Volume 2, Chapter 10 - Storage

Users' Guidance:

If a UDFCD *Section* number in this chapter is **skipped**:
It was adopted as is; please refer to that Section in the **corresponding UDFCD Manual**, Volume, Chapter and *Section.*

If a UDFCD *Section* number in this chapter is **amended or a new COFC *Section* in this Chapter is added**:
It is **listed below**; please refer to it in **this document**.

If a UDFCD *Section* in this chapter is **deleted then** it was **not** adopted by the City of Fort Collins; The deleted UDFCD *Section* number will be **identified as deleted in the text below**.

(1) *Section 3.1.1* is amended to read as follows:

3.1.1 Use of Simplified On-Site Detention Sizing Procedures

(a) There are two methodologies approved by the City for sizing detention storage basins, the Rational Formula-based Federal Aviation Administration (FAA) procedure and the Stormwater Management Model (SWMM). The City is the determining authority regarding the appropriate methodology to use under different circumstances. Early contact with the City is encouraged for the timely determination of the appropriate detention storage sizing methodology.

(b) In general, the Rational Formula-based FAA procedure may only be used in the design of detention storage facilities with tributary areas that are less than five (5) acres in size. The Stormwater Management Model (SWMM) must be used to model and size stormwater detention storage facilities with tributary areas of twenty (20) acres or more. Preliminary sizing of detention storage volume may be performed for site planning purposes using the Rational Formula-based FAA procedure in conjunction with a twenty (20) percent upward adjustment to account for the larger resulting storage volume that would be obtained from SWMM modeling.

(c) For tributary areas between five and twenty (20) acres in size, either SWMM or the Rational Formula-based FAA procedure may be used to calculate detention storage volume. However, if the Rational Formula-based FAA procedure is chosen as the preferred method, the resulting storage volume must be increased by a factor of twenty (20) percent to better match the result that would be obtained from SWMM modeling.

(2) *Section 3.1.2* is amended to read as follows:

3.1.2 Detention Pond Hydrograph Sizing Procedure

(a) Whenever the area limits described above in Section 3.1.1 are exceeded (for tributary catchments larger than twenty acres for the FAA Procedure) the City requires the use of hydrograph flood routing procedures (e.g., using SWMM reservoir routing calculations). In addition, if there are upstream detention facilities in the watershed that catch and route runoff for portions of the upstream tributary area, hydrograph routing methods must be employed.

(b) If off-site tributary areas contribute runoff to an on-site detention storage facility, the total tributary area at existing development rate must be accounted for in the design of the storage facility by routing the flows generated by that off-site area around the proposed storage facility or, by fully accounting for these flows in the design of the spillway system for that storage facility.

(3) *Section 3.1.3* is amended to read as follows:

<u>3.1.3 Water Quality Capture Volume in Sizing Detention Storage</u>

When detention storage volume is sized for a site that also incorporates a water quality capture volume (WQCV) defined in Volume 3 of this Manual, the 100-year volume required for quantity detention must be added to the entire WQCV. The WQCV must also be added in its entirety to the required 5- or 10-year volume.

(4) *Section 3.2.1* is deleted in its entirety.

(5) *Section 3.2.2* is deleted in its entirety.

(6) *Section 3.2.3* is amended to read as follows:

<u>3.2.3 Rational Formula-Based Modified FAA Procedure</u>

The Rational Formula-based Federal Aviation Administration (FAA) (1966) detention sizing method (sometimes referred to as the "FAA Procedure"), as modified by Guo (1999a), provides a reasonable estimate of storage volume requirements for on-site detention facilities. This method provides sizing for one level of peak control only and not for multi-stage control facilities.

The input required for this Rational Formula-based FAA volume calculation procedure includes:

A = area of the catchment tributary to the storage facility (acres)

C = runoff coefficient

Q_{po} = allowable maximum release rate from the detention facility

T_c = time of concentration for the tributary catchment (minutes) (see the Runoff chapter)

P_i = 2-hour design rainfall depth (inches) at the site taken from the Rainfall chapter for the relevant return frequency storms

The calculations are best set up in a tabular (spreadsheet) form with each 5-minute increment in duration being entered in rows and the following variables being entered, or calculated, in each column:

1. Storm Duration Time, T (minutes), up to 180 minutes.
2. Rainfall Intensity, I (inches per hour).
3. Inflow volume, Vi (cubic feet), calculated as the cumulative volume at the given storm duration using the equation:

$$Vi = CIA\,(60T) \qquad \text{(SO-6)}$$

4. Outflow adjustment factor m (Guo 1999a):

$$m = 1/2\,(1 + T_c/T) \qquad 0.5 \leq m \leq 1 \text{ and } T \geq Tc \qquad \text{(SO-7)}$$

5. Calculated average outflow rate, Q_{av} (cfs), over the duration T:

$$Q_{av\,v} = m\,Q_{po} \qquad \text{(SO-8)}$$

6. Calculated outflow volume, V_o, (cubic feet), during the given duration and the adjustment factor at that duration calculated using the equation:

$$V_o = Q_{av}\,(60\,T) \qquad \text{(SO-9)}$$

7. Required storage volume, Vs (cubic feet), calculated using the equation:

$$Vs = V_i - V_o \qquad \text{(SO-10)}$$

The value of Vs increases with time, reaches a maximum value, and then starts to decrease. The maximum value of Vs is the required storage volume for the detention facility. Sample calculations using this procedure are presented in Design Example 6.2. The modified *FAA Worksheet* of the UD-Detention Spreadsheet performs these calculations.

(7) *Section 3.2.4* is deleted in its entirety.

(8) *Section 3.2.5* is deleted in its entirety.

(9) *Section 3.2.6* is deleted in its entirety.

(10) *Section 3.2.7* is deleted in its entirety.

(11) *Section 3.3.3* is amended to read as follows:

3.3.3 Spillway Sizing and Design

(a) The overflow spillway of a storage facility must be designed to pass flows in excess of the design flow of the outlet works. When the storage facility falls under the jurisdiction of the Colorado State Engineer's Office (SEO), the spillway's design storm is prescribed by the SEO. If the storage facility is not a jurisdictional structure, the size of the spillway design storm must be based upon analysis of the risk and consequences of a facility failure. Generally, embankments should be fortified against and/or have spillways that, at a minimum, are capable of conveying the total not-routed peak 100-year storm discharge from a fully developed total tributary catchment, including all off-site areas, if any. However, detailed analysis, of downstream hazards must be performed and may indicate that the embankment protection and, or spillway design needs to be sized for events much larger than the 100-year design storm.

(b) The detention pond spillway crest must be set at the 100-year water surface elevation in the pond and the spillway shall be designed such that any spills shall be no more than six (6) inches in depth at the crest during the 100-year storm. The detention pond top of embankment shall be set at all points a minimum of one foot above the spillway crest elevation.

(c) Emergency spillways must be protected from catastrophic erosion failure through the use of bank protection procedures downhill from the spillway to the toe of slope. The slope protection for spillway embankments shall be designed in accordance with all the specifications set forth in Volume 1, Chapter 7, Major Drainage, Section 4.4.4.3, “Riprap Specifications and Applicability”, of this Manual.

(d) A concrete cutoff wall eight inches in thickness, three feet deep, extending five feet into the embankment beyond the spillway opening is required on private detention ponds larger than one acre-foot in volume and are also required on all publicly-owned regional detention ponds larger than that size. The emergency spillway crest elevation must be tied back to the top of the pond embankment at a maximum slope of four to one.

(12) *Section 3.3.4* is amended to read as follows:

3.3.4 Retention Facilities

(a) A retention facility (a basin with a zero release rate or a very slow release rate) is used on a temporary basis when there is no available formal downstream drainageway, or one that is grossly inadequate. When designing a retention facility, the hydrologic basis of design is difficult to describe because of the stochastic nature of rainfall events. Thus, sizing for a given set of assumptions does not ensure that another scenario produced by nature (e.g., a series of small storms that add up to large volumes over a week or two) will not overwhelm the intended design. For this reason, retention basins are not permissible as a permanent solution for drainage problems. When used, they can become a major nuisance due to problems that may include mosquito breeding, safety concerns, odors, etc.

(b) When temporary use of a retention basin is proposed as a solution, the City requires that it be sized to capture, at a minimum, the runoff equal to two times the two hour, 100-year storm plus one foot of freeboard. The facility must be situated and designed so that when it overtops, no human-occupied or critical structures (e.g., electrical vaults, homes, etc.) will be flooded, and no catastrophic failure at the facility (e.g., loss of dam embankment) will occur. It is also required that retention facilities be as shallow as possible to encourage infiltration and other losses of the captured urban runoff. When a trickle outflow can be accepted downstream or a small conduit can be built, it shall be provided and sized in accordance with the locally approved release rates, and be preferably capable of emptying the full volume in seventy-two (72) hours or less.

(c) All retention ponds must be built with a pump back-up system and with a concrete hard surface at the bottom of the pond that is capable of evacuating the full volume in seventy-two (72) hours or less.

(d) All retention ponds must be built and operated in accordance with all applicable State and Federal laws and must respect all established water rights.

(13) *Section 3.4* is amended to read as follows:

3.4 Reservoir Routing of Storm Hydrographs for Sizing of Storage Volumes

The reservoir routing procedure for the sizing of detention storage volumes is more complex and time consuming than the use the FAA procedure. Its use requires the designer to develop an inflow hydrograph for the facility. This is generally accomplished using SWMM computer models as described in the RUNOFF chapter of this Manual. The hydrograph routing sizing method is an iterative procedure that follows the steps detailed below (Guo 1999b).

1. Select Location: The detention facility's location must be based upon criteria developed for the specific project. Regional storage facilities are normally placed where they provide the greatest overall benefit. Multi-use objectives (e.g. use of the detention facility as a park or for open space, preserving or providing wetlands and/or wildlife habitat, or others uses and community needs) influence the location, geometry, and nature of these facilities.

2. Determine Hydrology: Determine the inflow hydrograph to the storage basin and the allowable peak discharge from the basin for the design storm events. The hydrograph may be available in City's published Master Drainage Plans or other basin-wide studies. The allowable peak discharge is limited by the local criteria or by the requirements spelled out in the City-approved Master Drainage Plan.

3. Initial Storage Volume Sizing: It is recommended that the initial size of the detention storage volume be estimated using the modified FAA method described in Section 3.2.3 or the hydrograph volumetric method detailed in Section 3.4.1.

4. Initial Shaping of the Facility: The initial shape of the facility must be based upon site constraints and other goals for its use discussed under item 1, above. This initial shaping is needed to develop a stage-storage-discharge relationship for the facility. The design spreadsheets of this Manual are useful for initial sizing.

5. Outlet Works Preliminary Design: The initial design of the outlet works entails balancing the initial geometry of the facility against the allowable release rates and available volumes for each stage of hydrologic control. This step requires the sizing of outlet elements such as a perforated plate for controlling the releases of the WQCV, orifices, weirs, outlet pipe, spillways, etc.

6. Preliminary Design: A preliminary design of the overall detention storage facility must be completed using the results of steps 3, 4 and 5, above. The preliminary design phase is an iterative procedure where the size and shape of the basin and the outlet works are checked using a reservoir routing procedure and then modified as needed to meet the design goals. The modified design is then checked again using the reservoir routing and further modified if needed. Though termed "preliminary design," the storage volume and nature and sizes of the outlet works are essentially in final form after completing this stage of the design. They may be modified, if necessary, during the final design phase.

7. Final Design: The final design phase of the storage facility is completed after the hydraulic design has been finalized. This phase includes structural design of the outlet structure, embankment design, site grading, a vegetation plan, accounting for public safety, spillway sizing and assessment of dam safety issues, etc.

(14) *Section 4.3* is amended to read as follows:

4.3 Geometry of Storage Facilities

(a) The geometry of a storage facility depends on specific site conditions such as adjoining land uses, topography, geology, preserving or creating wildlife habitat, volume requirements, etc. Several key features must be incorporated in all storage facilities located within the City (see Figure SO-6). These include:

i. Four to one (4H : 1V) or flatter side slopes of all banks.

ii. Low-flow or trickle-flow channel unless a permanent pool takes its place or the pond is designed to handle low flows through infiltration.
iii. Forebay.
iv. Pond bottom sloped at least one percent to drain toward the low-flow or trickle-flow channel or the outlet.
v. Emergency spillway or fortification of the embankment to prevent catastrophic failure when overtopped, spillway shall be designed to safely convey the 100-year overtopping discharge for the entire area tributary to the storage facility.
vi. The micro pool surface elevation must be set at an elevation equal to the invert of the pond which results in the value of D_{MP} being set at 0 ($D_{MP} = 0$) as shown in Figure SO-6 of this Manual.

(b) For safety as well as maintenance considerations, the maximum allowable ponding depth of water in a detention storage facility during the 100-year, 2-hour storm event is ten (10) feet.

(c) Detention storage facilities must be located at least twenty (20) feet away from an irrigation canal or ditch. Whenever a detention pond parallels a canal no more than twenty percent (20%) of the detention pond perimeter can be parallel to the irrigation canal.

(d) In ponds that contain a littoral zone, the littoral zone should be very flat (i.e. 40H:1V or flatter) with the depth ranging from six (6) inches near the shore and extending to no more than twelve (12) inches at the furthest point from the shore.

(e) For more detailed guidance regarding pond shaping and geometry please refer to the document titled “Detention Pond Landscape Standards and Guidelines” dated November 2009 included as an addendum to this Manual.

(15) *Section 4.8* is amended to read as follows:

4.8 Trash Racks

Trash racks must be of sufficient size such that they do not interfere with the hydraulic capacity of the outlet. See Figure SO-7 for minimum trash rack sizes. Trash racks must be designed in accordance with the specifications set forth in Volume 2, Chapter 9, Culverts, Section 8.3, “Grate Specifications” and with the City’s Water Utilities Development Construction Standards.

(16) *Section 4.9* is amended to read as follows:

4.9 Landscaping

Detention storage facilities must be landscaped to provide a water quality benefit as well as an aesthetically pleasing amenity. Landscaping should be accomplished with native vegetation whenever possible to reduce the amount of irrigation required after establishment**.** All detention ponds must be designed and constructed in accordance with the “Detention Pond Landscaping Standards and Guidelines” dated November 2009 included as an addendum to this Manual.

(17) *Section 4.10* is amended to read as follows:

4.10 Operation and Maintenance

The performance and reliability of detention storage facilities can be reduced by natural and man-made debris, as well as natural and man-induced sedimentation. These can, over a period of time, reduce the storage capacity of a detention basin and thereby reduce the degree of flood protection provided. The obstruction of outflow conduits by debris and sediment can reduce outlet capacity and cause the premature filling of the detention basin with stormwater, again reducing the flood protection provided by the structure. Consequently, adequate care must be exercised in design to provide for protection of the outlet works from debris and for the control and regular removal of sedimentation in the basin.

Maintenance requirements during design include the following:

1. Use of flat side slopes along the banks and the installation of landscaping (thick, thorny shrubs) that will discourage entry along the periphery near the outlets and steeper embankment sections are advisable. Use of a safety railing at vertical or steeper than four to one structural faces is required to promote public safety. If the impoundment is situated at a lower grade than, and adjacent to a highway, installation of a guardrail is in order. Providing features to discourage public access to the inlet and outlet areas of the facility must be considered.
2. The facility must be accessible to maintenance equipment for removal of silt and debris and for repair of damages that may occur over time. Easements and/or rights-of-way are required to allow access to the impoundment by the owner or agency responsible for maintenance.
3. Bank slopes, bank protection needs, and vegetation types are important design elements for site aesthetics and maintainability.
4. Permanent ponds must have provisions for complete drainage for sediment removal or other maintenance. The frequency of sediment removal will vary among facilities, depending on the original volume set aside for sediment, the rate of accumulation, rate of growth of vegetation, drainage area erosion control measures, and the desired aesthetic appearance of the pond.
5. For facilities designed for multipurpose use, especially those intended for active recreation, the play area might need special consideration during design to minimize the frequency and periods of inundation and wet conditions. It may be advisable to provide an underground tile drainage system if active recreation is contemplated.
6. Adequate dissolved oxygen supply in ponds (to minimize odors and other nuisances) can be maintained by artificial aeration. Use of fertilizer and EPA approved pesticides and herbicides adjacent to the permanent pool pond and within the detention basin must comply with all State and Federal regulations.
7. Secondary uses that would be incompatible with sediment deposits should not be planned unless a high level of maintenance will be provided.
8. French drains or the equivalent are almost impossible to maintain, and should be used with discretion where sediment loads are apt to be high.
9. Underground tanks or conduits designed for detention should be sized and designed to permit pumping or multiple entrance points to remove accumulated sediment and trash.
10. All detention facilities should be designed with sufficient depth to allow accumulation of sediment for several years prior to its removal.
11. Permanent pools should be of sufficient depth to discourage excessive aquatic vegetation on the bottom of the basin, unless specifically provided for water quality purposes.
12. Often designers use trash racks and/or fences to minimize hazards. These may become trap debris, impede flows, hinder maintenance, and, consequently, fail to prevent access to the outlet. On the other hand, desirable conditions can be achieved through careful design and positioning of the structure, as well as through landscaping that will discourage access (e.g., positioning the outlet away

from the embankment when the permanent pool is present, etc.). Creative designs, integrated with innovative landscaping, can be safe and can also enhance the appearance of the outlet and pond. Such designs often are less expensive initially.

13. To reduce maintenance and avoid operational problems, outlet structures should be designed with no moving parts (i.e., use only pipes, orifices, and weirs). Manually and/or electrically operated gates should be avoided. To reduce maintenance, outlets should be designed with openings as large as possible, compatible with the depth-discharge relationships desired and with water quality, safety, and aesthetic objectives in mind. One way of doing this is to use a larger outlet pipe and to construct orifice(s) in the headwall to reduce outflow rates. Outlets should be robustly designed to lessen the chances of damage from debris or vandalism. Avoid the use of thin steel plates as sharp-crested weirs to help prevent potential accidents, especially with children. Trash/safety racks must protect all outlets.
14. Clean out all forebays and sediment traps on a regular basis or when routine inspection shows them to be a quarter to half full.
15. For all landscaped storage facilities the minimum amount of biodegradable, nontoxic fertilizers and herbicides needed shall be used to maintain the facility. All landscape debris must be collected and disposed of off-site.
16. All detention facilities must be designed to minimize required maintenance and to allow access by equipment and workers to perform maintenance. The City will generally maintain regional facilities and facilities on public lands. Maintenance responsibility for facilities located on private land shall be the responsibility of the property owner.
17. The entire detention basin including all appurtenances necessary for the operation and maintenance of the detention facility and the area within the required freeboard for the detention storage must be within a dedicated drainage easement.
18. All detention ponds with a water ponding depth of over four (4) feet must have a water depth gauge. The depth gauge must be referenced to the deepest point in the pond. The numbers on the gauge shall be visible from the detention pond access point or the nearest street.

See Volume 3 of this Manual for additional requirements regarding operation and maintenance of water quality-related facilities, some of which also apply to detention facilities designed to meet other objectives.

(18) *Section 4.11* is amended to read as follows:

4.11 Access

(a) An all-weather stable maintenance access must be provided to the bottom of detention ponds. The surface of this maintenance access shall constitute a solid driving surface of gravel, rock, concrete, or gravel-stabilized turf and should allow maintenance access to the inflow forebay, and the outlet works areas. Maximum grades for equipment access shall be no steeper than ten percent. For ponds less than one acre-foot in volume, access may be allowed from an adjacent drivable surface that is not within the detention pond area as long as equipment can safely reach and maintain all of the facility’s features and appurtenances.

(b) When detention storage facilities abut private property, it is the responsibility of the parties involved to develop and implement a policy regarding fencing and safety.

(19) A new *Section 4.14* is added, to read as follows:

4.14 Trickle Channels in Storage Facilities

(a) Measures must be taken to control standing water and to control nuisance flows. Detention basin bottoms are recommended to have a minimum cross slope (measured perpendicular to the trickle channel) of two percent for grassed surfaces and one percent for pavement surfaces where possible. For cross slopes less than these please refer to the detailed guidance provided regarding the appropriateness of the use of trickle channels in the addendum to this Manual titled “Detention Pond Landscape Standards and Guidelines” dated November 2009.

(b) Whenever trickle channels are called for these must be designed to carry approximately one percent of the 100-year design flow with a minimum longitudinal slope of half a percent.

(20) A new *Section 4.15* is added, to read as follows:

<u>4.15 Detention Ponds in Parking Areas</u>

(a) The maximum permissible detention pond depth within parking areas is twelve (12) inches.

(b) For commercial properties an exception may be granted by the Utilities Executive Director or his designee for ponding depths of up to eighteen (18) inches, if the percentage of spaces with ponding depths of greater than twelve (12) inches is less than twenty-five percent (25%) of the total parking spaces provided.

(c) In all circumstances, one foot of freeboard must be provided between the high water elevation and the minimum opening elevations of adjacent buildings.

(d) If a water quality detention is included in a parking lot detention pond, the water quality portion of the total detention volume must be located in vegetated areas not on pavement.

(21) A new *Section 4.16* added, to read as follows:

<u>4.16 Underground Detention</u>

The use of underground detention is generally discouraged. Underground BMPs should not be considered for detention storage when surface-based systems are practicable**.** For most areas of new urban development or significant redevelopment, it is feasible and desirable to provide the required storage on the surface. The responsible party must demonstrate that surface-based detention or other BMPs have been thoroughly evaluated and found to be infeasible before an underground system is proposed. In the event where an underground storage system is proposed, a written request for approval of such a system must be submitted by the Owner describing the system in detailing. The Utilities Executive Director may approve such a system upon a determination that the requirements of this provision have been met and that no adverse impacts are expected to result from the proposed system. For any underground detention, runoff must flow through a pre-treatment facility before it enters the underground detention facility. A standard operating procedures manual must be submitted and approved by the City for all underground facilities. A final copy of the approved standard operating procedures manual must be provided to City and must be maintained on-site by the entity responsible for the facility maintenance. Annual reports must also be prepared and submitted to the City discussing the results of the maintenance program (i.e. inspection dates, inspection frequency, volume loss due to sedimentation, corrective actions taken, etc.).

(22) A new *Section 4.17* is added, to read as follows:

<u>4.17 Rooftop Detention</u>

The use of rooftop detention is prohibited.

(23) A new *Section 4.18* is added, to read as follows:

<u>4.18 On-Stream Storage Facilities</u>

The use of on-stream detention is strongly discouraged. Off-stream detention is the preferred detention storage method in the City. On-stream detention locates the detention facility on a drainageway that collects runoff from the upstream watershed and flows through the proposed development site. The on-stream facility will treat runoff from the proposed development site and runoff generated further upstream from off-site areas. An off-stream storage facility collects and treats runoff from the proposed development site before entering the drainageway. Off-site flow is conveyed by the drainageway through the proposed development site without treatment.

(24) A new *Section 4.19* is added, to read as follows:

4.19 Spill Control for Gas Stations and Vehicle Maintenance Facilities

Spill control structures are required for all new and redeveloping gas stations and vehicle maintenance facilities. In addition to emergency spill response procedures, such as the use of absorbent booms, structural spill controls must be used to protect creeks and tributaries from petroleum products and other pollutants that are stored and handled at gas stations and vehicle maintenance facilities. The spill control structure must have a minimum capacity of 150 gallons.

(25) *Section 5.0* is deleted in its entirety.

(26) *Section 6.1* is deleted in its entirety.

(27) *Table SO-1* is deleted in its entirety.

(28) *Figure SO-8* is deleted in its entirety