for each sub-area including T_c, RCN, soils and land use.

- Hydrologic Soil Groups approved for use in the District are contained in the *Soil Survey of the District of Columbia Handbook*.

- On sites where substantial grading has occurred or will occur, or on fill sites, adjustments (see Table H.2) shall be made to the hydrologic soil group classifications.

Table H.2 Soil Group Adjustment

Existing Soil	Adjusting Soil
A	B
B	C
C	D
D	D

H.2 Urban Hydrology for Small Watersheds TR-55

Chapter 6 of *Urban Hydrology for Small Watersheds TR-55, Storage Volume for Detention Basins*, or *TR-55* shortcut procedure, is based on average storage and routing effects for many structures, and can be used for multistage outflow devices. Refer to *TR-55* for more detailed discussions and limitations.

Information Needed:
To calculate the required storage volume using *TR-55*, the pre-development hydrology for the 2-year storm, and the pre-project hydrology for the 15-year storm are needed, along with post-development hydrology for both the 2-year and 15-year storms. The pre-development hydrology for the 2-year storm is based on natural conditions (meadow), and will determine the site's pre-development peak rate of discharge, or allowable release rate, qo_2, for the 2-year storm, where as the pre-project hydrology for the 15-year storm is based on existing conditions, and will determine the site's pre-project peak rate of discharge, or allowable release rate, qo_{15}, for the 15-year storm.

The post-development hydrology may be determined using the reduced curve numbers calculated in the Stormwater Compliance Spreadsheet (See ***Appendix A***) or more detailed routing calculations. This will determine the site's post-development peak rate of discharge, or inflow for both the 2-year and 15-year storms, qi_2 and qi_{15}, respectively, and the site's post-developed runoff, Q_2 and Q_{15}, in inches. (Note that this method does ***not*** require a hydrograph.) Once the above parameters are known, the *TR-55* Manual can be used to approximate the storage volume required for each design storm. The following procedure summarizes the *TR-55* shortcut method.

Procedure:
1. Determine the peak development inflows, qi_2 and qi_{15}, and the allowable release rates, qo_2 and qo_{15}, from the hydrology for the appropriate design storm.

Using the ratio of the allowable release rate, qo , to the peak developed inflow, qi , or qo/qi , for both the 2-year and 15-year design storms, use **Figure H.1** (or Figure 6.1 in *TR-55*) to obtain the ratio of storage volume, Vs , to runoff volume, Vr , or Vs_2 / Vr_2 and Vs_{15} / Vr_{15} for Type II storms.

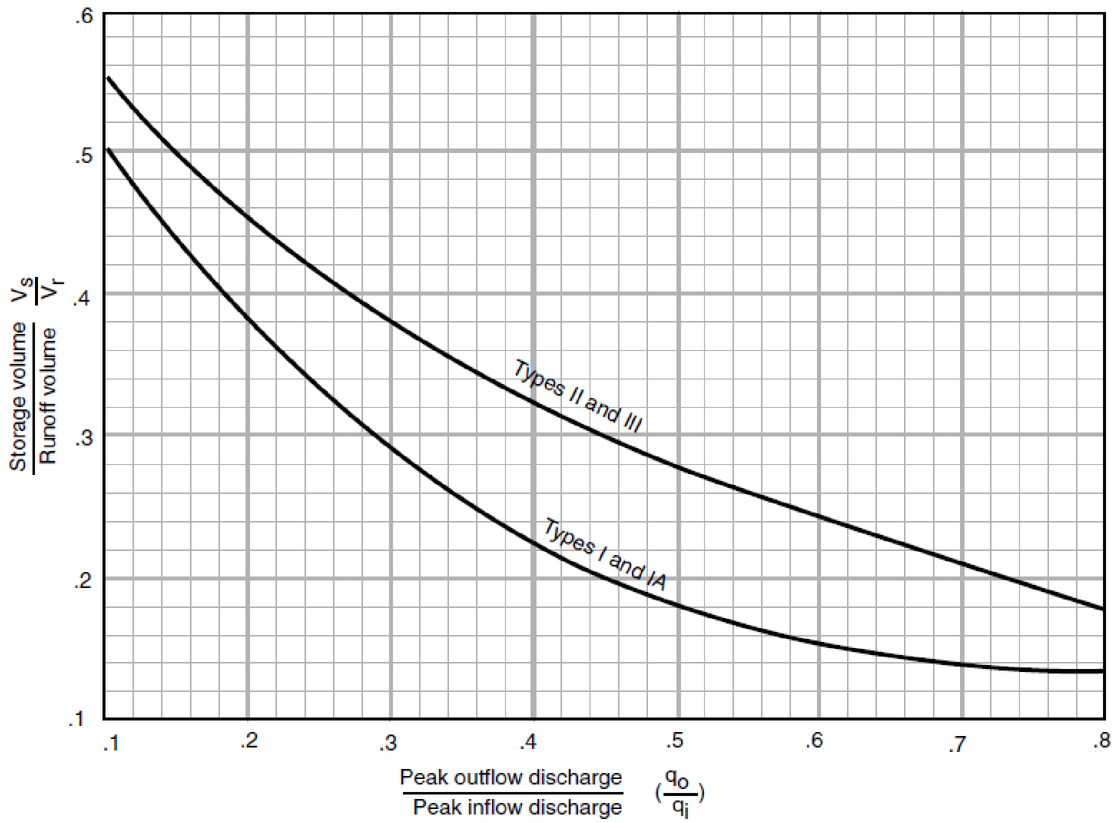

Figure H.1 Approximate Detention Basin Routing for Rainfall Types I, IA, II and III

2. Determine the runoff volumes, Vr_2 and Vr_{15}.

$Vr_2 = 53.33 \text{ x } Q_2 \text{ x } Am$

where:
53.33 = conversion factor from in-mi^2 to acre-feet
Q_2 = post-development runoff, in inches for the 2-year storm
Am = drainage area, in square miles

Vr_{15} = 53.33 x Q_{15} x Am

where:
53.33 = conversion factor from in-mi^2 to acre-feet
Q_{15} = post-development runoff, in inches for the 15-year storm
Am = drainage area, in square miles

3. Multiply the Vs /Vr ratios from Step 1 by the runoff volumes, Vr_2 and Vr_{15}, from Step 2, to

determine the storage volumes required, Vs_2 and Vs_{15} , in acre-feet.

$$(\frac{Vs_2}{Vr_2})Vr_2 = Vs_2$$

$$(\frac{Vs_{15}}{Vr_{15}})Vr_{15} = Vs_{15}$$

Note: In most cases, Vs_{15} represents the total storage required for the 2-year storm and the 15-year storm, and the outflow, qo_{15}, includes the outflow qo_2. In some cases, Vs_{15} may be less than Vs_2. In these cases, the storage volume provided for the 2-year storm (Vs_2)may or may not be sufficient to meet the 15-year requirements, and must be checked via stage-storage curve analysis.

The design procedure presented above may be used with *Urban Hydrology for Small Watersheds TR-55* Worksheet 6a. The worksheet includes an area to plot the stage-storage curve, from which actual elevations corresponding to the required storage volumes can be derived. The characteristics of the stage-storage curve are dependent upon the topography of the proposed storage practice and the outlet structure design (See ***Appendix G***), and may be best developed using a spreadsheet or appropriate hydraulics software.

Limitations

This routing method is less accurate as the qo/qi ratio approaches the limits shown in Figure H.1. The curves in figure H.1 depend on the relationship between available storage, outflow device, inflow volume, and shape of the inflow hydrograph. When storage volume (Vs) required is small, the shape of the outflow hydrograph is sensitive to the rate of the inflow hydrograph. Conversely, when Vs is large, the inflow hydrograph shape has little effect on the outflow hydrograph. In such instances, the outflow hydrograph is controlled by the hydraulics of the outflow device and the procedure therefore yields consistent results. When the peak outflow discharge (qo) approaches the peak flow discharge (qi) parameters that affect the rate of rise of a hydrograph, such as rainfall volume, curve number, and time of concentration, become especially significant.

The procedure should not be used to perform final design if an error in storage of 25 percent cannot be tolerated. Figure H.1 is biased to prevent undersizing of outflow devices, but it may significantly overestimate the required storage capacity. More detailed hydrograph development and storage indication routing will often pay for itself through reduced construction costs.

H.3 Storage-Indication Routing

Storage-Indication Routing may be used to analyze storage detention practices. This approach requires that the inflow hydrograph be developed through one of the methods listed in this appendix (TR-55, WinTR-55, SWMM, etc.), as well as the required maximum outflows, qo_2 and qo_{15}. Using the stage-discharge relationship for a given combination outlet devices, the detention volume necessary to achieve the maximum outflows can be determined.

H.4 HEC-1, WinTR-55, TR-20, and SWMM Computer Models

If the application of the above computer models is needed, the complete input data file and printout will be submitted with the stormwater management plans at the 85% submittal stage. Submission of stormwater management plans shall include the following computer model documentation:

- For all computer models, supporting computations prepared for the data input file shall be submitted with the stormwater management plans.
- Inflow-outflow hydrographs shall be computed for each design storm presented graphically, and submitted for all plans.
- Schematic (node) diagrams must be provided for all routings.

H.4 Rational and Modified Rational Methods

While these methods are not recommended, as they cannot account for the retention/detention benefits of the BMPs applied on a site, these methods will be permitted for use in a development of five acres or less. When applying these methods, the following steps must be taken in the design consideration:

- In the case of more than one sub-drainage area, the longest time of concentration shall be selected.
- Individual sub-drainage flows shall not be summed to get the total flow for the watershed.
- The runoff coefficient, C, shall be a composite of the future site development conditions for all contributing areas to the discharge point. Runoff coefficient factors for typical District land uses are provided in Table H.1.
- The flow time in storm sewers shall be taken into account in computing the watershed time of concentration.
- The storm duration shall be dependent upon the watershed time of concentration.
- The storm intensity can be selected from the selected storm duration.

Table H.1 Runoff Coefficient Factors for Typical District of Columbia Land Uses

Zone	Predominant Use	Minimum Lot Dimensions		Runoff Coefficient C
		Width (feet)	Area (sq ft)	
R-1-A	One-family detached dwelling	75	7,500	0.60
R-1-B	One-family detached dwelling	50	5,000	0.65
R-2	One-family semi-detached dwelling	30	3,000	0.65
R-3	Row dwelling	20	2,000	0.70
R-4	Row dwelling	18	1,800	0.75
R-5-A	Low density apartment	--	--	0.70
R-5-B	Medium density apartment house	--	--	0.75
R-5-C	Medium high density apartment house	--	--	0.80
R-5-D	High density building	--	--	0.80
C	Commercial	--	--	0.85 - 0.95
M	General Industry	--	--	0.80 - 0.90
Park		--	--	0.35

References

United States Department of Agriculture Natural Resources Conservation Service *Urban Hydrology for Small* Watersheds *TR-55*. June 1986.

Virginia Department of Conservation and Recreation *DRAFT 2009 Virginia Stormwater Management Handbook.* September 2009.