IOWA STORM WATER MANAGEMENT MANUAL

9.02 METHODS TO ESTIMATE REQUIRED DETENTION STORAGE

IOWA DEPARTMENT OF NATURAL RESOURCES

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Refer to the glossary for words in **bold black text**.
Some items of emphasis are in **bold blue text.**

9.02-1 INTRODUCTION

This section includes a procedure to develop preliminary estimates of the amount of storage that will be required to meet desired flow rate reductions through a stormwater detention practice. This can be used by the designer to determine the minimum area needed to provide the estimated storage volume within a reasonable depth for certain events.

It is strongly encouraged that this procedure be completed early in the design process. Many times, practices have been proposed that are unable to meet all aspects of the Unified Sizing Criteria (USC) because insufficient space had been dedicated. In other cases, practices have been installed with steeper side slopes or with greater ponding depths to “squeeze in” a practice that meets the USC goals. This can complicate establishment and maintenance of desired vegetation, make the practice less suitable for public access and reduce the potential to create a valuable resource and amenity out of the site.

Completing this simple method early in the evaluation process can start off the site selection process with a better understanding of the area that should be dedicated—and could reduce the potential for more expensive redesign time later in the process.

9.02-2 PARAMETERS REQUIRED TO ESTIMATE STORAGE

Three design parameters are needed to use the methods described in this section to estimate the required detention storage needed to meet project goals. These are (1) the **allowable outflow release rate** from the practice, (2) the expected **inflow rate** to the practice and (3) the expected **inflow volume** to the practice. If these flow rates are known, a simple method can be used (best incorporated into a spreadsheet) to calculate an estimate of required storage.

A. Events to be Studied

To develop required storage volume estimates to comply with stormwater management guidelines for the entire spectrum of events, the flow information for the following events should be calculated:

- Channel protection event (1-year storm)
- 2-year storm
- 5-year storm
- 10-year storm
- 25-year storm
- 50-year storm
- 100-year storm

B. Allowable Release Rate from Practice

If a stormwater detention basin is being designed to meet the stormwater management needs for the entire watershed area it receives, then solving for the allowable release rate is easier to define. Under these circumstances, follow the guidance below:

1. **Channel protection volume (1–year event):** The allowable release rate is determined by calculations required to provide extended, 24-hour detention of the runoff from this event. Refer to Section 3.02 for details on how to calculate this allowable release rate.
2. **All larger storm events:** The allowable release rate should be the smaller of the these values:
   - The natural condition for a similar storm event (meadow in good condition, similar soil type(?), Tc for natural conditions).
   - The peak flow anticipated to be generated by the 5-year storm event under existing conditions (current at time of design) - requirement may be waived by the local jurisdiction.

Calculations to determine rates and volumes of runoff above typically use the TR-55 method. Refer to Sections 2.05 and 3.01 for additional information.

If the detention area is not expected to meet the stormwater management requirements for the entire area from which it receives runoff (e.g., if a new development receives runoff from an undeveloped adjacent property or an upstream developed area that was built without adequate detention), calculating the allowable release rate is more complicated. Refer to Section 3.01-5 for information on calculating stormwater management release rate requirements in such special cases. The local jurisdiction may also set standards for specific areas to deal with such circumstances.

C. Expected Inflow Rates and Volumes to Practice

Follow guidance in Sections 2.05 and 9.03 to calculate the expected peak flow rates and volumes for each event to be studied. These flow rates should be based on the fully developed conditions for the watershed area that is intended to be served by the practice. Additional analyses may be required in special cases, as described within Section 3.01-5.

9.02-3 ESTIMATING STORAGE REQUIRED

A. DESIGN PROCEDURE

The following procedure can be used to **estimate** the storage volume that will be needed to reduce outflow from a given basin to allowable levels. These storage volume estimates are not intended to be a final value of the storage required for any given event. Compliance with USC related to stormwater detention is based the final design achieving the desired flow rate reductions, not whether a set volume of storage is provided.

However, using the following procedure can quickly give a designer a close approximation of the volume that will be necessary to meet the flow rate reduction requirements of the USC, as applied to a given site by the local jurisdiction. The estimated volume can approximate the required area to be dedicated for stormwater detention. If used early in the design process, an appropriate area for management practices can be set aside and proposed improvements can be planned around that area.

1. For each watershed area or subarea which is expected to drain to the proposed detention area, **calculate the NRCS curve number and time of concentration** for a given watershed or subwatershed. Do this for three conditions: **natural, existing and proposed.** For **urbanized areas**, curve number selection should be based on impervious cover and open space conditions and not selected from a table based on a typical land use. Refer to Section 2.03 and 2.05 for details.
2. **Identify rainfall data values** for the storm events to be analyzed. Select values based on one of the nine regions of the state that the project site is located within. Refer to Section 2.02.
3. Create **TR–55 models for the natural, existing and proposed conditions.** Use a time step analysis interval of 1-minute, when possible. For each event, review the peak flow and volume information for the hydrograph that is entering the detention area to be sized.

From these models, for each event, the following information will be required to complete the estimation procedure:

Output data:

- Peak rate of flow (cfs)
- Total runoff volume (cf)

Software packages may give results for runoff volume in **watershed-inches**, **acre-feet** or **cubic feet**. Note the required conversions for desired volume measurement.

Document the above for each of the following conditions:

- Natural condition (used to establish allowable release rate)
- Existing condition (used to establish allowable release rate, in some circumstances)
- Proposed condition

From this output, **the allowable release rate will need to be determined for each event.** Methods to determine the allowable release rate for a given location is described in detail in Section 3.01. **To determine the allowable release rate for CPv, refer to the procedure in Section 3.02.**

NOTE

This procedure uses similar computational methods to those described in Section 3.02 to estimate requirements for storage of the Channel Protection Volume.

NOTE

If modeling the WQv event is required, use an adjusted Curve Number, as described within Section 2.03.

NOTE

Most software programs running the TR–55 calculation methods can use this time step interval. However, the original Win–TR20 and Win–TR55 software packages are limited to a 0.1 hour (6–minute) interval. It is not recommended to use software with such limitations for watersheds less than 20 acres in size, as the true peak flow rate may occur in between the larger time intervals, resulting in an underestimation of flow.

4. For each event, use Equation 9.02-3-1, Storage volume/Runoff volume relationship, based on outflow/inflow ratio, to **solve for the estimated ratio** of detention storage required compared to the runoff volume from the study area during the storm event (Vs/Vr).

Where: qo = allowable release rate (cfs)

qi = inflow rate to basin, proposed condition (cfs)

Vs = required storage volume (cf, unknown variable at current step)

Vr = total runoff volume to basin (cf)

Equation 9.02-3-1: Storage volume/Runoff volume relationship, based on outflow/inflow ratio

$$\left(\frac{Vs}{Vr}\right) = 0.683 - 1.43\left(\frac{qo}{qi}\right) + 1.64\left(\frac{qo}{qi}\right)^2 - 0.804\left(\frac{qo}{qi}\right)^3$$

5. **Multiply Vr by the (Vs/Vr) ratio calculated in Step 4** to solve for the estimated detention storage volume required (Vs). These formulas can be incorporated into a spreadsheet in a format similar to the one shown below, so that the estimated volume is calculated once peak flow rate and volume data is entered. It is recommended to add 10–15% to these values, as use of extended detention to manage CPv may result in a slight increase in storage needed in final design for larger events.

Figure 9.02-3-1: Example of a spreadsheet used to estimate storage.

Initial Storage Estimation

Storm Event	qo cfs	qi cfs	qo/qi	Vs/Vr	Vr CF	Vs CF	Vs *1.15 CF
1	3.2	106	0.03	0.642	364,000	233,526	268,600
2	6.3	136	0.05	0.620	463,000	287,151	330,200
5	15.1	193	0.08	0.581	655,000	380,406	437,500
10	26.4	249	0.11	0.549	846,000	464,338	534,000
25	48.1	336	0.14	0.510	1,150,000	585,970	673,900
50	69.9	412	0.17	0.484	1,420,000	686,806	789,800
100	94.8	494	0.19	0.463	1,710,000	792,231	911,100

At this point, the preliminary storage volume for each event to be addressed by the detention practice is known. This can be used by the planner or designer to set aside a proper area for the BMP. When doing this, refer the specific ISWMM section dedicated to each practice to identify the recommended temporary ponding depths for each storm event.

Once the proper space has been reserved, more detailed grading plans can be developed of the detention area. This will lead to development of stage-storage relationships that will be used in final basin routing to determine expected performance.

NOTE

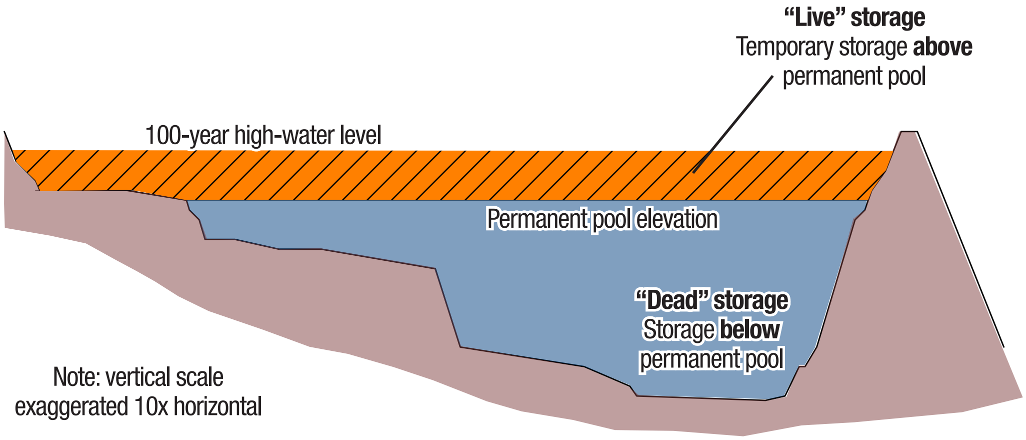
This value is not the final storage volume required. This is an initial estimate to allow the designer to locate a storage area on site with the approximate volume expected to be required.

NOTE

"Dead storage" may be used to address WQv requirements. Refer to the sections for each individual practice for requirements or more information.

B. DEAD VS. LIVE STORAGE

When estimating storage and performing final routing, it should be noted that these calculated values represent the volume available for temporary storage. This is the volume within the basin above any permanent pool or ground surface within the footprint of the basin. Space occupied by water below the normal pool of a pond or wetland is not available for use as temporary storage during a flood event. This is sometimes referred to as "dead storage". These volumes should not be counted toward the volume being used for detention. Essentially, when estimating or performing detention routing calculations, this dead storage should be ignored. The unoccupied space above the pool or bottom of the basin is the volume available for use as detention. This is referred to as "live storage" as it will only be occupied for a period of time after the storm event has passed.



9.02-4 ESTIMATION PROCEDURE EXAMPLE

Example Calculation for Preliminary Storage Estimate

1. **Calculate the NRCS Curve Number and Time of Concentration for each given watershed area; do this for natural (pre–settlement), existing, and proposed conditions.**

Use the TR-55 methods for selecting a curve number and calculating time of concentration for each watershed area.

TABLE 9.02-4.1: CURVE NUMBER AND TIME OF CONCENTRATION

SUBWATER-SHED ID	LAND USE*	AREA (ACRES)	% IMPERVIOUS	CURVE NUMBER			TIME OF CONCENTRATION (MIN)		
				NATURAL	EXISTING	PROPOSED	NATURAL	EXISTING	PROPOSED
1	C	11	73	58	78	92	40.3	18.7	8.2
2	C	9	73	58	78	92	37.2	17.3	7.6
3	M	15	65	58	78	85	45.6	21.2	12.2
4	S	25	43	58	78	75	56.0	26.0	20.5
5	S	20	73	58	78	75	51.2	23.8	18.8

* C= Commercial; M = Multi-family; S = Single-family

2. **Identify rainfall data values for the storm events to be analyzed.**

For this example, the site is in Primghar, Iowa. Use the Section 1 (Northwest Iowa) rainfall data for the 24-hour storm:

TABLE 9.02-4.2: 24-HR STORM

RETURN PERIOD	RAINFALL DEPTH (IN)
1-yr	2.51
2-yr	2.92
5-yr	3.67
10-yr	4.39
25-yr	5.50
50-yr	6.46
100-yr	7.50

3. **Create a TR–55 model for the natural, existing, and proposed conditions. For each storm event, collect the peak rate of flow (cfs) and total runoff volume (cf).**

For this example, Hydraflow Hydrographs 2019 was used to model the inflows using the CN and Tc form step 2.

NOTE

Total site area = 80 acres

TABLE 9.02-4.3: RUNOFF FLOW RATES AND VOLUMES FROM TR-55 MODEL OF NATURAL, EXISTING, AND DEVELOPED CONDITIONS							
		NATURAL		EXISTING		DEVELOPED	
STORM EVENT	RAINFALL (IN)	PEAK RATE (CFS)	VOLUME (CF)	PEAK RATE (CFS)	VOLUME (CF)	PEAK RATE (CFS)	VOLUME (CF)
1	2.51	2.1	39,469	62	231,383	98	291,890
2	2.92	5.7	72,301	86	312,296	127	378,428
5	3.67	17	151,712	135	474,094	183	547,995
10	4.39	33	247,189	184	641,449	239	720,598
25	5.50	65	422,842	263	914,860	329	999,301
50	6.46	97	596,265	333	1,161,569	408	1,248,756
100	7.50	135	801,389	410	1,436,144	494	1,525,034

4. **For each event, use the peak flows (qi) and runoff volumes (Vr) in Equation 9.02–3–1 to solve for the estimated ratio, Vs/Vr, of detention storage required compared to the runoff entering the basin.**

In this example, a local ordinance requires detaining so that the outflow (qo) is the minimum of the natural flow rate and the existing 5-year flow rate. The values for the 10-year event are shown explicitly; Table 9.02-4.4 summarizes only the calculation results.

The allowable 10-year outflow for the basin is the minimum of the 10-year natural peak flow (33 cfs) and the 5-year existing conditions (135 cfs). Use the 10-year natural conditions (33 cfs) for qo. The proposed inflow under fully developed conditions is 239 cfs.

$$\left(\frac{qo}{qi}\right) = \frac{33}{239}$$

$$\left(\frac{qo}{qi}\right) = 0.14$$

10	4.39	33.30	247,189	183.6	641,449	239.4	720,598

$$\left(\frac{Vs}{Vr}\right) = 0.683 - 1.43\left(\frac{qo}{qi}\right) + 1.64\left(\frac{qo}{qi}\right)^2 - 0.804\left(\frac{qo}{qi}\right)^3$$

$$\left(\frac{Vs}{Vr}\right) = 0.683 - 1.43(0.14) + 1.64(0.14)^2 - 0.804(0.14)^3$$

Vs/Vr = 0.514

It shoiuld be noted that the outflow rate for the CPv event is calculated using the procedure shown in Section 3.02.

First, convert the runoff VOLUME for the developed condition to watershed-inches:

Qa = VOLUME (CF) x 12 (inches/foot) ÷ (AREA (acres) x 43,560 (SF/AC))

Qa = 291,890 CF x 12 ÷ (80 ac x 43,560)

Qa = 1.01 watershed-inches

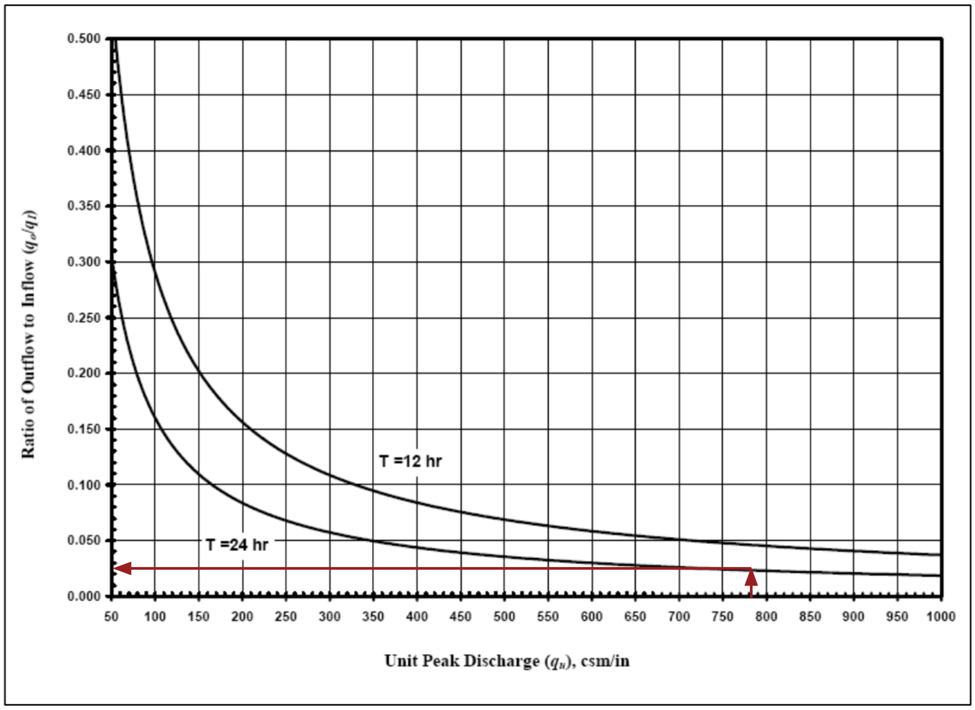
Second, calculate the unit peak discharge rate (qu)

qu = PEAK RATE (cfs) x 640 (acres/mi2) ÷ (Area (acres) x Qa (watershed-inches)

qu = 98.1[1] cfs x 640 (acres/mi2) ÷ (80 acres x 1.01 wtr-in)

qu = 781 (cfs x mi2 / inch or csm/in)

Third, use the chart from Section 3.02 to determine the OUTFLOW to INFLOW RATIO (qo/qi):



For qu = 781 csm/in, qo/qi = 0.025[2]

Finally, multiply the INFLOW RATE to the BMP by the qo/qi RATIO to solve for the allowable outflow rate:

qo (cfs) = qi (cfs) x (qo/qi)

qo = 98.1 cfs x 0.025

qo = 2.5 cfs

1. The PEAK RATE of 98.1 cfs is the developed flow to the practice, during a 1-year storm event. (See the table example on the previous page.)
2. In this example, the peak allowable rate of flow to provide extended detention of the Channel Protection event is slightly larger than the peak rate of flow calculated for natural site conditions (2.1 cfs -- see table on previous page).

NOTE

The 15% addition is a factor of safety addition, as in practice it has been shown that this estimation procedure may yield results that are slightly less than what will be the results of final design and modeling.

Incorporating this correction factor should make preliminary storage volumes used be closer to expected final results.

TABLE 9.02-4.4: USING INFLOW AND ALLOWABLE OUTFLOW RATES TO DETERMINE VS/VR RATIO				
STORM EVENT	QO (CFS)	QI (CFS)	QO/QI	VS/VR
1	2.5	98	0.025	0.648
2	5.7	127	0.04	0.622
5	17.3	183	0.09	0.562
10	33.3	239	0.14	0.514
25	64.9	329	0.20	0.458
50	96.8	408	0.24	0.425
100	134.5	494	0.27	0.399

5. **Multiply Vr by the Vs/Vr ratio obtained in step 4 by the storage volume, Vs, obtained in step 3. Add 15% to accommodate extended detention needs and provide flexibility in spatial planning.**

For example, the runoff volume proposed for the 10-year event under developed conditions is 720,598 cf.

$$\left(\frac{Vs}{Vr}\right) \times Vr = Vs$$

$$0.514 \times 720{,}598 = 370{,}141$$

Add 15% to accommodate extended detention needs and provide flexibility in spatial planning:

$$Vs \times 1.15 = 370{,}141 \times 1.15$$

$$Vs = 425{,}700 \text{ cf}$$

Table 9.02-4.5 includes the results of similar calculations for other storm events.

TABLE 9.02-4.5: USING VS/VR RATIO AND CALCULATED RUNOFF VOLUMES TO ESTIMATE STORAGE VOLUME, VS				
STORM EVENT	VR (CF)	VS/VR (CF)	VS (CF)	VS X 1.15 (CF)
1-yr	291,890	0.648	189,221	217,600
2-yr	378,428	0.622	235,418	270,700
5-yr	547,995	0.562	307,924	354,100
10-yr	720,598	0.514	370,141	425,700
25-yr	999,301	0.458	458,080	526,800
50-yr	1,248,756	0.425	530,814	610,400
100-yr	1,525,034	0.399	608,373	699,600

At this point, the preliminary storage volume for each event to be addressed by the practice is known.