Addressing the Unified Sizing Criteria

One of the primary goals of Maryland's stormwater management program is to maintain after development, as nearly as possible, the predevelopment runoff characteristics. To accomplish this goal, there must be a reasonable standard for predevelopment runoff characteristics that is easily recognized, reproducible, and applied without opportunity for misrepresentation. The simplest and most effective solution is to eliminate the need for evaluating predevelopment conditions on a site-by-site basis and apply the same standard to all sites. For rainfall amounts less than two to three inches, there is little difference in the amount of runoff from most sites in undeveloped conditions although runoff amounts are lowest for woods. To best maintain predevelopment runoff characteristics, the target for ESD implementation should be "woods in good condition".

The Act requires the implementation of ESD to the maximum extent practicable (MEP) to maintain predevelopment runoff characteristics. While ESD may be used to address Re_v and WQ_v, limiting it to these criteria alone may not provide sufficient treatment to mimic natural hydrology for wooded conditions or address Cp_v. It may be necessary to increase the size of single ESD practices and/or connect them in series to decrease the volume of runoff to that expected from a naturally forested area. Implementing ESD to that extent may not be practicable on all projects and a minimum standard is needed. Sizing ESD practices to capture and treat both Re_v and WQ_v is a practical minimum requirement for all projects.

Performance Standards for Using Environmental Site Design

- *The standard for characterizing predevelopment runoff characteristics for new development projects shall be woods in good hydrologic condition;*
- *ESD shall be implemented to the MEP to mimic predevelopment conditions;*
- *As a minimum, ESD shall be used to address both Re_v and WQ_v requirements; and*
- *Channel protection obligations are met when ESD practices are designed according to the Reduced Runoff Curve Number Method described below.*

Environmental Site Design Sizing Criteria

The criteria for sizing ESD practices are based on capturing and retaining enough rainfall so that the runoff leaving a site is reduced to a level equivalent to that leaving a wooded site in good condition runoff as determined using USDA NRCS methods (e.g., TR-55). The basic principle is that a reduced runoff curve number or (RCN) may be applied to post-development conditions when ESD practices are used. The goal is to provide enough treatment using ESD practices to address Cp_v requirements by replicating an RCN for woods in good condition for the 1-year rainfall event. This eliminates the need for structural practices from Chapter 3. If the design rainfall captured and treated using ESD is short of the target rainfall, a reduced RCN may be applied to post-development conditions when addressing stormwater management requirements. The reduced RCN from Table 5.x is calculated by subtracting the runoff treated by ESD practices (Q_E) from the total 1-year 24-hour design storm runoff.

Table 5.X was developed using the "Change in Runoff Curve Number Method" (McCuen, R., MDE, 1983) to determine goals for sizing ESD practices and reducing RCNs if those goals are not met. During the planning process, site imperviousness and soil conditions are used with Table 5.X to determine a target rainfall for sizing ESD practices to mimic wooded conditions. Table 5.X is also used to determine the reduced RCNs for calculating additional stormwater management requirements if the targeted rainfall cannot be met using ESD practices.

<u>ESD Sizing Requirements:</u>
P_E = Rainfall from Table 5.X used to size ESD practices

Q_E = Runoff depth in inches used in the design of ESD practices
= $P_E \times R_v$; R_v = the dimensionless volumetric runoff coefficient
= $0.05 + 0.009(I)$ where I is percent impervious cover

ESD_v = Runoff volume (in cubic feet or acre-feet) used in the design of ESD practices

$$= \frac{(P_E)(R_v)(A)}{12}$$ where A is the drainage area (in square feet or acres)

Addressing Stormwater Management Requirements Using ESD

- **Treatment:** *ESD practices shall be used to treat the runoff from 1 inch of rainfall (i.e., P_E = 1 inch) on all new developments where stormwater management is required.*

  ESD practices shall be used to the MEP to address Cp_v (e.g., treat the runoff from the 1-year 24-hour design storm) in accordance with the following conditions:

  - *Cp_v shall be addressed on all sites including those where the 1-year post-development peak discharge (q_i) is less than or equal to 2.0 cfs.*
  - *Cp_v shall be based on the runoff from the 1-year 24-hour design storm calculated using the reduced RCN (see Table 5.X). If the reduced RCN for a drainage area*

reflects "woods in good condition", then Cp_v has been satisfied for that drainage area.
- *When the targeted rainfall is not met, any remaining Cp_v requirements shall be treated using structural practices described in Chapter 3.*

ESD practices may be used to treat the Overbank Flood Protection and Extreme Flood Volumes (i.e., Q_{p2}, Q_{p10}, Q_f) using the tables found in Appendix E.X and the procedures described below.

- **Practices:** *The runoff, Q_E, shall be treated by acceptable practices from the lists presented in this Chapter (see Sections 5.1 and 5.2).* Q_E may be treated using a single practice or an interconnected series or "treatment train" of practices.

- **Multiple Drainage Areas:** E*SD requirements shall be addressed for the entire limit of disturbance.* When a project is divided into multiple drainage areas, ESD requirements should be addressed for each drainage area.

- **Off-Site Drainage Areas:** *ESD requirements shall be based on the drainage area to the practices providing treatment.* It is recommended that runoff from off-site areas be diverted away from or bypass ESD practices. However, if this is not feasible, then ESD practices should be based on all pervious and impervious areas located both on-site and off-site draining to them.

- **Reduced RCNs:** When using reduced RCNs, the following conditions apply:

  - ESD practices should be distributed uniformly within each drainage area.
  - Where multiple ESD practices are used within a drainage area, individual practices may be oversized on a limited scale to compensate or over manage for smaller practices. The size of any practice(s) is limited to the runoff, Q_E, draining to it.

Basis for Using Table 5.X to Determine ESD Sizing Criteria

- **Application:** *Table 5.X shall be used to determine both the rainfall targets for sizing ESD practices and the additional stormwater management requirements if those targets are not met.*

- **Hydrologic Soil Groups:** Each chart in Table 5.X reflects a different hydrologic soil group (HSG). Designers should use the charts that most closely match the project's soil conditions. If more than one HSG is present within a drainage area, a composite RCN may be computed based on the proportion of the drainage area within each HSG (see examples below).

- **Measuring Imperviousness:** *The measured area of a site that does not have vegetative or permeable cover shall be considered total impervious cover.* Estimates of proposed imperviousness may be used during the planning process where direct measurements of impervious cover may not be practical. Estimates should be based on actual land use and homogeneity and may reflect NRCS land use/impervious cover relationships (see Table 2.2a in TR-55, USDA-NRCS, 1986) where appropriate. The percent imperviousness (%I) may be calculated from measurements of site imperviousness.

- **RCN*:** RCN* is used in the design of alternative surfaces (e.g., permeable pavements, green roofs) to determine the effect of each surface on ESD sizing and stormwater management requirements. Detailed RCN reduction procedures are provided in Section 5.1.5.

- **Reduced RCNs:** Areas shown in green (right hand side) on Table 5.X show the target RCN for "woods in good condition" for the respective HSG. Areas shown in yellow (left hand side) show the reduced RCN for each HSG that is applied to stormwater management calculations if the design rainfall is below the target.

- **Rainfall (Inches):** Target rainfall (P_E) amounts for sizing ESD practices to mimic wooded conditions for each respective HSG are located across the top of Table 5.X. These rainfall amounts are also used to determine the reduced RCNs for calculating additional stormwater management requirements if the targeted amounts cannot be met.

Table 5.X Rainfall Targets/Runoff Curve Number Reductions used for ESD

Hydrologic Soil Group A										
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"	2.2"	2.4"	2.6"
15%	48	**38**								
20%	51	40	**38**	**38**						
25%	54	41	40	39						
30%	57	42	41	39	**38**					
35%	60	44	42	40	39					
40%	61	44	42	40	39					
45%	66	48	46	41	40					
50%	69	51	48	42	41	**38**				
55%	72	54	50	42	41	39				
60%	74	57	52	44	42	40	**38**			
65%	77	61	55	47	44	42	40			
70%	80	66	61	55	50	45	40			
75%	84	71	67	62	56	48	40	**38**		
80%	86	73	70	65	60	52	44	40		
85%	89	77	74	70	65	58	49	42	**38**	
90%	92	81	78	74	70	65	58	48	42	**38**
95%	95	85	82	78	75	70	65	57	50	39
100%	98	89	86	83	80	76	72	66	59	40

Hydrologic Soil Group B										
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"	2.2"	2.4"	2.6"
15%	67	**55**								
20%	68	60	**55**	**55**						
25%	70	64	61	58						
30%	72	65	62	59	**55**					
35%	74	66	63	60	56					
40%	75	66	63	60	56					
45%	78	68	66	62	58					
50%	80	70	67	64	60					
55%	81	71	68	65	61	**55**				
60%	83	73	70	67	63	58				
65%	85	75	72	69	65	60	**55**			
70%	87	77	74	71	67	62	57			
75%	89	79	76	73	69	65	59			
80%	91	81	78	75	71	66	61			
85%	92	82	79	76	72	67	62	**55**		
90%	94	84	81	78	74	70	65	59	**55**	
95%	96	87	84	81	77	73	69	63	57	
100%	98	89	86	83	80	76	72	66	59	**55**

Cp_v Addressed (RCN = Woods in Good Condition) (green)

RCN Applied to Cp_v Calculations (yellow)

Table 5.X Runoff Curve Number Reductions used for Environmental Site Design (continued)

Hydrologic Soil Group C										
%I	**RCN***	**P_E = 1"**	**1.2"**	**1.4"**	**1.6"**	**1.8"**	**2.0"**	**2.2"**	**2.4"**	**2.6"**
15%	78	**70**								
20%	79	**70**								
25%	80	72	**70**	**70**						
30%	81	73	72	71						
35%	82	74	73	72	**70**					
40%	84	77	75	73	71					
45%	85	78	76	74	71					
50%	86	78	76	74	71					
55%	86	78	76	74	71	**70**				
60%	88	80	78	76	73	71				
65%	90	82	80	77	75	72				
70%	91	82	80	78	75	72				
75%	92	83	81	79	75	72				
80%	93	84	82	79	76	72				
85%	94	85	82	79	76	72				
90%	95	86	83	80	77	73	**70**			
95%	97	88	85	82	79	75	71			
100%	98	89	86	83	80	76	72	**70**		

Hydrologic Soil Group D										
%I	**RCN***	**P_E = 1"**	**1.2"**	**1.4"**	**1.6"**	**1.8"**	**2.0"**	**2.2"**	**2.4"**	**2.6"**
15%	83	**77**								
20%	84	**77**								
25%	85	78								
30%	85	78	**77**	**77**						
35%	86	79	78	78						
40%	87	82	81	79	**77**					
45%	88	82	81	79	78					
50%	89	83	82	80	78					
55%	90	84	82	80	78					
60%	91	85	83	81	78					
65%	92	85	83	81	78					
70%	93	86	84	81	78					
75%	94	86	84	81	78					
80%	94	86	84	92	79					
85%	95	86	84	82	79					
90%	96	87	84	82	79	**77**				
95%	97	88	85	82	80	78				
100%	98	89	86	83	80	78	**77**			

Cp_v Addressed (RCN = Woods in Good Condition) (green)

RCN Applied to Cp_v Calculations (yellow)

Design Examples: Computing ESD Stormwater Criteria

Design examples are provided only to illustrate how ESD stormwater sizing criteria are computed for hypothetical development projects. These design examples are also utilized elsewhere in the manual to illustrate design concepts.

Design Example No. 5.1: Residential Development – Reker Meadows

The layout of the Reker Meadows subdivision is shown in Figure 2.6.

Site Data:

Location:	Frederick County, MD
Site Area:	38.0 acres
Drainage Area:	38.0 acres
Soils:	60% B, 40% C
Impervious Area:	13.8 acres

Step 1: Determine ESD Implementation Goals

The following basic steps should be followed during the planning phase to develop initial targets for ESD implementation.

A. Determine Pre-Developed Conditions:

The goal for implementing ESD on all new development projects is to mimic forested runoff characteristics. The first step in this process is to calculate the RCN for "woods in good condition" for the project:

- Determine Soil Conditions and RCNs for "woods in good condition":

Soil Conditions

HSG	RCN[†]	Area	Percent
A	38[‡]	0	0%
B	55	22.8 acres	60%
C	70	15.2 acres	40%
D	77	0	0%

[†] RCN for "woods in good condition" (Table 2-2, TR-55)
[‡] RCN is different than Table 2-2

- Determine composite RCN for "woods in good condition":

$$RCN_{woods} = \frac{(55 \times 22.8\text{ acres}) + (70 \times 15.2\text{ acres})}{38\text{ acres}} = 61$$

The target RCN for "woods in good condition" is 61.

B. Determine Target P_E Using Table 5.X:

P_E = Rainfall used to size ESD practices

During project planning and preliminary design, site soils and proposed imperviousness are used to determine the target P_E for sizing ESD practices to mimic wooded conditions.

- Determine Proposed Imperviousness (%I)

Proposed Impervious Area (as measured from site plans): 13.8 acres;
%I = Impervious Area / Drainage Area
= 13.8 acres / 38 acres
= 36.3%;

Because %I is between 35% and 40%, both values should be checked and the more conservative result used to determine target P_E.

For this example, assume imperviousness is distributed proportionately (60/40) in B and C soils.

- Determine P_E from Table

Using %I = 35% & 40% and B Soils:

		Hydrologic Soil Group B					
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.
15%	67	**55**					
20%	68	60	**55**	**55**			
25%	70	64	61	58			
30%	72	65	62	59	**55**		
35%	74	66	63	60	56		
40%	75	66	63	60	56		
45%	78	68	66	62	58		

$P_E \geq 1.8$ inches will reduce the RCN to reflect "woods in good condition" for %I = 35% & 40%

Using %I = 35% & 40% and C Soils:

		Hydrologic Soil Group C					
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	
15%	78	**70**					
20%	79	**70**					
25%	80	72	**70**	**70**			
30%	81	73	72	71			
35%	82	74	73	72	**70**		
40%	84	77	75	73	71		
45%	85	78	76	74	71		

For %I = 35%, $P_E \geq 1.6$ inches will reduce the RCN to reflect "woods in good condition"
For %I = 40%, $P_E \geq 1.8$" to achieve the same goal.

For this project, P_E happens to be the same for both soil groups, therefore use $P_E = 1.8$ inches of rainfall as the target for ESD implementation.

C. Compute Q_E :

Q_E = Runoff depth used to size ESD practices
Q_E = P_E x R_v, where
P_E = 1.8 inches
R_v = 0.05 + (0.009)(I); I = 36.3
= 0.05 + (0.009 x 36.3) = 0.38

Q_E = 1.8 inches x 0.38
= 0.68 inches

ESD targets for the Reker Meadows project:

P_E = 1.8 inches
Q_E = 0.68 inches

By using ESD practices that meet these targets, Re_v, WQ_v, and Cp_v requirements will be satisfied. Potential practices could include swales or micro-bioretention to capture and treat runoff from the roads. Likewise, raingardens and disconnection of rooftop runoff could be used to capture and treat runoff from the houses.

Step 2: Determining Stormwater Management Requirements After Using ESD

For this example, it is assumed that ESD techniques and practices were implemented to treat only 1.2 inches of rainfall (e.g., $P_E = 1.2$ inches) over the entire project. After all efforts to implement ESD practices have been exhausted, the following basic steps should be followed to determine how much additional stormwater management is required.

A. Calculate Reduced RCNs

P_E = Rainfall used to size ESD practices

During the planning and design processes, site soils, measured imperviousness, and P_E are used to determine reduced RCNs for calculating Cp_v requirements.

- Determine Reduced RCN for P_E = 1.2 inches

Using %I = 35% & 40%, B Soils, and P_E = 1.2 inches:

		Hydrologic Soil Group B				
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"
15%	67	**55**				
20%	68	60	**55**	**55**		
25%	70	64	61	58		
30%	72	65	62	59	**55**	
35%	74	66	63	60	56	
40%	75	66	63	60	56	
45%	78	68	66	62	58	

For B Soils, P_E = 1.2 inches, and %I = 35% & 40%, reduced RCN = 63

Using %I = 35% & 40%, C Soils, and P_E = 1.2 inches:

		Hydrologic Soil Group C				
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"
15%	78	**70**				
20%	79	**70**				
25%	80	72	**70**	**70**		
30%	81	73	72	71		
35%	82	74	73	72	**70**	
40%	84	77	75	73	71	
45%	85	78	76	74	71	

For C Soils, P_E = 1.2 inches, and %I = 35% & 40%, reduced RCN = 73 & 75, respectively

Use the more conservative value, 75, for calculating a composite RCN for the site.

A composite RCN may be calculated as follows:

For P_E = 1.2 inches:

$$\text{RCN} = \frac{(63 \times 22.8\text{ acres}) + (75 \times 15.2\text{ acres})}{38\text{ acres}} = 67.8$$

Use 68

B. Calculate Cp_v Requirements

The composite RCN for “woods in good condition” is 61 (see Step 1A above).

The design RCN (68) does not reflect the composite RCN for “woods in good condition” (61) and, therefore Cp_v must be addressed. However, $P_E \geq 1.0$ inches and Cp_v requirements are based on the runoff from the 1-year 24-hour design storm calculated using the reduced RCN (68).

- Compute Cp_v Storage Volume

When $P_E \geq 1.0$ inches, Cpv shall be the runoff from the 1-year 24-hour design storm calculated using the reduced RCN. If the reduced RCN for a drainage area reflects "woods in good condition", then Cpv has been satisfied for that drainage area.

Calculate Cp_v using design $P_E = 1.2$ inches (RCN = 68):

$Cp_v = Q_1 \text{ x } A$

where: Q_1 is the runoff from the 1-year 24-hour design storm

$$Q_1 = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad \text{(Equation 2.3, TR-55, USDA NRCS 1986)}$$

where: P = 1-year 24-hour design storm
S = (1000/RCN) – 10 (Equation 2-4, TR-55)
= (1000/68) – 10
= 4.7

$$Q_1 = \frac{[2.6 - (0.2x4.7)]^2}{[2.6 + (0.8x4.7)]} = \frac{2.76}{6.36} = 0.43 \text{ inches}$$

$Cp_v =$ 0.43 inches x 38 acres
= 1.36 ac. – ft. or 59, 240 cubic feet

Cp_v Storage Requirements for Reker Meadows

Rainfall (P_E)	Cp_v (ac-ft)	Cp_v (cu. ft.)	Notes:
$P_E \geq 1.8$ inches	NA	NA	Target P_E for RCN = woods
$P_E = 1.2$ inches	1.36	59,240	Design P_E
Conventional Design	1.65	71,875	from Chapter 2 (see page 2.18)

Stormwater management requirements for the Reker Meadows project include using ESD practices to treat 1.2 inches of rainfall and structural practices from Chapter 3 (e.g., shallow wetland) to treat the Cp_v of 59,240 cubic feet.

Design Example No. 5.2: Commercial Development - Claytor Community Center

The layout of the Claytor Community Center is shown in Figure 2.9.

Site Data:

Location:	Dorchester County
Site Area:	3.0 acres
Drainage Area:	3.0 acres
Soils:	100% B
Impervious Area:	1.9 acres

<u>Step 1: Determine ESD Implementation Goals</u>

The following basic steps should be followed during the planning phase to develop initial targets for ESD implementation.

A. Determine Pre-Developed Conditions:

The goal for implementing ESD on all new development projects is to mimic forested runoff characteristics. The first step in this process is to calculate the RCN for "woods in good condition" for the project.

- Determine Soil Conditions and RCNs for "woods in good condition"

Soil Conditions

HSG	RCN†	Area	Percent
A	38‡	0	0%
B	55	3.0 acres	100%
C	70	0 acres	0%
D	77	0	0%

† RCN for "woods in good condition" (Table 2-2, TR-55)
‡ RCN is different than Table 2-2

The site is entirely located in HSG B, and the target RCN for "woods in good condition" is 55.

B. Determine Target P_E Using Table 5.X

P_E = Rainfall used to size ESD practices

During the project planning and preliminary design, site soils and proposed imperviousness are used to determine target P_E for sizing ESD practices to mimic wooded conditions.

- Determine Proposed Imperviousness (%I)

Proposed Impervious Area (as measured from site plans): 1.9 acres
%I = Impervious Area / Drainage Area
= 1.9 acres / 3.0 acres
= 63.3%

Because %I is closer to 65% than 60%, use the more conservative value, 65%.

- Determine P_E from Table

Using %I = 65% & B Soils:

		Hydrologic Soil Group B						
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"	2.2"
15%	67	**55**						
20%	68	60	**55**	**55**				
25%	70	64	61	58				
30%	72	65	62	59	**55**			
35%	74	66	63	60	56			
40%	75	66	63	60	56			
45%	78	68	66	62	58			
50%	80	70	67	64	60			
55%	81	71	68	65	61	**55**		
60%	83	73	70	67	63	58		
65%	85	75	72	69	65	60	**55**	
70%	87	77	74	71	67	62	57	

$P_E \geq 2.0$ inches will reduce the RCN to reflect "woods in good condition" for %I = 65%

For this project, use P_E = 2.0 inches

C. Compute Q_E :

Q_E = Runoff depth used to size ESD practices
Q_E = P_E x R_v, where
P_E = 2.0 inches
R_v = 0.05 + (0.009)(I); I = 63.3%
= 0.05 + (0.009 x 63.3)
= 0.62

Q_E = 2.0 inches x 0.62
= 1.24 inches

ESD targets for the Claytor Community Center project:

P_E = 2.0 inches
Q_E = 1.24 inches

By using ESD practices that meet these targets, Re_v, WQ_v, and Cp_v requirements will be satisfied. Potential practices could include permeable pavements, micro-bioretention, or landscape infiltration to capture and treat runoff from the rooftops, parking lots, and drive aisles.

Step 2. Determine Stormwater Management Requirements After Using ESD

For this example, it is assumed that ESD techniques and practices were implemented to treat only 1.6 inches of rainfall (e.g., P_E = 1.6 inches) over the entire project. After all efforts to implement ESD practices have been exhausted, the following basic steps should be followed to determine if any additional stormwater management is required.

A. Calculate Reduced RCNs

P_E = Rainfall used to size ESD practices

During the design process, site soils, measured imperviousness, and P_E are used to determine reduced RCNs for calculating Cp_v requirements.

- Determine Reduced RCN for P_E = 1.6 inches

Using %I = 65%, B Soils, and P_E = 1.6 inches:

		Hydrologic Soil Group B				
%I	**RCN***	**P_E = 1"**	**1.2"**	**1.4"**	**1.6"**	**1.8"**
15%	67	**55**				
20%	68	60	**55**	**55**		
25%	70	64	61	58		
30%	72	65	62	59	**55**	
35%	74	66	63	60	56	
40%	75	66	63	60	56	
45%	78	68	66	62	58	
50%	80	70	67	64	60	
55%	81	71	68	65	61	**55**
60%	83	73	70	67	63	58
65%	85	75	72	69	65	60
70%	87	77	74	71	67	62

For B Soils, P_E = 1.6 inches, and %I = 65%, reduced RCN = 65

B. Calculate Cp_v Requirements

The RCN for "woods in good condition" = 55 (see Step 1A above).

The design RCN (65) does not reflect "woods in good condition" (55) and therefore Cp_v must be addressed. However, $P_E \geq 1.0$ inches, and Cp_v is based on the runoff from the 1-year 24-hour design storm calculated using the reduced RCN (65).

- Compute Cp_v Storage Volume

When $P_E \geq 1.0$ inches, Cp_v shall be the runoff from the 1-year 24-hour design storm calculated using the reduced RCN. If the reduced RCN for a drainage area reflects "woods in good condition", then Cp_v has been satisfied for that drainage area.

Calculate Cp_v using design $P_E = 1.6$ inches (RCN = 65)

$Cp_v = Q_1 \text{ x } A$

where: Q_1 = runoff from the 1-year 24-hour design storm

$$Q_1 = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$ (Equation 2.3, TR-55, USDA NRCS 1986)

where: P = 1-year 24-hour design storm
S = (1000/RCN) – 10 (Equation 2-4, TR-55)
= (1000/65) – 10
= 5.4

$$Q_1 = \frac{[2.8 - (0.2x5.4)]^2}{[2.8 + (0.8x5.4)]} = \frac{2.96}{7.12} = 0.42 \text{ inches}$$

Cp_v = 0.42 inches x 3.0 acres
= 0.105 ac. – ft. or 4,574 cubic feet

Cp_v Storage Requirements for Claytor Community Center

Rainfall (P_E)	Cp_v (ac-ft)	Cp_v (cu. ft.)	Notes:
$P_E \geq 2.0$ inches	NA	NA	Target P_E for RCN = woods
$P_E = 1.6$ inches	0.105	4,574	Design P_E
Conventional Design	0.21	9,150	See Note Below*

*NOTE: This site is located on the Eastern Shore where Cp_v is not required. However, an estimated 0.21 ac.-ft (9,150 cubic feet) would be needed to address Cp_v in Design Example No. 2 in Chapter 2.

Stormwater management requirements for the Claytor Community Center project include using ESD practices to treat 1.6 inches of rainfall and structural practices from Chapter 3 (e.g., shallow wetland) to treat the Cp_v of 4,574 cubic feet.

Design Example No. 5.3: Multiple Drainage Areas – Pensyl Pointe

The layout of the Pensyl Pointe subdivision is shown in Figure 2.12.

Site Data:

Location: Montgomery County, MD
Site Area: 38.0 acres
Drainage (DA) 1
  Area: 7.6 acres
  Soils: 60% B, 40% C
  Impervious Area: 2.25 acres

Drainage (DA) 2
  Area: 30.4 acres
  Soils: 60% B, 40% C
  Impervious Area: 11.55 acres

Step 1: Determine ESD Implementation Goals

The following basic steps should be followed during the planning phase to develop initial targets for ESD implementation.

A. Determine Pre-Developed Conditions:

The goal for implementing ESD on all new development sites is to mimic forested runoff characteristics. The first step in this process is to calculate the RCNs for "woods in good condition" for the project.

- Determine Soil Conditions and RCNs for "woods in good condition".

DA 1

Soil Conditions (DA 1)

HSG	RCN[†]	Area	Percent
A	38[‡]	0	0%
B	55	4.6 acres	60%
C	70	3.0 acres	40%
D	77	0	0%

[†] RCN for "woods in good condition" (Table 2-2, TR-55)
[‡] RCN is different than Table 2-2

- Determine Composite RCN for "woods in good condition" for DA 1

$$RCN_{woods} = \frac{(55 \times 4.6\text{ acres}) + (70 \times 3.0\text{ acres})}{7.6\text{ acres}} = 61$$

The target RCN for “woods in good condition” is 61

DA 2

Soil Conditions (DA 2)

HSG	RCN†	Area	Percent
A	38‡	0	0%
B	55	18.2 acres	60%
C	70	12.2 acres	40%
D	77	0	0%

† RCN for “woods in good condition” (Table 2-2, TR-55)
‡ RCN is different than Table 2-2

Determine Composite RCN for “woods in good condition” for DA 2

$$RCN_{woods} = \frac{(55 \times 18.2\text{ acres}) + (70 \times 12.2\text{ acres})}{30.4\text{ acres}} = 61$$

The target RCN for “woods in good condition” is 61

B. Determine Target P_E Using Table 5.X:

P_E = Rainfall used to size ESD practices

During the planning and preliminary design processes, site soils and proposed imperviousness are used to determine target P_E for sizing ESD practices to mimic wooded conditions.

- Determine Proposed Imperviousness (%I)

DA 1

Proposed Impervious Area (as measured from site plans): 2.25 acres;
%I = Impervious Area / Drainage Area
= 2.25 acres / 7.6 acres
= 30.0%

DA 2

Proposed Impervious Area (as measured from site plans): 11.55 acres;
%I = Impervious Area / Drainage Area
= 11.55 acres / 30.4 acres
= 38.0%

Because %I is closer to 40% than 35%, use the more conservative value , 40%, to determine target P_E.

For this example, assume imperviousness in DA 1 & DA 2 is distributed proportionately (60/40) in B and C soils.

- Determine P_E from Table

DA 1

Using %I = 30% and B Soils:

		Hydrologic Soil Group B				
%I	**RCN***	**P_E = 1"**	**1.2"**	**1.4"**	**1.6"**	**1.8"**
15%	67	**55**				
20%	68	60	**55**	**55**		
25%	70	64	61	58		
30%	72	65	62	59	**55**	
35%	74	66	63	60	56	

P ≥ 1.6 inches will reduce RCN to reflect "woods in good condition"

Using %I = 30% and C Soils:

		Hydrologic Soil Group C				
%I	**RCN***	**P_E = 1"**	**1.2"**	**1.4"**	**1.6"**	**1.8"**
15%	78	**70**				
20%	79	**70**				
25%	80	72	**70**	**70**		
30%	81	73	72	71		
35%	82	74	73	72	**70**	
40%	84	77	75	73	71	
45%	85	78	76	74	71	

$P_E \geq 1.6$ inches will reduce the RCN to reflect "woods in good condition".

For DA 1, P_E happens to be the same for both soil groups, therefore use P_E = 1.6 inches of rainfall.

DA 2

Using %I = 40% and B Soils:

		Hydrologic Soil Group B					
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"
15%	67	**55**					
20%	68	60	**55**	**55**			
25%	70	64	61	58			
30%	72	65	62	59	**55**		
35%	74	66	63	60	56		
40%	75	66	63	60	56		
45%	78	68	66	62	58		

$P_E \geq 1.8$ inches will reduce the RCN to reflect "woods in good condition".

Using %I = 40% and C Soils:

		Hydrologic Soil Group C					
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"	2.0"
15%	78	**70**					
20%	79	**70**					
25%	80	72	**70**	**70**			
30%	81	73	72	71			
35%	82	74	73	72	**70**		
40%	84	77	75	73	71		
45%	85	78	76	74	71		

$P_E \geq 1.8$ inches will reduce the RCN to reflect "woods in good condition".

For DA 2, P_E happens to be the same for both soil groups, therefore use P_E = 1.8 inches of rainfall.

C. Compute Q_E:

DA 1

Q_E = Runoff depth used to size ESD practices

Q_E = P_E x R_v, where

P_E = 1.6 inches

R_v = 0.05 + (0.009)(I); I = 30.0%

= 0.05 + (0.009 x 30.0)

= 0.32

Q_E = 1.6 inches x 0.32

= 0.51 inches

DA 2

Q_E = Runoff depth used to size ESD practices
Q_E = P_E x R_v, where
P_E = 1.8 inches
R_v = 0.05 + (0.009)(I); I = 38.0%
= 0.05 + (0.009 x 38.0)
= 0.39

Q_E = 1.8 inches x 0.39
= 0.70 inches

ESD targets for the Pensyl Pointe project:

DA 1

P_E = 1.6 inches
Q_E = 0.51 inches

DA 2

P_E = 1.8 inches
Q_E = 0.70 inches

By using ESD practices that meet these targets, Re_v, WQ_v, and Cp_v requirements will be satisfied. Potential practices could include swales or micro-bioretention to capture and treat runoff from the roads. Likewise, raingardens and disconnection of runoff could be used to capture and treat runoff from the houses.

Step 2. Determining Stormwater Management Requirements After Using ESD

For this example, it is assumed that ESD techniques and practices were implemented to treat only 1.6 inches of rainfall (e.g., P_E = 1.6 inches) over the entire project. After all efforts to implement ESD practices have been exhausted, the following basic steps should be followed to determine if any additional stormwater management is required.

A. Calculate Reduced RCNs

P_E = Rainfall used to size ESD practices

During the planning and design processes, site soils, measured imperviousness, and P_E are used to determine reduced RCNs for calculating Cp_v requirements.

- Determine Reduced RCNs for P_E = 1.6 inches

<u>DA 1</u>

Using %I = 30%, B Soils, and P_E = 1.6 inches:

		Hydrologic Soil Group B				
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"
15%	67	**55**				
20%	68	60	**55**	**55**		
25%	70	64	61	58		
30%	72	65	62	59	**55**	
35%	74	66	63	60	56	

For B Soils, P_E = 1.6 inches, and %I = 30%, reduced RCN = 55 (woods in good condition)

Using %I = 30%, C Soils, and P_E = 1.6 inches:

		Hydrologic Soil Group C				
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"
15%	78	**70**				
20%	79	**70**				
25%	80	72	**70**	**70**		
30%	81	73	72	71		
35%	82	74	73	72	**70**	
40%	84	77	75	73	71	
45%	85	78	76	74	71	

For C Soils, P_E = 1.6 inches, and %I = 30%, reduced RCN = 70 (woods in good condition)

Composite RCNs may be calculated as follows:

For P_E = 1.6 inches:

$$\text{RCN} = \frac{(55 \times 4.6\text{ acres}) + (70 \times 3.0\text{ acres})}{7.6\text{ acres}} = 60.9$$

Use 61

<u>DA 2</u>

Using %I = 40%, B Soils, and P_E = 1.6 inches:

		Hydrologic Soil Group B				
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"
15%	67	**55**				
20%	68	60	**55**	**55**		
25%	70	64	61	58		
30%	72	65	62	59	**55**	
35%	74	66	63	60	56	
40%	75	66	63	60	56	
45%	78	68	66	62	58	

For B Soils, P_E = 1.6 inches, and %I = 40%, reduced RCN = 56

Using %I = 40%, C Soils, and P_E = 1.6 inches:

		Hydrologic Soil Group C				
%I	RCN*	P_E = 1"	1.2"	1.4"	1.6"	1.8"
15%	78	**70**				
20%	79	**70**				
25%	80	72	**70**	**70**		
30%	81	73	72	71		
35%	82	74	73	72	**70**	
40%	84	77	75	73	71	
45%	85	78	76	74	71	

For C Soils, P_E = 1.6 inches, and %I = 40%, reduced RCN = 71

Composite RCNs may be calculated as follows:

For P_E = 1.6 inches:

$$RCN = \frac{(56 \times 18.2\ \text{acres}) + (71 \times 12.2\ \text{acres})}{30.4\ \text{acres}} = 62$$

Reduced RCNs for the Pensyl Pointe project:

	DA 1	**DA 2**
P_E = 1.6 inches	RCN = 61	RCN = 62

B. Calculate Cp_v Requirements

DA 1

The composite RCN for "woods in good condition" is 61 (see Step 1A above).

The design RCN (61) for P_E = 1.6 inches reflects "woods in good condition" and therefore Cp_v is addressed.

Cp_v Storage Requirements for Pensyl Pointe - DA 1

Rainfall (P_E)	Cp_v (ac-ft)	Cp_v (cu. ft.)	Notes:
$P_E \geq$ 1.6 inches	NA	NA	Target P_E for RCN = woods
P_E = 1.6 inches	NA	NA	Design P_E
Conventional Design	0.30	13,070	From Chapter 2 (see page 2.32)

DA 2

The composite RCN for "woods in good condition" is 61 (see Step 1A above).

The design RCN (62) does not reflect the composite RCN for "woods in good condition" (61) and Cp_v must be addressed. However, $P_E \geq$ 1.0 inches, and Cp_v is based on the runoff from the 1-year 24-hour design storm calculated using the reduced RCN (62).

Calculate Cp_v using design P_E = 1.6 inches (RCN = 62)

$Cp_v = Q_1 \times A$

Where Q_1 is the runoff from the 1-year 24-hour design storm

$$Q_1 = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{(Equation 2.3, TR-55, USDA NRCS 1986)}$$

where: P = 1-year 24-hour design storm
S = (1000/RCN) – 10 (Equation 2-4, TR-55)
= (1000/62) – 10
= 6.1

$$Q_1 = \frac{[2.6 - (0.2x6.1)]^2}{[2.6 + (0.8x6.1)]} = \frac{1.90}{7.48} = 0.25 \text{ inches}$$

Cp_v = 0.25 inches x 30.4 acres
= 0.63 ac. – ft. or 27,440 cubic feet

Cp_v Storage Requirements for Pensyl Pointe – DA 2

Rainfall (P_E)	Cp_v (ac-ft)	Cp_v (cu. ft.)	Notes:
$P_E \geq$ 1.8 inches	NA	NA	Target P_E for RCN = woods
P_E = 1.6 inches	0.63	27,440	Design P_E
Conventional Design	1.31	57,065	From Chapter 2 (see page 2.33)

Stormwater management requirements for the Pensyl Pointe project include using ESD practices to treat 1.6 inches of rainfall and structural practices from Chapter 3 (e.g., shallow wetland) to treat the Cp_v of 27,440 cubic feet.