

2B-1 Unified Sizing Criteria

A. General information

This section presents an integrated approach for meeting the stormwater runoff quality and quantity management requirements in the minimum standards for development (see Section 2A-3) by addressing the key adverse impacts of stormwater runoff from a development site. The purpose is to provide a framework for designing a stormwater management system to:

- Remove stormwater runoff pollutants and improve water quality (minimum guideline #2)
- Prevent downstream streambank and channel erosion (minimum guideline #3)
- Reduce downstream overbank flooding (minimum guideline #4)
- Safely pass or reduce the runoff from extreme storm events (minimum guideline #5)

For these objectives, an integrated set of engineering criteria, known as the unified stormwater sizing criteria have been developed to size and design structural stormwater controls. Table 1 below briefly summarizes the criteria.

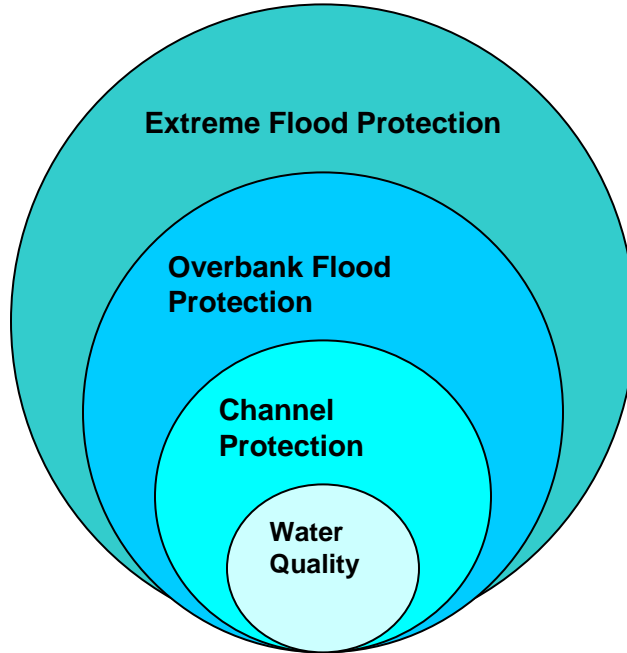
Table 1: Summary of the recommended unified stormwater sizing criteria for management of stormwater quality and quantity

Sizing Criteria	Recommended Method
Water Quality Volume WQv (acre-feet)	Treat the runoff from 90% of the storms that occur in an average year. For Iowa, this equates to providing water quality treatment for the runoff resulting from a rainfall depth of 1.25 inches or less. Goal is to reduce average annual post-development total suspended solids loadings by 80%. $WQv = (Rv)(A)(P)/12$ Rv = site runoff volume coefficient A = site drainage area (acres) P = design rainfall depth (90% cumulative frequency depth) (~ 1.25 inches)
Recharge Volume Rev (acre-feet)	Fraction of WQv, depending on pre development soil hydrologic group. $Rev = [(S) (Rv) (A)]/12$ S = soil specific recharge factor in inches
Channel Protection Storage Volume Cpv	Provide 24 hours of extended detention of the runoff from the 1-year 24-hr duration storm event to reduce bank-full flows and protect downstream channels from erosive velocities and unstable conditions.
Overbank Flood Protection Qp	Provide peak discharge control of the 5-year storm event such that the post-development peak rate does not exceed the downstream conveyance capacity and/or cause overbank flooding in local urban watersheds. Some jurisdictions may require peak discharge control for the 2-yr storm event.
Extreme Flood Protection Qf	Evaluate the effects of the 100-year storm on the stormwater management system, adjacent property, and downstream facilities and property. Manage the impacts of the extreme storm event through detention controls and/or floodplain management.

The unified stormwater sizing criteria are intended to be used collectively to address the overall stormwater impacts from a development site. When used as a set, the unified criteria control the entire range of hydrologic events, from the smallest runoff producing rainfalls (≥ 0.1 -inches) to the 100-year storm.

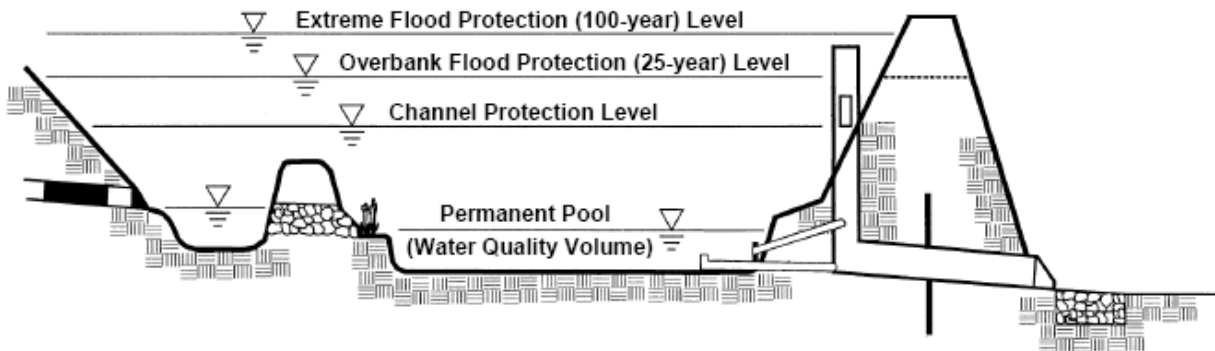
Figure 1 graphically illustrates the relative volume requirements of each of the unified stormwater sizing criteria, as well as demonstrates that the criteria are "nested" within one another, i.e., the extreme flood protection volume requirement also contains the overbank flood protection volume, the channel protection volume, and the water quality treatment volume. Figure 2 shows how these volumes would be allocated and configured in a typical stormwater wet detention basin (wet pond) designed to handle all four criteria.

Figure 1: Relationship of the unified stormwater sizing criteria



Adapted from Georgia Stormwater Manual, Vol. 2, 2001

Figure 2: Configuration of unified sizing criteria water surface elevations in a wet detention basin (stormwater wet pond)



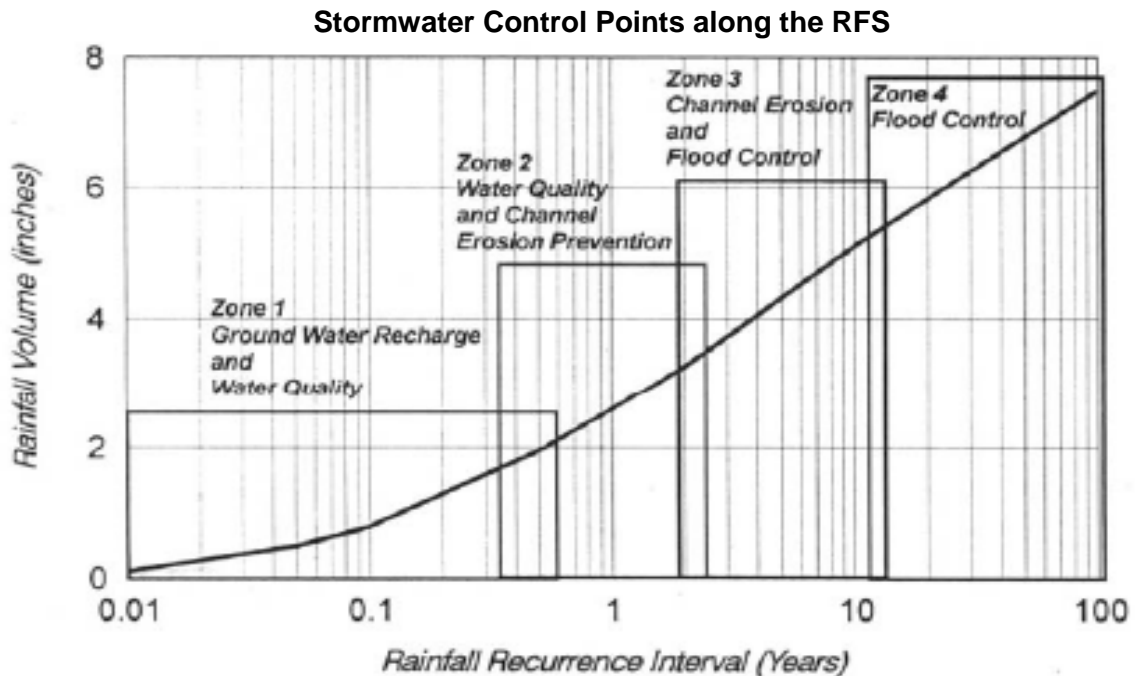
Source: Adapted from Georgia Stormwater Manual, Vol. 2, 2001

B. Rainfall frequency spectrum (RFS)

The effectiveness of any stormwater water quality treatment practice is a function of how much stormwater runoff is treated by the system and how much bypasses the practice. Since storms vary dramatically in magnitude, stormwater best management practices must be sized to capture a reasonable percentage of all runoff but bypass excessively large events. The rainfall frequency spectrum or RFS, which is defined as the distribution of all rainfall events, is a useful tool for establishing water quality treatment volume sizing criteria. This distribution is the cumulative volume from all storm events ranging from the smallest most frequent events in any given year to the largest most extreme events over a long duration, say, the 100-year frequency event.

The RFS consists of classes of frequencies often broken down by return interval, such as the 2-year storm return interval. Four principle classes are typically targeted for control by stormwater management practices. The two smallest, most frequent, classes are often referred to as water quality storms, where the control objectives are groundwater recharge, pollutant load reduction, and to some extent, control of channel erosion producing events. The two larger classes are typically referred to as quantity storms, where the control objectives are channel erosion control, overbank control, and flood control. Figure 3 illustrates the conceptual representation of these four classes:

Figure 3: Classes of rainfall distribution



After Claytor and Schueler, 1996

A more detailed discussion on procedures for rainfall and runoff analysis is included in Part 2C of this manual.

C. Water quality volume (WQv)

The water quality volume (denoted as WQv) is the storage needed to capture and treat the runoff from 90% of the average annual rainfall. In numerical terms, it is equivalent to the rainfall depth in inches (the 90% cumulative frequency rainfall depth) multiplied by the volumetric runoff coefficient (Rv) for the site, and the site drainage area. The specific rainfall depth to be used can be tailored to the local and/or regional rainfall for the specific project site in Iowa. A detailed procedure for determining the 90% cumulative frequency rainfall depth is included in Section 2C-2. The design rainfall depth to be used for determining the WQv in Iowa is 1.25 inches. This depth represents the 90% cumulative frequency rainfall for most all jurisdictions in Iowa. (Note: this depth is determined based on the long-term rainfall record; rainfall events less than 0.1 inch were not included in the total number of events). The 3-month recurrence interval rainfall depth for a particular climate region can be used as an initial approximation.

Two methods can be utilized to estimate the WQv. Both rely on computing a volumetric runoff coefficient (Rv) and multiplying this by the rainfall volume to obtain a runoff volume in watershed inches.

1. **Short cut method.** The first method uses Equation 2 to estimate the volumetric runoff coefficient, Rv (Schueler, 1987). It is recommended that the short cut method be used where the site consists of predominately one type of land surface or for quick calculations to obtain a reasonably accurate estimate of the water quality treatment volume.

The following equations are used to determine the storage volume, WQv (in acre-feet of storage):

- a. **Water quality volume (WQv)**

$$\frac{WQv = [(P)(Rv)(A)]}{12} *$$

Equation 1

P = rainfall depth in inches for selected area of state (i.e. 1.25 inches)

A = area in acre

*Multiply Equation 1 by 43,560 to convert WQv to units of ft³

- b. **Volumetric runoff coefficient for the project site (Rv)**

$$Rv = 0.05 + 0.009(I)$$

Equation 2

I = % impervious area

- c. **Example calculation of the short cut method.** Assume a 5-acre commercial (business park) development that is 64% impervious. The design rainfall depth, P, (90% cumulative rainfall frequency) is 1.25 inches.

$$Rv = 0.05 + 0.009(64\%)$$

$$Rv = 0.63$$

$$WQv = (1.25 \text{ in})(0.63) = 0.79 \text{ watershed inches}$$

$$WQv = (0.79 \text{ in})(1 \text{ ft}/12 \text{ in})(5 \text{ acre})(43,560 \text{ ft}^2/\text{acre}) = 14,338 \text{ ft}^3$$

2. **Small storm hydrology method.** The second method utilizes the work done by Pitt and others to compute an Rv based on the specific characteristics of the pervious and impervious surfaces of the drainage catchment. This method presents a relatively simple relationship between rainfall amount, land surface, and runoff volume. The Rvs used to compute the volume of runoff are identified in Table 2. The small storm hydrology model involves the following:
 - a. For a given rainfall depth, the runoff coefficients for land surfaces present on the subject site are selected.
 - b. A weighted runoff coefficient for the entire site is computed.
 - c. If a portion of the site has disconnected impervious surfaces, reduction factors are applied to Rv. The reduction factors (from Table 3) are multiplied by the computed Rv for connected impervious areas to obtain the corrected value.
 - d. For the given rainfall, the runoff volume (in watershed inches) is computed. WQV is equal to the rainfall times the Rv (same as Equation 1 above).

Table 2: Volumetric runoff coefficient Rv for urban runoff for directly connected impervious areas

Impervious Area	Precipitation (inches)			
	0.75	1.00	1.25	1.50
Flat roofs and large unpaved parking lots	0.82	0.84	0.86	0.88
Pitched roofs and large impervious areas (large parking lots)	0.97	0.97	0.98	0.98
Small impervious areas and narrow streets	0.66	0.70	0.74	0.77
Sandy soils (HSG-A)	0.02	0.02	0.03	0.05
Silty soils (HSG-B)	0.11	0.11	0.13	0.15
Clayey soils (HSG-C and D)	0.20	0.21	0.22	0.24

Source: Pitt, 1994

Table 3: Reduction factors to volumetric runoff coefficient Rv for disconnected impervious surfaces

Impervious Area	Precipitation (inches)			
	0.75	1.00	1.25	1.50
Strip commercial shopping center	0.99	0.99	0.99	0.99
Medium to high density residential with paved alleys	0.27	0.38	0.48	0.59
Medium to high density residential without alleys	0.21	0.22	0.22	0.24
Low density residential	0.20	0.21	0.22	0.24

Source: Pitt, 1994

The small storm hydrology method has the advantage of evaluating the precise elements of a particular site and can be utilized for most design applications to estimate accurate runoff volumes. The method requires somewhat more effort to identify the specific land surface area ratios and additional effort is needed to assess the disconnections of impervious areas. The method rewards site designs that utilize disconnections of impervious surfaces by lowering the computed Rv and the required WQv. An example calculation for the small storm hydrology method is below:

- e. **Example calculation of the small storm hydrology method.** Assume a 5-acre shopping center having a 1.8-acre flat roof, 2.2-acres of parking, and a 1-acre open space (HSG-B soil), for a 1.25-inch rainfall event and no disconnection of impervious surfaces.

The weighted volumetric runoff coefficient is: (from Table 2)

flat roof:	1.8 acres	x	0.86	=	1.55
parking:	2.2 acres	x	0.98	=	2.16
open space:	1.0 acre	x	0.13	=	0.13
total:	5.0 acres			=	3.84

The weighted volumetric runoff coefficient

$$R_v = \frac{3.84}{5.0} = 0.77$$

for P = 1.25 inches

WQv = (1.25 inches)(0.77) = 0.96 watershed inches

WQv = (0.96 inches)(1 ft/12 in)(5.0 acre)(43,560 ft²/acre) = 17,424 ft³

In order to use the reduction factors for disconnected impervious surfaces as general guidance, the impervious area above the pervious surface area should be less than one-half of the pervious surface, and the flow path through the pervious area should be at least twice the impervious surface flow path.

3. **Basis for determining water quality treatment volume.** As a basis for design, the following assumptions may be made:
- **Measuring impervious cover:** The measured area of a site plan that does not have vegetative or permeable cover shall be considered total impervious cover. Where direct measurement of impervious cover is impractical, NRCS land use/impervious cover relationships can be used to estimate impervious cover (see Table 2.2a in TR-55 v2.1, NRCS, 1986 or WINTR-55, NRCS 2003). Estimates should be based on actual land use and homogeneity.
 - **Multiple drainage areas:** When a project contains or is divided by multiple drainage areas, the WQv is addressed for each drainage area. See the design examples in Section 2C-6.
 - **Offsite drainage areas:** The WQv is based on the impervious cover of the proposed site. Offsite existing impervious areas may be excluded from the calculation of the WQv requirements.
 - **Sensitive streams:** Consult with the appropriate local review authority to determine if a greater WQv is warranted to protect sensitive streams.
 - **BMP treatment:** The final WQv is treated by an acceptable BMP(s) from the list presented in Part 2D, or an equivalent practice allowed by the appropriate review authority.
 - **Subtraction for structural practices:** Where structural practices for treating the Re_v are employed upstream of a BMP, the recharge volume requirements (Re_v) may be subtracted from the WQv used for design.
 - **Subtraction for non-structural practices:** Where non-structural practices are employed in the site design, the WQv could be reduced by local jurisdictions.
 - **Determining peak discharge for WQv storm:** When designing flow splitters for offline practices, consult the small storm hydrology method provided in Section 2C-7.
 - **Extended detention for WQv:** The water quality requirement can be met by providing a 24-hour drawdown of a portion of the WQv in conjunction with a stormwater pond or wetland system as described in Parts 2G and 2H. Referred to as ED, this is different than providing

the extended detention of the one-year storm for the channel protection volume (Cpv). The ED portion of the WQv may be included when routing the Cpv.

D. Recharge volume requirements (Rev)

The criteria for maintaining recharge is based on the average annual recharge rate of the hydrologic soil groups (HSG) present at a site, as determined from USDA, NRCS soil surveys, or from detailed site investigations. More specifically, each specific recharge factor is based on the USDA average annual recharge volume per soil type divided by the average annual rainfall in Iowa (32 inches per year) and multiplied by 90%. This keeps the recharge calculation consistent with the WQv methodology. The annual recharge volume requirement is specified for a site as follows:

1. **Site recharge volume requirement.**

a. **Percent volume method.**

$$Re\ v = \frac{[(S)(Rv)(A)]}{12} \tag{Equation 3}$$

where:

$$Rv = 0.05 + 0.009(I)$$

where I = percent impervious cover

A = site area in acres

S = soil-specific recharge factor (from HSG)

b. **Percent area method.**

$$Re\ v = \frac{[(S)(Ai)]}{12} \tag{Equation 4}$$

where Ai = measured impervious area

S = soil specific recharge factor (from HSG)

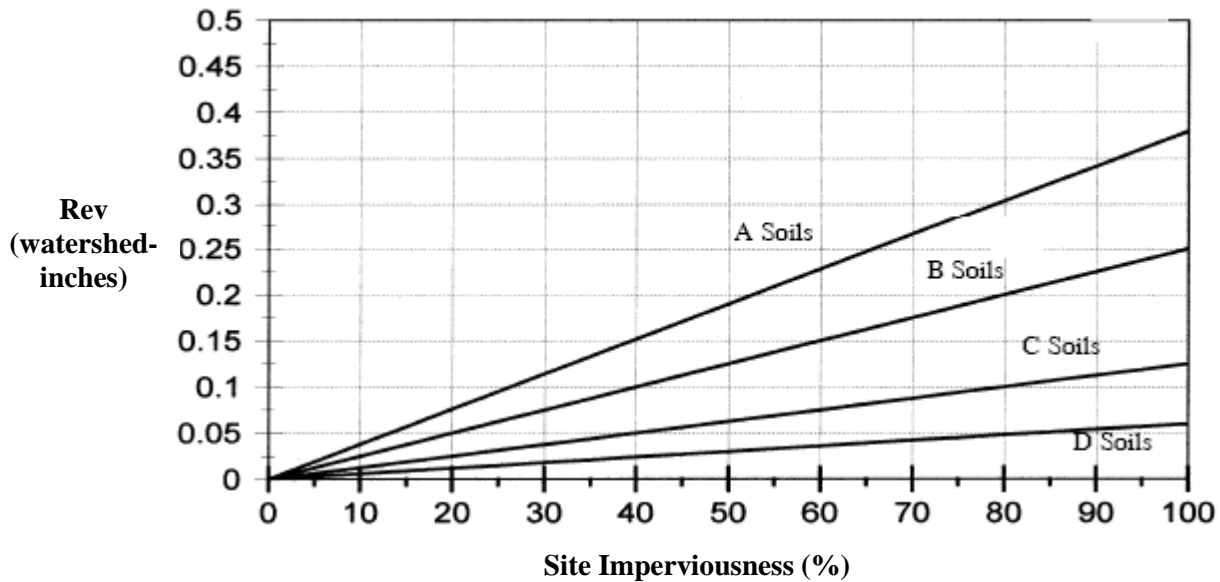
Table 4: Soil specific recharge factors

Hydrologic Soil Group	Average Annual Recharge Volume (in/yr)	Soil Specific Recharge Factor (S)
A-Sandy	18	0.51
B-Silty	12	0.34
C-Clayey	6	0.17
D-Clayey	3	0.08

The recharge volume is considered part of the total WQv that must be provided at a site and can be achieved either by a structural practice (e.g., infiltration, bioretention), a nonstructural practice (e.g., buffers, disconnection of rooftops), or a combination of both. Drainage areas having no impervious cover and no proposed disturbance during development may be excluded from the Rev calculations. Designers are encouraged to use these areas as non-structural practices for Rev treatment. Note: Rev and WQv are inclusive. When treated separately, the Rev may be subtracted from the WQv when sizing the water quality BMP.

The intent of the recharge criteria is to maintain existing groundwater recharge rates at development sites. This helps to preserve existing water table elevations, thereby maintaining the hydrology of streams and wetlands during dry weather. The volume of recharge that occurs on a site depends on slope, soil type, vegetative cover, precipitation, and evapotranspiration. Sites with natural ground cover, such as forest and meadow, have higher recharge rates, less runoff, and greater transpiration losses under most conditions. Because development increases impervious surfaces, a net decrease in recharge rates is inevitable. The relationship between Rev and site imperviousness is shown in graphical form in Figure 4.

Figure 4: Relationship between groundwater recharge, Rev, and site impervious cover



2. **Procedures for determining recharge volume, Rev.** If more than one HSG is present at a site, a composite soil specific recharge factor must be computed based on the proportion of total site area within each HSG. The recharge volume provided at the site should be directed to the most permeable HSG available.

The percent volume method is used to determine the Rev treatment requirement when structural practices are used to provide recharge. These practices include infiltration and exfiltration structures (i.e., infiltration, bioretention, dry swales, or sand filters with storage below the underdrain). In this method, the volume of runoff treated by structural practices must meet or exceed the computed Rev.

The percent area method is used to determine the Rev treatment requirements when non-structural practices are used. Under this method, the recharge requirement is evaluated by mapping the percent of impervious area that is effectively treated by an acceptable non-structural practice and comparing it to the minimum recharge requirements. Acceptable non-structural practices include filter strips that treat rooftop or parking lot runoff, sheet flow discharge to stream buffers and grass channels that treat roadway runoff.

The recharge volume criteria do not apply to any portion of a site designated as a stormwater hotspot, nor any project considered as redevelopment. In addition, the appropriate local review authority may alter or eliminate the Rev requirement if the site is situated on unsuitable soils (e.g.,

marine clays), karst or in an urban redevelopment area. If the Rev is treated by structural or non-structural practices separate and upstream of the WQv treatment, the WQv is adjusted accordingly.

E. Channel protection storage volume requirements (Cpv)

To protect channels from erosion, 24-hour extended detention of the 1-year, 24-hour storm event should be provided. The rationale for this criterion is that runoff will be stored and released in such a gradual manner that critical erosive velocities during bank-full and near-bank-full events will seldom be exceeded in downstream channels. Local governments may wish to use alternative methods to provide equivalent stream channel protection such as the distributed runoff control method or bank-full capacity/duration criteria (MacRae, 1993).

The method for determining the Cpv requirement is detailed in Section 2C-6. A detention pond or underground vault is normally needed to meet the Cpv requirement (and subsequent Q_{p10} and Q_f criteria). Schematics of a typical design are shown in Figure 2.

The following represent the minimum basis for designing for channel protection storage volume:

- The models TR-55 and TR-20 (or approved equivalent) are used for determining peak discharge rates.
- Rainfall depths for the 1-year, 24 hour storm event are provided in Table 2 in Section 2C-2.
- Off-site areas are modeled as present land use in good condition for the 1-year storm event.
- The length of overland flow used in time of concentration (t_c) calculations is limited to no more than 100 feet for post development conditions.
- The Cpv storage volume is computed using the methodology presented in Section 2C-6. This method is based on the NRCS WINTR55 methods and the detention basin storage is determined as described in Chapter 6 of the TR55 v2.31 (1986). A design example is provided in Section 2C-6. WINTR55 is the newer Windows OS version of TR55 released in 2003, and is an updated version of the older DOS version of TR-55 (v.2.31) released in 1986. The WINTR55 program is recommended for use since the hydrograph method has been updated. The program is available for download, along with full user manual, from the NRCS national Water Climate Center. <http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr55.html>.
- Cpv is not required at sites where the 1-year post development peak discharge (q_i) is less than or equal to 2.0 cfs. A Cpv orifice diameter (d_o) of less than 3 inches is subject to approval by the appropriate review authority and is not recommended unless an internal control for orifice protection is used (see Section 2C-6).
- Cpv is calculated for the entire site. If a site consists of multiple drainage areas, Cpv may be distributed proportionately to each drainage area.
- Extended detention storage provided for the Cpv does not meet the WQv requirement (that is, Cpv and WQv are treated separately).
- The stormwater storage needed for Cpv may be provided above the WQv storage in stormwater ponds and wetlands; thereby meeting all storage criteria except Rev in a single facility with appropriate hydraulic control structures for each storage requirement.
- Infiltration is not recommended for Cpv control because of large storage requirements.

F. Overbank flood protection volume requirements (Qp)

The primary purpose of the overbank flood protection volume sizing criteria is to prevent an increase in the frequency and magnitude of out-of-bank flooding generated by development (e.g., flow events that exceed the bank-full capacity of the channel and therefore must spill over into the floodplain). Overbank flood protection for the 10-year storm shall only be required if local approval authorities have no control of floodplain development, no control over infrastructure and conveyance system capacity design, or determine that downstream flooding will occur as a result of the proposed development.

For most regions of the state, the overbank flood control criteria equates to preventing the post-development 5-year (or 10-year), 24-hour storm peak discharge rate (Q_{p5}) from exceeding the pre-development peak discharge rate. In some local jurisdiction drainage systems, due to local piped conveyance constraints, the 2-year pre-development peak discharge may dictate the release rate for post-development flows due. In many jurisdictions, the storm sewer intake and piping capacity is sized for conveyance of the 5-year frequency runoff. For control of local flooding for areas connected to these conveyance systems, the upstream controlled release rate will need to meet the existing conveyance capacity to prevent local flooding of streets and properties. For drainage areas connected directly to open channel conveyances (swales and natural stream channels) the 10-year frequency runoff discharge is used. The rainfall depths associated with the 2- and 10-year, 24-hour storm events are provided in Section 2C-2 (Rainfall and Runoff Analysis).

When addressing the overbank flooding design criteria, the following represent the minimum basis for designing for overbank flood protection volume:

- The models TR-55 and TR-20 (or an equivalent approved by the appropriate local authority) should be used for determining peak discharge rates and runoff volume. WINTR55 will also provide an inflow hydrograph and a storage routing to establish the required CPv. WINTR55 can be used for drainage areas ≤ 2000 acres. The local approving authority shall determine adjustments for unique land features, such as Karst topography.
- The Rational method may be used for small catchments (≤ 60 acres) that are uniform in land cover/type. (Note: The rational method will provide a peak flow rate only; the user will need to use the modified rational method to determine the required volume; use of the modified rational method for storage calculation is limited to drainage catchments ≤ 20 acres).
- The standard for characterizing pre-development hydrologic land use for non-forested vegetated areas (including agriculture) shall be meadow in good hydrologic condition.
- Off-site areas should be modeled as "present land use condition" in good hydrologic condition for both the 2- and 10-year storm events.
- The length of overland flow used in T_c calculations is limited to no more than 100 feet for pre-development conditions and 100 feet for post-development conditions. For urban watershed the overland flow paths need to be carefully determined as the sheet flow path will often be < 100 feet (i.e. residential setting with houses set back 30-40 feet from the street curb line).
- For control of local overbank and/or local street flooding, and for protection of individual properties, the runoff discharge from developments is limited to no more than the pre-development 5-year frequency runoff. The post-development runoff for the 10-year through 50-year frequency design storms is also controlled to the pre-development 5-year rate. Onsite or regional detention basins are used for the control of post-development runoff discharge to meet the required maximum release rate. The design of detention basin system is addressed in Part 2G.

G. Extreme flood volume (Qf)

The intent of the extreme flood criteria is to:

- Prevent flood damage from large storm events
- Maintain the boundaries of the pre development 100-year Federal Emergency Management Agency (FEMA) and/or locally designated floodplain
- Protect the physical integrity of BMP control structures

This is typically done in two ways:

1. **100-year control.** Requires storage to attenuate the post development 100-year, 24-hour peak discharge (Qf) to pre development rates. The Qf is the most stringent and expensive level of flood control, and is generally not needed if the downstream development is located out of the 100-year floodplain. In many cases, the conveyance system leading to a stormwater structure is designed based on the discharge rate for the 10-year storm (Qp10). In these situations, the conveyance systems may be the limiting hydrologic control.
2. **Reserve ultimate 100-year floodplain.** 100-year storm control may be required by an appropriate review authority if:
 - a. Buildings or development are located within the ultimate 100-year floodplain
 - b. The reviewing authority does not completely control the 100-year floodplain

Hydraulic/hydrologic investigations may be required to demonstrate that downstream roads, bridges and public utilities are adequately protected from the Qf storm. These investigations typically extend to the first downstream tributary of equal or greater drainage area or to any downstream dam, highway, or natural point of restricted stream flow. Specific requirements for floodplain management and construction of infrastructure and/or excavation within the floodway can be found in Iowa Code Chapter 335.