Stormwater Design Guidance - Addressing Quantity Control Requirements

Revisions to Maryland's stormwater management regulations in 2010 require that environmental site design (ESD) be used to the maximum extent practicable (MEP) to reduce the volume of runoff from the one-year design storm to levels equivalent to woods in good condition. This will address the groundwater recharge, water quality, and channel protection volumes (Re_v, WQ_v, and Cp_v, respectively) as described in Chapter 2 of the **2000 Maryland Stormwater Design Manual**[1] (the Manual). However, the ESD to the MEP mandate may not completely address overbank flood protection volume (Qp_2 or Qp_{10}) requirements for peak management of the two or ten-year design storm where locally required. In these situations, the volume of runoff that is captured using ESD techniques and practices (ESD_v) may contribute to meeting these requirements.

As described above and in Chapter 5 (see p. 5.19 of the Manual), the volume of storage within various ESD practices, or ESD_v, may be considered when determining Qp_2 and/or Qp_{10} requirements. There are several methods that may be used and designers are encouraged to consult with the local approval authority to find out which are acceptable. The Maryland Department of the Environment (MDE) recommends using the "Change in Runoff Curve Number Method"[2] as an acceptable approach for this purpose.

The "Change in Runoff Curve Number Method" was developed to be used with TR-20[3] to model how capturing runoff in small-scale, uniformly distributed practices would effect the hydrograph for a given drainage area. The method uses Equation 1 below to calculate a storm-specific runoff curve number, CN^*, that reflects the runoff volume stored by ESD techniques and practices. In this equation, P is the rainfall depth in inches for the specific design storm (e.g., 10 year 24 hour design storm). The second variable, Q, is the difference between the post-development runoff depth (e.g., Q_{10}) and Q_E, the runoff depth stored in ESD techniques and practices[‡] (e.g., $Q = Q_{10} – Q_E$). The resulting CN^* is used with either the TR-20 or TR-55[4] programs to develop downstream hydrographs that account for the difference in runoff from the two and/or ten-year design storms and the runoff already treated using ESD.

Equation 1. $$CN^* = \frac{200}{(P + 2Q + 2) - \sqrt{5PQ + 4Q^2}}$$

MDE offers the following examples for using the "Change in Runoff Curve Number Method" to address Qp_2 and Qp_{10} using ESD. These examples are based on the Reker Meadows and Claytor Community Center designs found in both Chapters 2 and 5 of the Manual. In each example, the existing and proposed conditions reflect the Unified Sizing Criteria and structural approach to stormwater management design described in Chapter 2 of the Manual while the ESD goals reflect newer design requirements found in Chapter 5.

Example 1 – Reker Meadows

Using the Reker Meadows design examples found in Chapters 2 and 5 (see pp. 2.14 - 2.21 and 5.23 - 5.27), the effect of ESD on ten-year peak discharge control could be determined as follows:

[‡] NOTE: According to the Design Manual (see p. 5.18), Q_E is the depth of runoff treated using ESD practices and is equal to the product of P_E and the volumetric runoff coefficient, R_V. Because ESD requirements are based on the 1-year rainfall event, Q_E is limited to the runoff from the 1 year, 24 hour design storm.

Site Data:

Existing Conditions

Total Drainage Area:	38 acres
Soil Types:	60% B, 40% C
Land Use:	Residential
Runoff Curve Numbers	
Pre-Development:	63
Wooded Conditions:	61
Time of Concentration (t_c):	0.35 hours
Ten-Year Peak Discharge:	50.4 cubic feet per second (cfs)

Proposed Conditions

Impervious Cover (I):	13.8 acres; %I = 13.8/38 or 36.3%	
Lot Size:	½ acre lots	
Runoff Curve Number:	78	
Time of Concentration:	0.19 hours	
Qp_{10} Criteria (see pp. 2.14 - 2.21 of the Manual)		
Ten-Year Rainfall (P_{10}):	5.0 inches	(see Table 2.2, p. 2.11)
Ten-Year Runoff (Q_{10}):	2.71 inches	(from TR-55, see p. 2.21)
Ten-Year Peak Discharge:	130 cfs	(from TR-55, see p. 2.21)
ESD Criteria (see pp. 5.23 - 5.27 of the Manual)		
One-Year Rainfall (P_1):	2.5 inches	
P_E:	1.8 inches	(see p. 5.25)
Q_E:	0.68 inches	($Q_E = P_E$ x R_v; see pp. 5.18 and 5.25)
ESD_v:	2.15 ac-ft or 93,800 ft^3 (see pp. 5.18 and 5.25)	

This example assumes that the ESD targets shown in Chapter 5 for the Reker Meadows project have been met. For the ten-year design storm, the design rainfall depth, or P_{10}, is 5.0 inches, Q_{10} (the post-development runoff depth) is 2.71 inches and Q_E (the runoff depth stored in ESD practices) is 0.68 inches. *Q,* (Q_{10} minus Q_E) is 2.03 inches. Using these values and Equation 1 (see above), the revised post-development RCN (*CN**) is determined as follows:

$$CN^* = \frac{200}{(P_{10} + 2Q + 2) - \sqrt{5P_{10}Q + 4Q^2}} = \frac{200}{[5 + (2 \times 2.03) + 2] - \sqrt{(5 \times 5 \times 2.03) + (4 \times 2.03^2)}} = 70$$

The revised *CN** of 70 is used with either the TR-20 or TR-55 models to determine a revised runoff depth and peak discharge that reflect the effect of ESD on peak discharge controls. However, for this example, the impact of ESD on Qp_{10} requirements is summarized below. Please recognize that steps in the process may be missing as this is not meant as an example of how to use TR-55.

To be conservative, this example assumes that there is no change in the post-development time of concentration (t_c). The example also uses an initial abstraction (I_a) of 0.857 inches (see Table 4-1, p. 4-1 of TR-55 for an RCN of 70), a P_{10} of 5.0 inches, and using Exhibit 4-II (p. 4-6, TR-55), the unit peak discharge (q_u) is 750 cfs/mi^2/in. Using these values, the post-development peak discharge or q_{p10} may be calculated as follows:

$$q_{p10} = q_u A_m Q F_p \quad \text{(Equation 4-1, TR-55)}$$

where A_m is the site area in square miles (38 acres/640 acres per mile^2 or 0.0594), Q is the 10-year post-development runoff depth for an RCN of 70 (2.03 inches), and F_p is an adjustment for ponds or swamps within the watershed (in this case, $F_p = 1.0$). Using these values, the post-development peak discharge is:

$$q_{p10} = q_u A_m Q F_p = 750 \times 0.0594 \times 2.04 \times 1 = 90.8\,cfs$$

Using Figure 6-1 (see p. 6-2 of TR-55), for a inflow rate (q_{in}) of 90.8 cfs and an allowable outflow rate (q_{out}) of 50.4 cfs, the storage volume (V_s) necessary for control is 1.68 acre-ft (73,180 ft^3). This is almost 50,000 ft^3 less than the 123,275 ft^3 storage volume needed to address Qp_{10} without ESD.

Example 2 – Claytor Community Center

Using the Claytor Community Center design examples found in Chapters 2 and 5 (see pp. 2.22 - 2.27 and 5.28 - 5.31 of the Manual), the effect of ESD on two-year peak discharge control might be determined as follows:

Site Data:

Existing Conditions		
Total Drainage Area:	3 acres	
Soil Types:	100% B	
Land Use:	Commercial	
Runoff Curve Numbers		
Pre-Development:	57	
Wooded Conditions:	55	
Time of Concentration (t_c):	0.42 hours	
Two-Year Peak Discharge:	0.58 cfs	
Proposed Conditions		
Impervious Cover:	1.9 acres; I = 1.9/3 or 63.3%	
Runoff Curve Number:	83	
Time of Concentration:	0.16 hours	
Qp_2 Criteria (see pp. 2.22 - 2.27 of the Manual)		
Two-Year Rainfall (P_2):	3.4 inches	(see Table 2.2, p. 2.11)
Two-Year Runoff (Q_2):	1.77 inches	(from TR-55, see p. 2.27)
Two-Year Peak Discharge:	7.11 cfs	(from TR-55, see p. 2.27)
Storage Volume (V_s):	10,630 ft^3	(see p. 2.25)
ESD Criteria (see pp. 5.28 - 5.31)		
One-Year Rainfall (P_1):	2.8 inches	
Target P_E:	2.0 inches	(see p. 5.29)
Design P_E:	1.6 inches	(see p. 5.30)
Target Q_E:	1.24 inches	(see pp. 5.18 and 5.29)
Design Q_E:	0.99 inches	(see p. 5.30)
Target ESD_v:	13,505 ft^3	(see pp. 5.18 and 5.29)
Design Cp_V[§]:	3,265 ft^3	

This example assumes that the ESD targets shown above have not been met. When this occurs, the CN^* should be determined using the P_E and Q_E provided, which for this example are 1.6 inches and 0.99 inches respectively. For the two-year design storm, the design rainfall depth or P_2 is 3.4 inches, Q_2 is 1.77 inches, Q_E is 0.99 inches, and Q is 0.78 inches. Using these values and Equation 1, CN^* is determined as follows:

[§] Because the ESD targets have not been met, structural practices (see Chapter 3 of the Manual) must be used to capture and treat the difference in the 1 year design storm runoff from the achieved RCN of 65 (0.42 inches, see Manual, pp. 5.30 -5.31) and that for woods in good condition (runoff for an RCN =55 is 0.12 inches). Therefore, Cp_V is equal to [(0.42"– 0.12")x3 acres]/12", or approximately 3,265 ft^3.

$$CN^* = \frac{200}{(P_2 + 2Q + 2) - \sqrt{5P_2Q + 4Q^2}} = \frac{200}{[3.4 + (2 \times 0.78) + 2] - \sqrt{(5 \times 3.4 \times 0.78) + (4 \times 0.78^2)}} = 66$$

The revised CN* of 66 is used with either the TR-20 or TR-55 models to determine a revised runoff depth and peak discharge that reflect the effect of ESD on peak discharge controls. However, the impact of ESD on Qp_2 requirements is also summarized below. Again, to be conservative, the calculations assume that there is no change in the post-development time of concentration (t_c). The example also uses initial abstraction (I_a) of 1.03 inches (see Table 4-1, p. 4-1 of TR-55 for an RCN of 66), the 2-year rainfall depth (P_2) of 3.4 inches, and the unit peak discharge (q_u) is 775 cfs/mi^2/in (see Exhibit 4-II, TR-55). The site area (A_m) is 0.00468 square miles (3 acres/640 acres per mile^2), the 2-year post-development runoff depth (Q) for a RCN of 66 is 0.78 inches, and F_p is 1.0. Using these values, the post-development peak discharge or q_{p2} may be calculated using Equation 4-1 from TR-55 as follows:

$$q_{p2} = q_u A_m Q F_p = 775 \times 0.00468 \times 0.75 \times 1 = 2.7\, cfs$$

Using Figure 6-1 (see p. 6-2 of TR-55), for a q_{in} of 2.7 cfs and an allowable q_{out} of 0.58 cfs, the storage volume (V_s) necessary for control is 3,595 ft^3. This is almost 7,000 ft^3 less than the 10,630 ft^3 storage volume needed to address Qp_2 without ESD.

Conclusion

The primary purpose of the overbank flood protection criteria is to prevent increases in the frequency and magnitude of out-of-bank flooding attributed to new development. In Maryland, controlling overbank flooding is required only if the local approval authority determines that additional stormwater management is necessary because there are historical flooding problems and downstream floodplain development cannot be controlled. While designers should consult with the local approval authority for acceptable methods, MDE recommends using the “Reduced Runoff Curve Number Method” for determining the effect of ESD when determining Qp_2 and/or Qp_{10} requirements. As shown in the two examples above, meeting the ESD to the MEP mandate does not necessarily mean that overbank flood protection requirements are addressed as well. Where needed to manage peak discharges, additional storage may be provided by increasing the size of ESD practices, adding structural practices, or using some combination of ESD and structural practices.

Resources

[1] 2000 Maryland Stormwater Design Manual, Volumes I and II, MDE, October 2000 (http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.aspx)

[2] “Modeling Infiltration Practices Using the TR-20 Hydrologic Program”, McCuen, R., MDE 1983 (http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/SoilErosionandSedimentControl/Documents/Modeling%20Infiltration%20wTR%2020.pdf)

[3] “Technical Release 20 - Computer Program for Project Formulation Hydrology”, United States Department of Agriculture – Natural Resources Conservation Service, 1964, 1986, & 1992

[4] “Technical Release 55 – “Urban Hydrology for Small Watersheds”, United States Department of Agriculture – Natural Resources Conservation Service, 1986