SECTION 14
DETENTION FACILITIES

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14.1 INTRODUCTION

The criteria presented in this section shall be used in the design and evaluation of detention facilities. The main purpose of a detention facility is to store the excess storm runoff associated with an increased basin imperviousness due to development and discharge this excess runoff at the runoff rate experienced from the basin without development. The value of such detention facilities is discussed in Section 3.3.6. Any special design conditions and criteria, which are not defined by these CRITERIA, shall be reviewed and approved by the Public Works Director/City Engineer before proceeding with design.

14.2 DETENTION PONDS

All development sites within the CITY shall have an on-site detention pond. All detention facilities, unless designated as regional detention facilities by the CITY, are to be privately owned and maintained.

All detention ponds must have a three-stage outlet structure to control the water quality release rate, the minor storm (5-year) release rate, and the major storm (100-year) release rate.

Two types of detention ponds are allowed by the CITY: grass-lined and parking lot. For a grass-lined detention pond, the entire major storm storage volume is contained within a grassed area. For parking lot detention, the minor storm storage volume and water quality volume is contained within a grassed area while the parking lot can store the additional volume required for the major storm within certain depth criteria.

14.3 DESIGN CRITERIA

14.3.1 Design Frequency

All detention facilities must be designed to detain the water quality, minor storm, and major storm runoff volumes as set forth in Section 3.3.6.

14.3.2 Release Rates

The total maximum runoff rates from a site are given in the following table. These runoff rates are considered to be the "historic" runoff rates. The predominate soil group for the site area shall be used for determining the maximum "historic" runoff rate. Information on the soil types in the CITY can be found in Reference 25.

MAXIMUM "HISTORIC" SITE RUNOFF RATES - CFS/ACRE

CONTROL FREQUENCY	**SOIL GROUP**		
	A	**B**	**C & D**
Water Quality	Refer to MANUAL Volume 3		
5-year	0.07	0.13	0.17
100-year	0.50	0.85	1.00

These "historic" runoff rates are the total maximum runoff rates allowed from the site. If the entire site is not tributary to the on-site detention pond, the on-site detention pond must be modified (i.e. the pond volume must be increased and the release rates must be decreased) to compensate for that portion of the site that the runoff is not detained.

14.3.3 Volume Requirements

All detention facilities must be designed to detain the water quality, minor storm, and major storm site runoff to the "historic" site release rates given in Section 14.3.2. The water quality storage volume may be included in the storage volume available for the major storm but not for the minor storm.

For basins less than 90 acres, the required detention pond storage volumes shall be calculated using the empirical equations or the FAA method as outlined below. For basins greater than 90 acres, hydrograph routing procedures are to be used in the design of the detention ponds.

1. Water Quality Volume

   The water quality volume shall be designed in accordance with the MANUAL. The design water quality volume shall be computed as follows:

   $$\text{Design Volume} = (\text{WQCV}/12) * \text{Area} * 1.2 \qquad (14\text{-}1)$$

   Where: WQCV (watershed inches) = per the MANUAL

   Area = tributary area, acres
   1.2 = multiplier to account for sediment accumulation

2. Empirical Equations for Minor and Major Storm Storage Volumes

   The following empirical equations can only be used if the entire site is tributary to the on-site detention pond.

Minimum Detention Volume:

$$V = KA \qquad (14\text{-}2)$$

For the major storm,

$$K_{100} = (1.78I - 0.002I^2 - 3.56)/1000 \qquad (14\text{-}3)$$

For the minor storm,

$$K_5 = (0.77I - 2.26)/1000 \qquad (14\text{-}4)$$

Where: V = required volume (acre-feet)
I = developed basin imperviousness (%)
A = tributary area (acres)

3. FAA Method for Minor and Major Storm Storage Volumes

If the entire site is not tributary to the on-site detention pond, the pond volume must be increased and the release rate decreased in order to compensate for the undetained site runoff. The maximum pond release rate is calculated as the total site ‘historic’ runoff rate per Section 14.3.2 minus the undetained flowrate. Thus, the peak flow from the entire site meets the ‘historic’ runoff rate criteria.

In order to determine the required detention pond volume, a simplified hydrograph routing procedure is used. Table 1401 presents the form to be used with this procedure. The pond inflow volume is determined; the outflow volume is calculated based on the required pond release rate; the required detention volume is then the difference between the inflow volume and the outflow volume.

14.3.4 Outlet Structure

Two typical detention pond outlet configurations are presented on Figure 1401. Other outlet configurations may be permitted provided they meet the requirements of the permitted release rates and include proper provisions for maintenance and reliability.

As shown on Figure 1401, a Type 1 outlet consists of a water quality control outlet, a grated drop inlet, an outlet pipe, a weir for the major storm, and an emergency spillway. The release rate for the water quality detention is controlled by the water quality outlet with the designed water surface elevation at the crest of the drop inlet box. The minor storm water surface elevation is at the crest of the major storm weir with the minor storm release rate controlled by either an orifice plate or the outlet pipe. An orifice plate at the entrance of the outlet pipe may be required to control the release rate. The outlet pipe must have an adequate slope to ensure throat control in the pipe. The difference in the flow rate between the major storm release rate and the flow released through the minor storm outlet is released through the major storm weir. An emergency spillway is required with sufficient capacity to pass twice the flowrate from the major storm entering the detention facility.

A Type 2 outlet consists of a water quality control outlet, a grated drop inlet with an orifice opening for the minor storm release, an outlet pipe with an orifice plate to control the major storm release, and an emergency spillway. The release rate for the water quality detention is controlled by the water quality outlet with the designed water surface elevation at the invert of the minor storm orifice. The minor storm water surface elevation is at the crest of the drop inlet box with the minor storm release rate controlled by an orifice opening in the drop inlet box. The major storm release is controlled at the throat of the outlet pipe. The outlet pipe must have an adequate slope to ensure throat control in the pipe. The water surface elevation for the major storm is at the crest of the emergency spillway. An emergency spillway is required to pass twice the flowrate from the major storm entering the detention facility.

14.3.5 Hydraulic Design Data

The hydraulic design data for detention facilities outlet works is as follows.

1. Water Quality Outlet

   The water quality outlet shall be designed per the MANUAL.

2. Orifice Flow

   The equation governing the flow through an orifice opening is shown below:

$$Q = C_d A \, (2gh)^{1/2} \qquad (14\text{-}5)$$

   Where:
   Q = discharge (cfs)
   C_d = orifice coefficient
   A = area (ft^2)
   g = gravitational constant (32.2 ft/sec^2)
   h = head on the orifice measured from the centerline of the orifice (ft)

   An orifice coefficient (C_d) value of 0.65 shall be used for the sizing of square edged orifice openings. The minimum orifice opening will be 3-inch diameter or 3-inch rise for non-round openings.

3. Weir Flow

   The flow for horizontal crested weirs is given by the following equation:

$$Q = CLH^{3/2} \qquad (14\text{-}6)$$

Where: Q = discharge (cfs)
C = weir coefficient (see Table 1103)
L = horizontal length (feet)
H = total energy head (feet)

For a v-notch weir, the flow equation is as follows:

$$Q = 2.5 \tan(\theta/2)\, H^{5/2} \qquad (14\text{-}7)$$

Where: θ = angle of the notch at the apex (degrees)
Q = discharge (cfs)
H = total energy head (feet)

When designing or evaluating weir flow, the effects of submergence due to the tailwater condition must be considered. A check on weir submergence can be made by comparing the tailwater elevation to the headwater elevation.

4. Drop Inlet Structure

The drop inlet box shall have a grate on top with a minimum area of no less than twice the required orifice opening. The minimum box dimensions are 3-foot by 3-foot or a 4-foot diameter manhole to provide for construction and maintenance access. The crest of the drop inlet box shall have a sufficient weir length to pass twice the minor storm release rate for the Type 1 outlet structure and twice the major storm release rate for the Type 2 outlet structure. The effective weir length (L) for the crest is the sum of three sides of the drop inlet box or ¾ of the circumference of the manhole. This design ensures that the control of the discharge occurs at the throat of the outlet pipe or orifice.

5. Outlet Pipe

The minimum diameter of the outlet pipe is 15-inches. The outlet pipe shall have adequate slope to ensure that the discharge is controlled at the throat of the pipe. The tailwater conditions of the outlet pipe must be taken into consideration. Erosion protection may be required at the pipe outlet in accordance with Section 12.

6. Major Storm Weir

A spillway for the major storm event is constructed with a Type 1 outlet structure. The conveyance capacity of the weir is limited to the maximum major storm release rate at the design weir depth.

Figure 1402 provides a detail of the typical spillway, which consists of a cut-off wall and buried rip-rap on the downstream embankment. No structures shall be permitted in the flow path of the spillway.

7. Emergency Spillway

Whenever a detention pond uses an embankment to contain water, the embankment shall be protected from catastrophic failure due to overtopping. Overtopping can occur when the pond outlets become obstructed or when a larger than major storm occurs. The emergency spillway shall have a minimum conveyance capacity of twice the major storm flowrate computed entering the detention facility. The crest of the emergency spillway shall be at the water surface elevation for the major storm event.

Figure 1402 provides a detail of the emergency spillway, which consists of a cut-off wall and buried rip-rap on the downstream embankment. No structures shall be permitted in the path of the emergency spillway

8. <u>Trash Racks</u>

Trash racks may be required at the outlet structure as designated by the CITY. Trash racks prevent debris from blocking the outlet structures during a storm event as well as provide a safety barrier. The centralized collection point also created by the trash rack allows for routine cleaning and hauling away of debris, which further protects the outlet structures from blockage during storm events. The design criteria is outlined in Chapter 7.

14.4 DESIGN STANDARDS FOR GRASS-LINED DETENTION PONDS

Table 1402 shall be used to assist in the design of the detention pond.

14.4.1 Depth Requirements

The maximum design depth of ponding in the major storm shall be 5 feet.

14.4.2 Grading Requirements

Slopes on earthen embankments shall not be steeper than 4 (horizontal) to 1 (vertical). All earthen slopes shall be covered with topsoil and re-vegetated with grass. The minimum bottom slope shall be 3.0 percent measured perpendicular to the trickle channel.

Detention ponds, which are designated as a park or other multi-use area, may have additional requirements as determined by the CITY on a case-by-case basis.

14.4.3 Freeboard Requirements

The minimum freeboard is 1.0 foot above the computed water surface elevation for the major storm.

14.4.4 Trickle Channel

All detention ponds shall include a concrete trickle channel. The trickle channel criteria is presented in Section 7.4.2.6. The minimum longitudinal slope of the trickle channel shall be 1.0 percent.

14.4.5 Vegetation Requirements

All detention ponds shall be re-vegetated with either irrigated sod or native grasses in accordance with the Official Development Plan.

14.4.6 Maintenance

Adequate maintenance access and easements will be provided per Section 3.3.7.

14.5 DESIGN STANDARDS FOR PARKING LOT DETENTION

A grass-lined pond area will capture and store the water quality volume and minor storm volume. A parking lot can provide the additional storage volume required for the major storm within certain depth criteria. All of the criteria given in Section 14.4 apply with the following modifications and additions.

14.5.1 Depth Limitation

The maximum allowable design depth of ponding in the parking lot for the major storm shall be 12 inches. The total maximum depth of the pond from the invert elevation of the outlet structure to the water surface elevation for the major storm shall be 5 feet.

14.5.2 Rundown Channel

A curb cut and rundown channel shall be provided to allow the conveyance of the runoff from the parking lot to the pond invert with minimal erosion in the pond bank. The design criteria for the rundown channel is given in Section 7.7.

14.5.3 Maintenance

Maintenance access to the outlet structure shall be provided in accordance with Section 3.3.7. The outlet structure shall be designed to minimize unauthorized modifications.

14.6 DESIGN EXAMPLES

Example 1: Detention Design

Given: A site that has the following characteristics:

Basin Area (A)	26 acres
Basin Imperviousness (I)	55%
Predominate Soil Group	D
Entire site is tributary to the detention pond	

Required: Water quality, minor storm (5-year), and major storm (100-year) storage volumes and release rates.

Solution:

Step 1: Since the entire site is tributary to the pond, the empirical equations can be used. Determine K_{100} using Equation 14-3:

$K_{100} = (1.78I - 0.002I^2 - 3.56)/1000$
$= (1.78(55) - 0.002(55)^2 - 3.56)/1000$
$= 0.0883$

Step 2: Determine K_5 using Equation 14-4:

$K_5 = (0.77I - 2.26)/1000$
$= 0.0401$

Step 3: Determine the minimum required 100-year storage volume using Equation 14-2:

$V_{100} = KA$
$= 0.0883 \times 26$ acres
$= 2.30$ acre-feet $= 100{,}190$ ft^3

Step 4: Determine the minimum required 5-year storage volume:

$V_5 = KA$
$= 0.0401 \times 26$ acres
$= 1.04$ acre-feet $= 45{,}400$ ft^3

Step 5: Determine the maximum allowed 100-year release rate:

$Q_{100} = 1.00\ A$
$= 1.00 \times 26$ acres
$= 26.0$ cfs

Step 6: Determine the maximum allowed 5-year release rate:

$Q_5 = 0.17$ A
$= 0.17 \times 26$ acres
$= 4.4$ cfs

Step 7: Determine the minimum required water quality volume:

WQCV (watershed inches) = 0.14 from the MANUAL

Design Volume = (0.14/12) * 26 acres * 1.2
= 0.4 acre-feet

<u>Example 2</u>: <u>Detention Pond Outlet Structure Design</u>

<u>Given</u>: Site characteristics given in Example 1
Storage volume requirements as per Example 1

Maximum 100-yr release rate	26.0 cfs
Maximum 5-year release rate	4.4 cfs
Type 2 outlet (refer to Figure 1401)	
100-year water surface elevation	106.0
5-year water surface elevation	104.5
Water quality pond elevation	102.5
100-year outlet pipe invert elevation	101.0
5-year outlet orifice invert elevation	102.5
Water Quality outlet orifice invert elevation	101.5
diameter of outlet pipe	24-inch

<u>Required</u>: Sizing of outlet structure

<u>Solution</u>:

Step 1: Determine the 5-year orifice opening size:

Assume the depth to centerline of orifice is 1.5 foot since orifice opening size is unknown.

$A = Q/(C_d\ (2gh)^{1/2})$ (Rearranged Equation 14-4)
$= 4.4/(0.65\ (2(32.2)(1.5))^{1/2})$
$= 0.69\ ft^2$

Step 2: Determine 5-year orifice diameter:

$\text{Diameter} = (4A/3.1416)^{1/2}$
$= (4(0.69)/3.1416)^{1/2}$
= 0.94 feet about 1.0 feet (12-inches)

Check the depth to centerline of orifice assumption:

Depth = (water surface elevation) - (orifice invert elevation) - (half of the rise dimension of the orifice opening)

Depth = 104.5 - 102.5 - 1/2(1) = 1.5 feet

If the depth assumption is incorrect, repeat step 1.

Step 3: Size the orifice plate for 100-year pipe outlet (the pipe outlet is given as a 24" RCP):

Head (h) = 106.0 – 101.0 - 1/2(2) = 4.0 ft

$A = Q/(C_d(2gh)^{1/2})$ (Rearranged Equation 14-4)

$A = 26.0/(0.65)((2(32.2)(4.0))^{1/2})$

$A = 2.49$ ft.^{2}

Step 4: Determine the 100-year orifice diameter:

Diameter = $(4A/3.1416)^{1/2}$

$= ((4)(2.49)/3.1416)^{1/2}$

= 1.8 feet = 22 inches

An orifice plate must be installed on the outlet pipe since the required orifice opening is less than the outlet pipe diameter.

Check the depth to centerline of orifice assumption:

Depth = (water surface elevation) - (orifice invert elevation) - (half of the rise dimension of the orifice opening)

Depth = 106.0 – 101.0 - 1/2(22/12) = 4.1 feet

If the depth assumption is incorrect, repeat step 3.

Step 5: Determine the minimum box dimensions (i.e., weir length) to assure control at the pipe inlet.

$L = 2 \times Q_{weir}/(CH^{3/2})$ (Equation 14-5)

C = 3.4 from Table 1103

H = 100-year water surface – the 5-year water surface (top of drop inlet structure) = 106.0 – 104.5 = 1.5

$L = 2 \times 26/((3.4(1.5)^{3/2})$

L = 8.3 feet

Since required weir length is only 8.3 feet, the minimum box size of 3-feet x 3-feet is selected.

Step 6: Check minimum size for grate opening area:

Minimum area = 2 x 100-year orifice opening area

$= (2)(1.8)$
$= 3.6\ ft.^2$

Since box opening area is 3-ft x 3-ft = 9 sq.ft., then the design requirements for the grate are satisfied.

Step 7: Determine the dimensions of the emergency spillway:

The undetained 100-year flow into the detention pond is 78 cfs.

$L = Q_{weir}/(CH^{3/2})$ (Equation 14-5)
C = 3.4 from Table 1103
Assume a weir head of 1-foot since this is the required freeboard.
$L = 78 / (3.4)(1^{3/2})$
L = 23 feet

Use a weir length of 23 feet for the emergency spillway since the weir length is not excessive. If a shorter weir length was needed, the depth of flow over the weir (the pond freeboard) would be increased.

Step 8: Determine the Water Quality Outlet Perforation Design

Assume water quality storage depth = 1 foot
Required Area per row = 2.5 sq. in. from the MANUAL
Perforation Sizing – 2 columns of 1 ¼ inch holes from the MANUAL

14.7 CHECKLIST

To aid the designer and reviewer, the following checklist has been prepared:

1. Detention pond side-slopes are to be 4:1 or flatter.

2. Minimum freeboard of 1 foot above the major storm water surface elevation is required.

3. Maximum pond depth is 5 feet. Maximum depth of ponding in a parking lot is 12 inches.

4. Detention ponds must include trickle channels.

5. Three-stage outlet structures are to be designed for the water quality, minor storm, and major storm release rates.

6. Emergency spillways must be provided on all detention pond embankments.

7. Provide rundown channels as necessary.

8. Provide trash racks at outlet structures.

9. Provide erosion protection at the outlet of the outlet pipe.

10. Provide maintenance access and required easements.

Table 1401
Detention Pond Sizing
FAA Method

Basin Area = ______ acres
Weighted Runoff Coefficient C_5 (5-year) = ________
Weighted Runoff Coefficient C_{100} (100-year) = _________

Time (min)	5-year Rainfall Intensity (in/hr)	100-year Rainfall Intensity (in/hr)	C x A	Inflow Volume (ft^3)	Release Rate (cfs)	Outflow Volume (ft^3)	Required Detention Volume (ft^3)	Required Detention Volume (ac-ft)
(1)	(2)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
5	4.92	9.48						
10	3.84	7.32						
15	3.24	6.16						
20	2.80	5.45						
25	2.50	4.85						
30	2.24	4.28						
35	2.08	3.95						
40	1.91	3.70						
45	1.78	3.45						
50	1.65	3.22						
55	1.54	3.00						
60	1.42	2.71						

(4) = (3) x (2) x (1) x 60
(5) = allowable detention pond release rate
(6) = (5) x (1) x 60
(7) = (4) –(6)

Table 1402
Detention Pond Volume Determination

Elevation	Surface Area (ac)	Incremental Depth (ft)	Incremental Volume (ac-ft)	Total Volume (ac-ft)
(1)	(2)	(3)	(4)	(5)

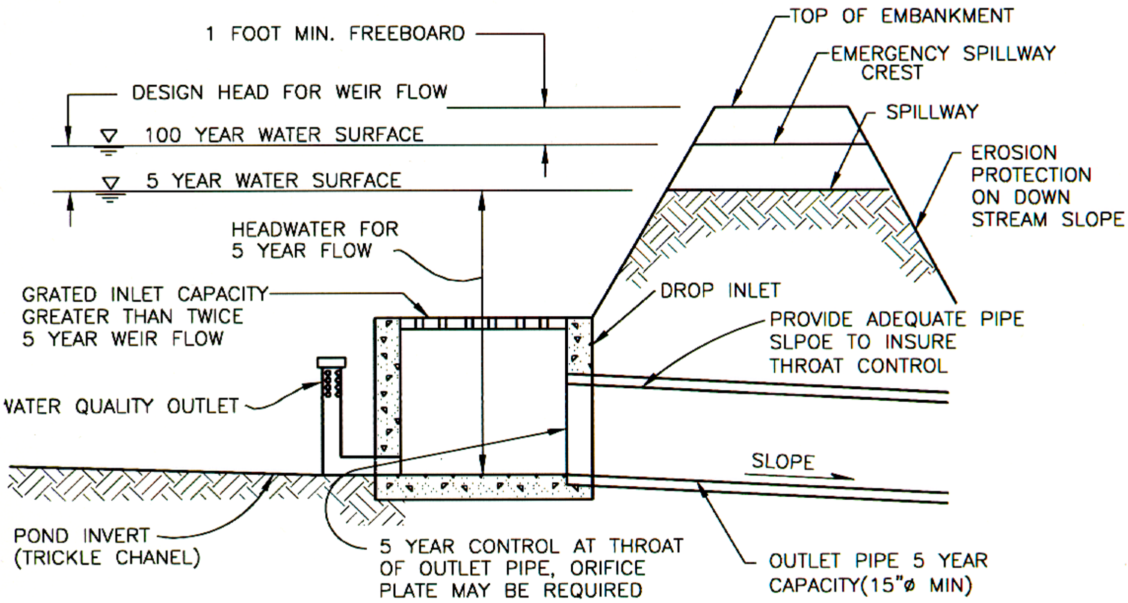
(4) = $((\text{area1} + \text{area2} + (\text{area1} * \text{area2})^{1/2}) * \text{incremental depth}) / 3$

Required Water Quality Pond Volume = ________________
Water Quality Pond Water Surface Elevation = ______________
Water Quality Pond Depth = _____________
Water Quality Release Rate = ____________

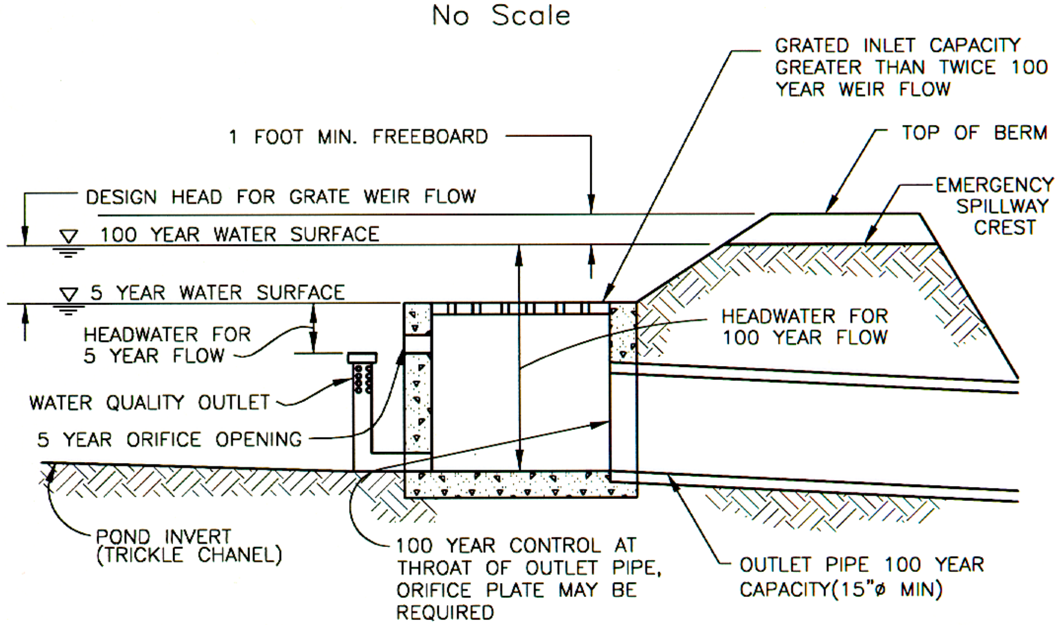
Required Minor Storm Pond Volume = _______________
Minor Storm Water Surface Elevation = ________________
Minor Storm Depth = ________________
Minor Storm Release Rate = ________________

Required Major Storm Pond Volume = ______________
Major Storm Water Surface Elevation = _________________
Major Storm Depth = _________________
Major Storm Depth in parking lot = __________________
Major Storm Release Rate = _______________

Figure 1401
Detention Pond Outlet Configurations



TYPE 1 OULET
No Scale



TYPE 2 OULET
No Scale

Reference: WRC Engineering, Inc.

Figure 1402
Typical Spillway Detail