# 7. Stormwater Detention

## 7.1 General

This section provides guidance on stormwater runoff storage for meeting stormwater management control requirements (i.e., water quality treatment, downstream channel protection, overbank flood protection, and extreme flood protection).

Stormwater detention within a stormwater management system is essential to provide the required flow reduction for water quality treatment and downstream channel protection, as well as for peak flow attenuation of larger flows for overbank and extreme flood protection. Runoff storage can be provided within an on-site system through the use of structural stormwater controls and/or nonstructural features and landscaped areas. Additional design guidance is provided in Chapter 8, Water Quality.

## 7.2 Method of Evaluation

Pre-development and post-development runoff shall be calculated to evaluate the use of stormwater detention. Runoff shall be evaluated for the 2-, 5-, 10-, 25-, 50-, and 100-year 24-hour storm events. For areas less than 20 acres, the Modified Rational Method may be used to evaluate pre-development and post-development runoff conditions. Areas greater than 20 acres shall be evaluated using the SCS TR-55 Method.

If another method is used, the Owner's Engineer shall submit the proposed method of evaluation for the sizing of the retention basin or detention basin to the City Design Review Engineer. The method will be evaluated for professional acceptance, applicability, and reliability by the City Design Review Engineer. No detailed review will be rendered before the method of evaluation of the retention or detention basin is approved.

### 7.2.1 The Modified Rational Method

The Modified Rational Method uses the peak flow calculating capability of the Rational Method paired with assumptions about the inflow and outflow hydrographs to compute an approximation of storage volumes for simple detention calculations. This approach has many variations. Figure 7.0 illustrates one application. The rising and falling limbs of the inflow hydrograph have a duration equal to the time of concentration ($t_c$). An allowable peak outflow is set ($Q_a$) based on pre-development conditions. The storm duration is $t_d$ and is varied until the storage volume (shaded gray area) is maximized.

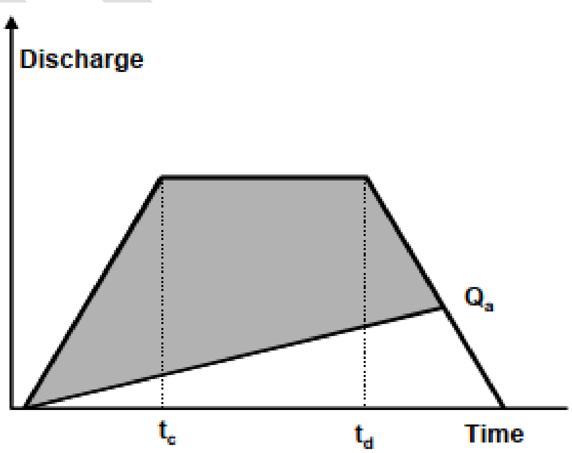


*Figure 7.0. Modified Rational Definitions*

The peak runoff rate can be determined from:

$$q_{pi} = C_a\, i\, A \qquad \textbf{Eq. 7.0}$$

Where: $q_{pi}$ = peak runoff from site (cfs)

$C_a$ = predevelopment Rational Method runoff coefficient

i = rainfall intensity for the corresponding time of concentration (in/hr)

A = area (acres)

It is assumed the peak of the outflow hydrograph falls on the recession limb of the inflow hydrograph and the rising limb of the outflow hydrograph can be approximated by a straight line.

The storage volume is determined by the critical (inflow) duration and using a constant outfall release rate. With these assumptions:

$$S_d = q_{pi} t_d - \frac{Q_a(t_d + t_c)}{2} \qquad \textbf{Eq. 7.1}$$

Where: $S_d$ = detention volume required ($ft^3$)

Qa = allowable peak (pre-development) outflow rate (cfs)

td = design storm duration (sec)

tc = time of concentration for the watershed (sec)

The design storm duration is the duration that maximizes the detention storage volume, $S_d$, for a given return period. The storm duration can be found by trial and error using rainfall data from NOAA Atlas 14. This is normally an iterative process done by hand or with a spreadsheet. Software such as HydraFlow Hydrographs will compute storm durations and determine the estimated volume for a storm event. Downstream analysis is not possible with this method, as only approximate graphical routing takes place.

### 7.2.2 Flood Routing

The most commonly used method for calculating detention basin volume is to route an inflow hydrograph through a detention pond utilizing the Storage Indication or modified Puls method. This method compares the difference in the average values of two closely spaced inflows and outflows, yielding the change in storage over a given time period. By continuing this process for the duration of the storm and beyond, the total required storage for the basin can be determined. This is the methodology utilized by HEC-HMS, WinTR-55, and other hydrology software and can also be completed through the use of a spreadsheet. A detailed description of the manual process for routing a storm through a detention basin is presented in Chapter 8 of FHWA's HEC-22.

## 7.3 Detention Volume

The detention volume calculated using the Modified Rational method should not be used for final design. The final design should be verified by using HEC-HMS or equivalent software to route the inflow hydrograph and determine if the proposed volume is adequate.

The volume of the basin is determined by developing a hydrograph and routing the design storm through the basin. If the design storm can be routed through the basin without overtopping or exceeding the freeboard requirements, the basin volume is adequate. If the routing procedure indicates the storage elevation of the basin exceeds the freeboard requirements or overtops the basin, additional volume in the basin is required.

The final design of a detention facility requires three items:

- an inflow hydrograph
- a stage vs. storage curve
- a stage vs. discharge curve

1. To check the capacity of a basin with a known volume, use the methods described in the previous sections.
   a. Develop an inflow hydrograph for the storm in question.
   b. Develop the stage-storage and stage-discharge curves for the basin.
   c. Route the storm through the basin to determine the outflow hydrograph. Check the peak of the outflow hydrograph to ensure that it does not exceed the allowable value. Also, check the peak storage volume to ensure that it does not exceed the capacity of the basin.

2. Analyzing a known basin utilizing the methods developed in the previous sections is relatively straightforward. However, determining the required size of a proposed basin is an iterative process, and can be quite time consuming without a method to develop a preliminary volume estimate. TR-55 provides a method for determining quick estimates of detention basin volumes.

   a. Figure 7.1 relates two ratios: peak outflow to peak inflow ($q_o/q_i$) and storage volume to runoff volume ($V_s/V_r$). The value for $q_i$ is determined by the peak of the inflow hydrograph. The value for $q_o$ is normally dictated by the allowable release rate. The volume of runoff can be calculated by the SCS method or tabular hydrograph method. The relationships in Figure 7.1 were determined on the basis of single stage outflow devices. Some were controlled by pipe flow, others by weir flow. Verification runs were made using multiple stage outflow devices, and the variance was similar to that in the base data.

   b. The method can therefore be used for both single- and multiple-stage outflow devices. The only constraints are that:
      1) Each stage requires a design storm and a computation of the storage required for it.
      2) The discharge of the upper stage(s) includes the discharge of the lower stage(s).

   c. The brevity of the procedure allows the designer to examine many combinations of detention basins. When combined with the Tabular Hydrograph Method, the procedure's usefulness is increased. Its principal use is to develop preliminary indications of storage adequacy.

      This estimating technique becomes less accurate as the $q_o/q_i$ ratio approaches the limits shown in Figure 7.1. The curves in Figure 7.1 depend on the relationship among available storage, outflow device, inflow volume, and shape of the inflow hydrograph. When the storage volume ($V_s$) required is small, the shape of the outflow hydrograph is sensitive to the rate of the inflow hydrograph. Conversely, when $V_s$ is large, the inflow hydrograph shape has little effect on the outflow hydrograph. In such instances, the outflow hydrograph is controlled by the hydraulics of the outflow device and the procedure therefore yields consistent results. When the peak outflow discharge ($q_o$) approaches the peak inflow ($q_i$), the parameters that affect the rate of rise of a hydrograph, such as rainfall volume, curve number, and time of concentration, become especially significant.

The procedure should not be used to perform final design if an error in storage of 25% cannot be tolerated. Figure 7.1 is biased to prevent under sizing of outflow devices, but it may significantly overestimate the required storage capacity. More detailed hydrograph development and routing will often pay for itself through reduced construction costs.

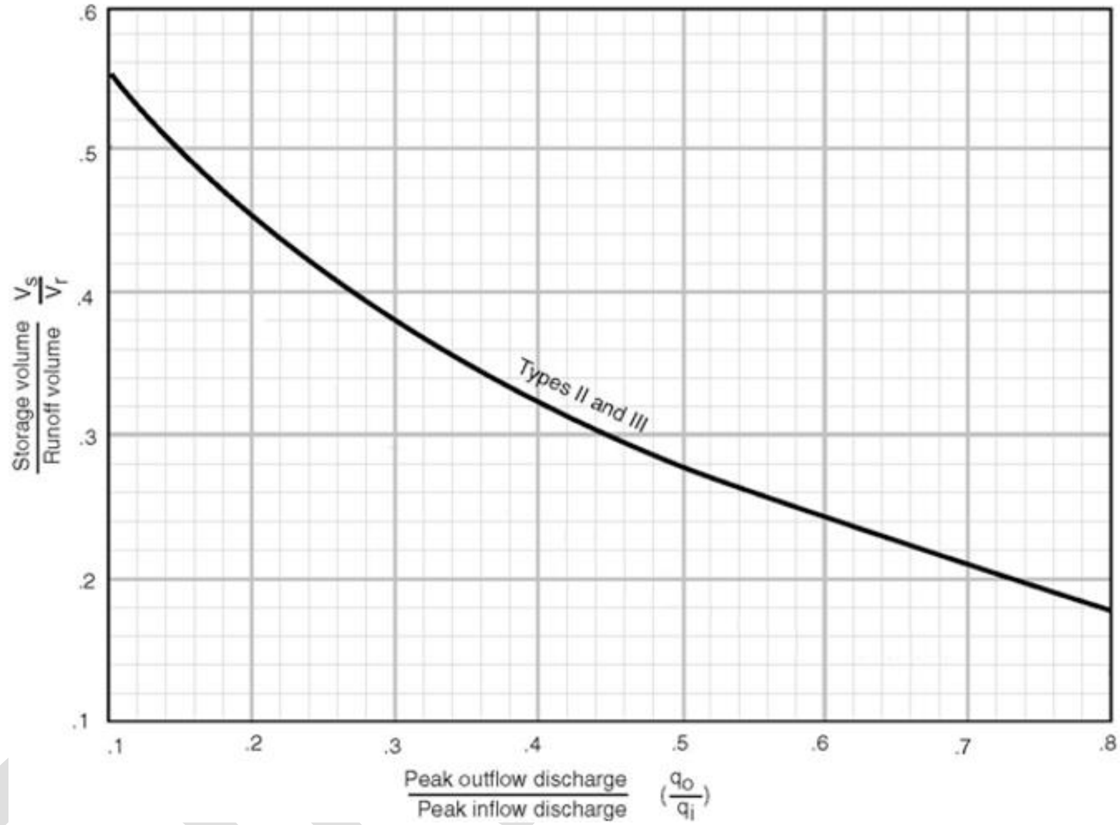


*Figure 7.1. Approximate Detention Basin Routing for Type II and III*

d. The purpose of Figure 7.1 is to provide a starting point for the size of the basin. The process may have to be repeated several times to achieve a basin that has sufficient volume and meets specific inlet and outlet controls.
e. Little Rock falls within the Type II rainfall category.

## 7.4 Methods of detention

Detention storage may be categorized as inline or offline. The City of Little Rock only allows inline storage if it can be demonstrated that offline storage is not practicable. Cost is not a justification to deem a design as not practicable; site constraints or other technical considerations are required for consideration of allowing inline storage. Figure 7.2 illustrates inline versus offline storage.

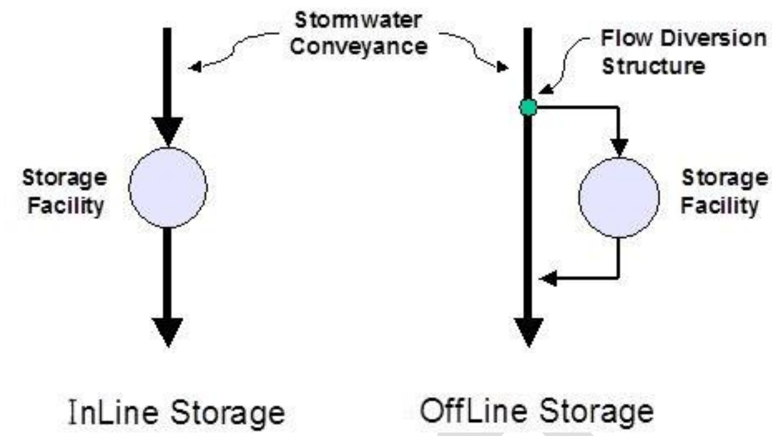


*Figure 7.2. Depiction of inline versus offline storage*

## 7.4.1 Structural Controls Appropriate for Detention

The following sections list the structural control practices appropriate for detention that are approved for use in the City of Little Rock. Mosquito control measures shall be taken for all proposed ponds. Avoid creating areas of shallow stagnant water and low dissolved oxygen which create mosquito habitat. To avoid creating a mosquito habitat, for wet detention, pools of water should be at least 5 feet deep and for dry detention hydraulic residence time should be less than 72 hours.

### 7.4.1.1 Stormwater Ponds

Stormwater ponds (also referred to as *retention ponds*, *wet ponds*, *or wet extended detention ponds*) are constructed stormwater retention basins that have a permanent (dead storage) pool of water throughout the year. They are categorized in this Manual as water quality structural controls and can meet the intent of the water quality criteria, however; they also can provide detention storage to meet the other stormwater criteria (Section 2.1).

In a stormwater pond, a certain design volume of runoff from each rain event is detained and treated in the pool through gravitational settling and biological uptake until it is displaced by runoff from the next storm. The permanent pool also serves to protect deposited sediments from re-suspension. Above the permanent pool level, additional temporary storage (live storage) is provided for runoff quantity control. Stormwater ponds are among the most cost-effective and widely used stormwater practices. A well-designed and landscaped pond can be an aesthetic feature on a development site when planned and located properly.

The most common of stormwater pond designs include the wet pond, the wet extended detention pond, and the micropool extended detention pond. In addition, multiple stormwater ponds can be placed in series or parallel to increase performance or meet site design constraints.

### 7.4.1.2 Stormwater Wetlands

Stormwater wetlands (also referred to as constructed wetlands) are constructed shallow marsh systems that are designed to both treat urban stormwater and control runoff volumes. As stormwater runoff flows through the wetland facility, pollutant removal is achieved through settling and uptake by marsh vegetation.

Stormwater wetlands are categorized as water quality structural controls to meet the water quality criteria, however; they also can provide detention storage to meet the other stormwater criteria (Section 2.1).

Wetlands are an effective stormwater practices in terms of water quality and offer aesthetic value and wildlife habitat. Stormwater wetlands require a continuous base flow or a high-water table to support aquatic vegetation. There are several design variations of the stormwater wetland, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland. These include the shallow wetland, the extended detention shallow wetland, pond/wetland system and pocket wetland.

### 7.4.1.3 Dry Detention / Dry ED Basins

Dry detention and dry extended detention (ED) basins are surface facilities intended to provide for the temporary storage of stormwater runoff to meet the downstream flood protection criteria. These facilities temporarily detain stormwater runoff, releasing the flow over a period of time. They are designed to completely drain following a storm event and are normally dry between rain events.

Both dry detention and dry ED basins provide limited pollutant removal benefits and are not intended for water quality treatment. Detention-only facilities should be used in a treatment train approach with other structural controls to provide water quality treatment.

### 7.4.1.4 Multi-purpose Detention Areas

Multi-purpose detention areas are site areas primarily used for one or more specific activities that are also designed to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. Examples of multi-purpose detention areas include:

- Sports Fields
- Recessed Plazas

Multi-purpose detention areas are normally dry between rain events, and by their nature must be usable for their primary function the majority of the time. As such, multi-purpose detention areas should be used for meeting the downstream flood protection criteria, but not for water quality criteria.

Multi-purpose detention areas should be used in a treatment train approach with other structural controls to provide water quality treatment.

### 7.4.1.5 Underground Detention

Underground detention facilities such as vaults, pipes, tanks, and other subsurface structures are designed to temporarily store stormwater runoff for water quantity control. As with above ground detention ponds, underground detention facilities are designed to drain completely between runoff events, thereby providing storage capacity for subsequent events. Underground detention facilities are intended to control peak flows, limit downstream flooding, and provide some channel protection. However, they provide little, if any, pollutant removal and are susceptible to re-suspension of sediment during subsequent storms.

Underground detention systems serve as an alternative to surface dry detention for stormwater quantity control, particularly for space-limited areas where there is not adequate land for a dry detention basin or multi-purpose detention area. Basic storage design and routing methods are the same as for detention basins except that the bypass for high flows is typically included.

Underground detention facilities may only be used where the hydraulic grade line (HGL) of the existing storm sewer network is low enough to allow adequate drainage to meet City design requirements within 72 hours after any design storm event. Underground detention facilities are not generally intended for water quality treatment and, unless it is specifically accommodated in design, should be used in a treatment train approach with other structural controls to provide water quality treatment. Providing treatment prior to discharging to the underground detention facility will help prevent the underground system from becoming clogged with trash or sediment and significantly reduces the maintenance requirements for the system.

## 7.5 Detention Design Criteria

Stormwater detention systems shall be designed to meet the stormwater sizing criteria described in Section 2.1 and shall provide structural control as needed to meet the pre-development rate for the design storm events.

### 7.5.1 Design Procedure

A general procedure for the design of storage facilities is presented below.

**Step 1** Perform preliminary calculations to evaluate detention storage requirements for the hydrographs as described above in Sections 7.21 and 7.3.

**Step 2** Determine the physical dimensions necessary to hold the estimated volume from Step 1. The maximum storage requirement calculated from Sections 7.21 and 7.3 should be used. From the selected shape determine the maximum depth in the pond. Develop the stage-storage curve for the detention basin.

**Step 3** Select the desired type of outlet and size the outlet structures based on allowable discharges for the design storm events, beginning with outlet structure sizing for the smaller events to the extreme flood event and taking into consideration the tailwater in the receiving stream. The estimated peak stage for each storm event (2-,5-,10-,25-,50-, and 100- year) will occur for the maximum associated volume from Step 2. The outlet structure(s) should be sized to convey the allowable discharge for the corresponding stage for each flood event. The outfall structure shall be designed with appropriate erosion prevention measures.

**Step 4** Perform routing calculations using inflow hydrographs from Step 1 to check the preliminary design using a storage routing computer model.

**Step 5** Evaluate whether the routed post-development peak discharges from the design storms exceed the existing pre-development peak discharges. If so, then revise the dimensions of the pond or outlet device geometry accordingly and repeat Steps 2 through 4 until the post-development peak discharges do not exceed the existing pre-development peak discharges for the watershed.

**Step 6** Evaluate the downstream effects of detention outflows for the 100-year 24-hour storm event to ensure that the routed hydrograph does not cause downstream flooding problems. The outflow hydrograph from the storage facility should be routed through the downstream channel system to a confluence point that reflects no appreciable increase in discharges compared to the pre-development discharges at that location, or to a point designated by the City (see Section 7.5.3).

**Step 7** Evaluate the control structure outlet velocity for all storms and provide channel and bank stabilization if the outlet velocities from any of the design storms will cause erosion problems downstream. Outlet protection shall include checking velocities and ensuring adequate erosion prevention measures to beyond the confluence with the receiving stream channel. Riprap placement or energy dissipater devices may be required. Guidance for riprap sizing and extents of placement and outlet design is provided in Section 6.2.

Routing of hydrographs through storage facilities is critical to the proper design of these facilities. Although storage design procedures using inflow/outflow analysis without routing have been developed, their use is not accepted by the City of Little Rock.

Water quality requirements and the associated Water Quality Protection Volume (WQv) shall be addressed in the design. Details regarding these requirements and the approach that may be used to address them are provided in Chapter 8, Water Quality.

For this Manual, it is assumed that designers will be using one of the many computer programs available for storage routing and thus other procedures and example applications will not be given here.

### 7.5.2 Detention Design Standards

The following conditions and limitations shall be observed in selection and use of the method or type of detention.

#### 7.5.2.1 General

Detention facilities shall be located within the parcel limits of the project under consideration. No detention or ponding will be permitted within public road right-of-ways. Location of detention facilities immediately upstream or downstream of the project will be considered by special request if proper documentation is submitted with reference to practicality, feasibility, and proof of ownership or right-of-use of the area proposed. To be in accordance with design requirements and not exceed pre-development discharges, orifices shall be provided to limit outflows.

#### 7.5.2.2 Dry Detention / Dry ED Basins

Dry detention ponds or dry reservoirs shall be designed with proper safety, stability, and ease of maintenance facilities. Maximum side slopes for grass reservoirs shall not exceed 1-foot vertical for 3-feet horizontal (3:1) unless approved by the City Design Review Engineer. For dry detention ponds, pond bottom slopes must be a minimum of 1% (longitudinal and cross-slope) to ensure positive drainage to outlet works. In no case shall the limits of maximum ponding elevation be closer than 20 feet horizontally from any building and less than 1 foot vertically below the lowest adjacent grade. The entire reservoir area shall be stabilized with vegetation established prior to final approval or issuance of certificate of occupancy unless approved by the Director of Planning and Development. Any area susceptible to, or designed as, overflow by higher design intensity rainfall shall be stabilized with sod or other approved vegetative stabilization practice or paved depending upon the outflow velocity. Plan view and cross-sections with adequate details for any dry detention basins and forebays and dry ED basins shall be provided in the Plans.

#### 7.5.2.3 Stormwater Ponds

Stormwater ponds with fluctuating volume controls may be used as detention areas provided that the limits of maximum ponding elevations are no closer than 50-feet horizontal from any building, are at least 2 feet below the lowest sill or floor elevation of any building, and at least 1 foot below lowest adjacent grade.

Maximum side slopes for the fluctuating area of stormwater ponds shall be l-foot vertical to 3-feet horizontal (3:1) unless provisions are included for safety, stability, and ease of maintenance. Safety railing or other safety measures such as a shallow shelf shall be provided for ponds located in residential areas. All stormwater ponds shall include a sediment forebay at the inflow to the basin to allow heavier sediments to drop out of suspension before runoff enters the permanent pool. Sediment forebays shall be located at each point where piping or other conveyances discharge into the stormwater pond. Forebays shall be located such that they are accessible by maintenance equipment. Forebays shall be designed with adequate depth (preferably 4 to 6 feet to dissipate turbulent inflow - lesser design depths may be justified with supporting velocity computations) and volume to dissipate the energy of incoming stormwater flows and allow coarse-grained sediments and particulates to settle out of the runoff. The sediment forebay should be sized to accommodate 0.25 inches of runoff per contributing on-site impervious acre of drainage area and should allow flow to exit the forebay at non-erosive velocities from the 1-year to 10-year 24-hour storm events. The forebay may be included as part of the required volume for detention with permanent pools.

The entire fluctuating area of the permanent reservoir shall be stabilized with vegetation established prior to final approval or issuance of certificate of occupancy unless approved by the Director of Planning and Development. Also, calculations must be provided to ensure adequate "live storage" is provided for the difference between the post- and pre-developed 100-year, 24-hour storm. Any area susceptible to or designed as overflow by higher design intensity rainfall (100-year frequency) shall be sodded, stabilized with an approved vegetative stabilization practice, or paved, depending on the design velocities. An engineering analysis shall be furnished of any proposed earthen dam or embankment configuration, with appropriate geotechnical testing and computations. Earthen dam structures shall be designed by an Arkansas Licensed Professional Engineer. Plan view and cross-sections with adequate details for any stormwater ponds shall be provided in the Construction Plans. Detention basin embankment shall have a minimum 10-foot crown width.

### 7.5.2.4 Low Impact Development Practices

Low impact development (LID) practices can help reduce the peak flow of stormwater leaving the site. If LID practices are used on the project, they should be used upstream of any proposed detention facility. This will potentially result in reducing the quantity of stormwater necessary to be detained. Refer to Chapter 8, section 8.2 for detailed design requirements for LID practices and for the approach to adjust peak discharges, where appropriate, based on implementation of LID features.

### 7.5.2.5 Other Methods

If other methods of detention are proposed, proper documentation of hydrologic and hydraulic calculations, soil data, percolation, geological features, etc., will be needed for review and consideration.

### 7.5.2.6 Outlet Works

Detention facilities shall be provided with effective outlet works. Flows shall be limited to pre-development rates for the design storm events.

Safety considerations shall be an integral part of the design of all outlet works. Plan view and sections of the structure with adequate construction details shall be included in Plans.

Overflow openings are required for all ponds. The overflow opening shall be designed to accept the fully urbanized 100-year flood event assuming blockage of the closed conduit portion of the outlet works with 6 inches of freeboard. Spillway requirements must also meet all appropriate state and federal criteria. Design calculations shall be included for all spillways.

### 7.5.2.7 Discharge Systems

Existing upstream detention structures may be accounted for in design. Field investigations and hydrologic analysis shall be performed to substantiate benefits. A field survey of the existing physical characteristics of both the outlet structure and ponding volume shall be performed. A comprehensive hydrologic analysis shall be performed that simulates the attenuation of the contributing area ponds. This should not be limited to a linear additive analysis, but rather should consist of a network of hydrographs that considers incremental timing of discharge and potential coincidence of outlet peaks.

### 7.5.2.8 Ownership of Stormwater Detention Ponds

Ownership of stormwater detention ponds that are not dedicated by the City of Little Rock shall be vested in the property owner.

The City will not process the Final Plat if all the drainage features are not complete. No alteration of the drainage system will be allowed without the approval of the Design Review Engineer.

### 7.5.2.9 Easements

Easements shall be provided on the plans for detention facilities. A minimum 20-feet wide drainage easement shall be provided along the reservoir area, providing vehicular access to the facility, and connecting the tributary pipes and the discharge system along the most passable route, when the discharge system is part of the public drainage system.

### 7.5.2.10 Maintenance

Detention facilities, when required, are to be built in conjunction with storm sewer installation and/or grading. Since these facilities are intended to control increased runoff, they must be partially or fully operational soon after the clearing of the vegetation. During project construction, silt and debris shall be removed as needed from the detention area and control structure(s) after each storm event to maintain the storage capacity of the facility.

Post-construction maintenance of detention facilities is divided into two components. The first is long-term maintenance that involves removal of sediment from the basin and outlet control structure. Maintenance to an outlet structure is minimal with proper initial design of permanent concrete or pipe structures. Studies indicate that in developing areas, basin cleaning by front-end loader or grader is estimated to be needed once every 5 to 10 years.

Annual maintenance is the second component and is the responsibility of the developer or association throughout the construction phases and of the pond owner in perpetuity after acceptance of the final plat or filing of the last subdivision phase that substantially adds stormwater to a detention basin.

These items include:

1. Minor dirt and mud removal,
2. Outlet cleaning,
3. Mowing,
4. Herbicide spraying (in strict conformance with the City's policies and procedures),

5. Litter control, and
6. Forebay cleaning (where applicable)

The responsibility for maintenance of the detention facilities and single-lot development projects shall remain with the general contractor until final inspection of the development is performed and approved, and a legal occupancy permit is issued. After legal occupancy of the project, the maintenance of detention facilities shall be vested with the owner of the detention pond.

## 7.5.3 Downstream Hydrologic Assessment

### 7.5.3.1 Introduction

The purpose of the overbank flood protection and extreme flood protection criteria is to protect downstream properties from increases in flood hazard due to upstream development. These criteria require the designer to control peak flow at the outlet of a site such that post-development peak discharge equals pre- development peak discharge. In certain cases, this does not always provide effective water quantity control downstream from the site and may exacerbate flooding problems downstream. The reasons for this have to do with the timing of the flow peaks, and the total increase in volume of runoff. This section outlines the procedure for determining the impacts of post-development stormwater peak flows and volumes on downstream flows. For sites less than 20 acres a downstream assessment is not required, however the site still must meet the pre-development discharge rates.

### 7.5.3.2 Reasons for Downstream Problems

**Flow Timing**
If water quantity control (detention) structures are indiscriminately placed in a watershed and changes to the flow timing are not considered, the structural control may increase the peak discharge downstream. The reason for this may be seen in Figure 7.3. The peak flow from the site is reduced appropriately, but the timing of the flow is such that the combined detained peak flow (the larger dashed triangle) is higher than if no detention were required. In this case, the shifting of flows to a later time brought about by the detention pond makes the downstream flooding worse than if the post-development flows were not detained.

**Increased Volume**
An important impact of new development is an increase in the total runoff volume of flow. Thus, even if the peak flow is effectively attenuated, the longer duration of higher flows due to the increased volume may combine with discharge from downstream tributaries to increase the downstream peak flows. Figure 7.3 illustrates this concept. The figure shows the pre- and post-development hydrographs from a development site (Tributary 1). The post-development runoff hydrograph meets the flood protection criteria (i.e., the post-development peak flow is equal to the pre-development peak flow at the outlet from the site). However, the post-development combined flow at the first downstream tributary (Tributary 2) is higher than pre-development combined flow. This is because the increased volume and timing of runoff from the developed site increases the combined flow and flooding downstream. In this case, the detention volume would have to have been increased to account for the downstream timing of the combined hydrographs to mitigate the impact of the increased runoff volume.

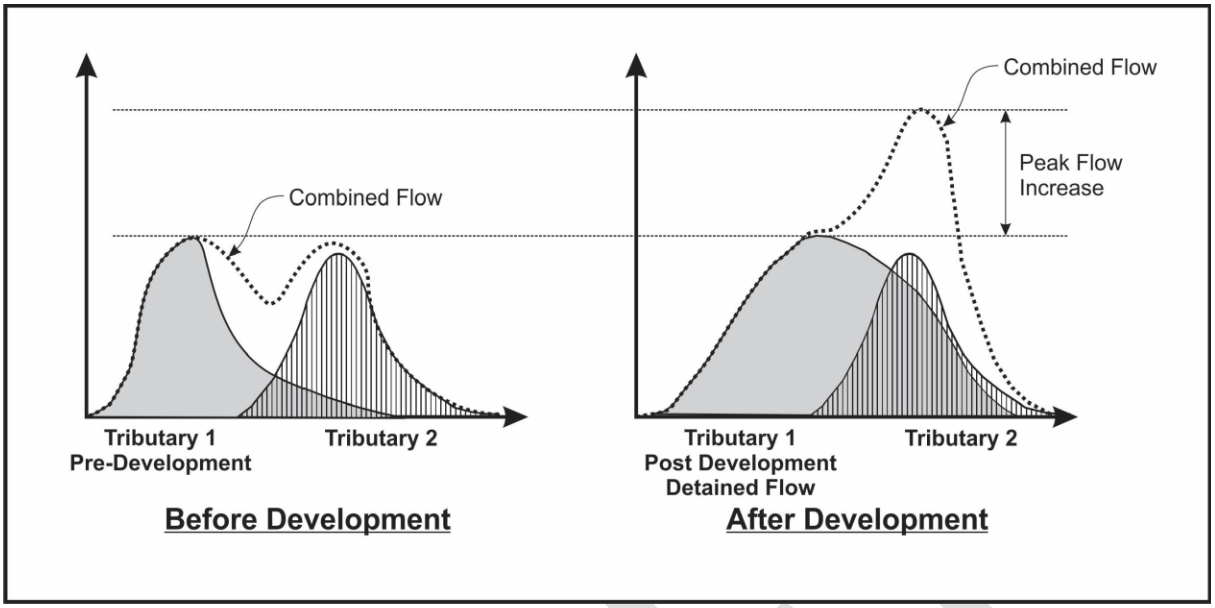


*Figure 7.3. Downstream hydrograph comparison of pre and post development of detention structure.*

### 7.5.3.3 The Ten-Percent Rule

In this Manual the "ten percent" criterion has been adopted as the most flexible and effective approach for ensuring that stormwater quantity detention ponds perform the desired function of maintaining pre-development peak flows throughout the system downstream.

The ten-percent rule recognizes the fact that a structural control providing detention has a "zone of influence" downstream where its effectiveness can be felt. Beyond this zone, the influence of the structural control becomes relatively small and insignificant compared to the runoff from the total drainage area at that point. Based on studies and master planning results for a large number of sites, that zone of influence is considered to be the point where the drainage area controlled by the detention or storage facility comprises 10% of the total drainage area. For example, if the structural control drains 10 acres, the zone of influence ends at the point where the total drainage area is 100 acres or greater. The City Design Review Engineer may assign additional locations for assessment based on locations of known downstream flooding, high erosion potential, downstream development, and channel constrictions.

Typical steps in the application of the ten-percent rule are:

1. Determine the target peak flow for the site for predevelopment conditions.
2. Using a topographic map, assess the anticipated lower limit of the zone of influence (10% point).
3. Using a hydrologic model, to the same level of detail as for site project design, determine the pre- development peak flows and timing of those peaks at each tributary junction beginning at the pond outlet and ending at the next tributary junction beyond the 10% point. The designer shall use hydrologic models obtained from the City of Little Rock or the data therefrom, if available, for the assessment of the downstream subareas.
4. Change the land use on the site to post-development and rerun the model.
5. Design the structural control facility such that the post development peak discharges are not increased above pre-development discharges at the outlet and the determined tributary junctions.

## 7.6 References

Drainage Criteria Manual | Fayetteville, AR - Official Website (fayetteville-ar.gov)

Atlanta Regional Commission, 2001. Georgia Stormwater Management Manual, Volume 1: Chapter 6, Floodplain Management.

Section 2G-1 - General Information for Detention Practices (iastate.edu)
HEC-22, 3rd edition Urban Drainage Design Manual (dot.gov)