BOULDER COUNTY
STORM DRAINAGE CRITERIA MANUAL

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CITY OF LONGMONT
STORM DRAINAGE CRITERIA MANUAL

SECTION 1200 DETENTION

1201 INTRODUCTION

The criteria presented in this section shall be used in the design and evaluation of all detention facilities for City of Longmont. The review of all planning submittals (see Section 200) will be based on the criteria presented in this section.

The main purpose of a detention facility is to store the excess storm runoff associated with an increased basin imperviousness and discharge this excess at a rate similar to the rate experienced from the basin without development. The value of such detention facilities is discussed in the POLICY Section 303.5.

The two types of detention facilities defined for use in City of Longmont are described in the POLICY Section 303.5, and are repeated here:

1. Local Detention
   Detention provided to serve only the developing area in question ("onsite" area) and not any of the area outside of the development boundaries ("offsite" area). Local detention is typically parking lot, roof top, or small (less than 1 acre-foot of storage) grassy areas, although the facility can be large for larger development.

2. Regional Detention
   Detention provided to serve both onsite and offsite areas. Regional detention generally is part of a park system or greenbelt area. All detention facilities that received runoff from offsite areas are considered as regional detention.

Also presented in this section, along with the technical criteria, is the general procedure for design and evaluation of both the local detention and regional detention facilities. Any special design conditions which cannot be defined by this criteria shall be reviewed by the City Engineer before proceeding with design.

1202 DESIGN STANDARDS

1202.1 State Engineer's Office

Any dam constructed for the purpose of storing water, with a surface area, volume, and/or dam height as specified in Colorado Revised Statutes 37-87-105, shall require the approval of the plans by the State Engineer's Office. Current legislation may revise these statutes. All detention storage areas shall be designed and constructed in compliance with current state statutes and/or criteria presented herein.

1202.2 Design Frequency

All detention facilities are to be designed for two storm frequencies: the 10-year and the 100-year recurrence interval floods.

A typical drainage system within a subdivision would consist of flow in the storm sewer and allowable flow in the gutter, which combined would carry the flows from the "minor" storm withouth the effects of detention. These flows would be discharged to a larger sewer system or an open channel with capacity for the "major" flood. As the storm intensity increases (i.e., 10-year storm), the onsite detention would reduce the developed flood peaks to "undeveloped" levels thereby allowing the storm sewer/street system to extend its effectivenss to major floods. During calculation of the major storm runoff, the benefits of upstream onsite detention can be accounted for during the routing of flood peaks through the development (see also Section 805).

1202.3 Grading Requirements

Slopes on earthen embankments less than 10-feet in height shall not be steeper than 4 (horizontal) to 1 (vertical). For embankments greater than 10-feet in height, the slopes shall be such to maintain slope stability. Contact the City Engineer for additional requirements. All earthen slopes shall be covered with topsoil and revegetated with grass. Criteria for grasses is given in Section 704.2(7). Slopes on riprapped earthen embankments shall not be steeper than 3 (horizontal) to 1 (vertical). For grassed detention facilities the minimum bottom slope shall be 0.5 percent measured perpendicular to the trickle channel. For parking lot detention, the maximum bottom slope shall be 10 percent.

1202.4 Depth Requirements

The maximum depth from water surface to outlet invert for parking lot detention is 6-inches for the 10-year design and 18-inches for the 100-year design. The maximum depth from water surface to outlet invert for rooftop detention is 3-inches. There is no maximum depth for grassed detention facilities as this parameter will be governed by the site topography.

1202.5 Freeboard Requirements

The minimum required freeboard for grassed and parking lot detention facilities is 1.0-feet above the computed 100-year water surface elevation. The minimum required freeboard for rooftop detention is 3-inches above the computed 100-year water surface elevation.

1202.6 Trickle Flow Control

All grassed detention ponds shall include a concrete trickle channel. Trickle flow criteria is presented in Section 704.2.6(a).

1202.7 Outlet Configuration

Presented on Figures-1201, -1202, and -1203 are four examples for detention pond outlet configuration. A Type 1 outlet consists of a grated drop inlet, outlet pipe, and an overflow weir in the pond embankment. The control for the 10-year discharge shall be at the throat of the outlet pipe under the head of water as defined on Figure-1201. The grate must be designed to pass the 10-year flow with a minimum of 50 percent blockage (i.e., twice the 10-year flow). Since the minimum size of the outlet pipe is 18-inches, then a control orifice plate at the entrance of the pipe may be required to control the discharge of the design flow (see Section 1202.8).

The difference between the 100-year and 10-year discharge is released by the overflow weir or spillway. The surcharge on the outlet pipe shall be included in the total discharge when sizing the overflow weir or spillway. If sufficient pond depth is available, the drop inlet and the grate can be replaced by a depressed inlet with a headwall and trashrack. Depression of the inlet is required to reduce nuisance backup of flow into the pond during trickle flows. The maximum trashrack opening dimension shall be equal to the minimum opening in the orifice plate.

A Type 2 outlet consists of a drop inlet with an orifice controlled inlet for the 10-year discharge and a crest overflow and pipe inlet control for the 100-year discharge. The control for the 10-year discharge occurs at the orifice opening for the head as shown on the figure. The control for the 100-year discharge occurs at the throat of the outlet pipe as shown on the figure. However, the difference between the 100-year and 10-year discharge must pass over the weir and therefore the weir must be of adequate length. The effective weir length (L) occurs for three sides of the box. To insure the 100-year control occurs at the throat of the outlet pipe a 50 percent increase in the required weir length is recommended. See Section 703.4.1 for discussion concerning weirs and Table-704 for weir coefficients. In addition, the outlet pipe must have an adequate slope to insure throat control in the pipe.

A Type 3 outlet is similar to the Type 2 outlet except the trashrack covers the entire outlet works. The 10-year and 100-year discharge control points are the same as the control points for the Type 2 outlet.

The Type 4 inlet is designed for use with parking lot detention. The inlet consists of a weir curb opening for 10-year flow control and a weir overflow section for 100-year flow control. The outlet channel shall be riprapped to prevent erosion of the berms and undermining of the curb and asphalt parking lot (see Section 705 for riprap criteria).

1202.8 Embankment Protection

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 100-year storm occurs. Failure protection for the embankment may be provided in the form of a buried heavy riprap layer (Type H, Section 705) on the entire downstream face of the embankment or a separate emergency spillway having a minimum capacity of twice the maximum release rate for the 100-year storm. Structures shall not be permitted in the path of the emergency spillway or overflow. The invert of the emergency spillway should be set equal to or above the 100-year water surface elevation.

1202.9 Hydraulic Design Data

Hydraulic design data for sizing of detention facilities outlet works is discussed in the MANUAL as follows:

1. Weir Flow
   Weir flow requirements and coefficients are located in Section 703.4.1 and Table-704.

2. Orifice Flow
   The orifice flow Equation 1001, located in Section 1004.1, shall be used to size orifice openings and plates. An orifice coefficient (Cd) value of 0.65 shall be used for sizing of orifice openings and plates.

1203 DESIGN CRITERIA

1203.1 Local ("Onsite") Detention

1. Equation Detention Method

The "traditional" method of computing detention storage requirements utilizes the Rational Method to size onsite detention for watersheds that are to small for analysis using the Colorado Urban Hydrograph Procedure (Reference-1). Because of the inexact nature of this procedure, errors can easily occur in determining the appropriate release rate(s) to maintain "historical" or "undeveloped" flow rates. The Urban Drainage and Flood Control District conducted extensive research into this problem. On the basis of its findings, the District developed allowable maximum unit area release rates and minimum volume requirements at these release rates for sizing detention ponds. These results are referred to in this MANUAL as the Equation Detention Method. The method is based on actual modelling results and represents the average of conditions that will be encountered. However, the simplification of the process and the consistency in the detention analysis are considered to compensate for the site specific differences that may occur.

Local detention facilities are to be designed using the "equation detention method" if flows only from the subject property are routed through the detention facility(s). There may be more than one local detention facility on the subject property. If the facilities are sequential (i.e., flows routed from one facility to another), then the sequential detention procedure shall be utilized (1203.1.3). Any undetained runoff shall meet the requirements of Section 1203.1.2.

For the "equation detention method", the minimum required volume and the maximum release rates at the ponding depths corresponding to the volumes shall be determined using the following equations:

Minimum Detention Volume:

$$V = KA \quad (1201)$$

For the 100-year,

$$K_{100} = (1.78I - 0.002I^2 - 3.56)/1000 \quad (1202)$$

For the 10-year,

$$K_{10} = (0.95I - 1.90)/1000 \quad (1203)$$

Where V = required volume for the 100- or 10-year storm (acre-feet)

I = Developed basin imperviousness (%)

A = Tributary area (Acres)

Maximum Release Rates:

$$Q_{100} = 1.00A \qquad (1204)$$

$$Q_{10} = 0.24A \qquad (1205)$$

Where Q-sub 100, Q-sub 10 = release rates for the 100- and 10-year storms respectively (cfs).

An example of the equation detention method is given in Section 1204.1.

2. Compensating Detention Procedure

Local detention facilities are to be designed using the "compensating detention procedure" if any runoff is to flow undetained from the subject property (see Section 1203.3). There may be more than one local detention facility on the site. The compensating detention procedure requires that the total release rates from the detained and undetained areas be equal to the allowable release rates from the total site. Therefore, the more undetained runoff, the less the allowable detention facility release rate. The limit on the undetained area is 5 percent or 5 acres, whichever is less.

Compensating detention is to be computed as follows:

Minimum Detention Volumes:

The minimum detention volumes shall be calculated using Equations 1201 through 1203. The imperviousness and area parameters for the basin contributing the undetained runoff shall be included in the minimum detention volume calculation as if this basin was tributary to the detention facility.

Maximum Release Rates:

The maximum release rates shall be calculated in two steps. First, the allowable release rates from the whole basin (detention and undetained areas) shall be computed using Equations 1204 and 1205. Then, the maximum release rates from the detention facility are set equal to the maximum release rates from the whole site minus the runoff rates from the undetained area. An example of the compensating detention method is given in Section 1204.2.

3. Sequential Detention Procedure

Local detention facilities are to be designed using the "sequential detention procedure" if any storm runoff is detained by two or more detention facilities in sequence before leaving the subject property. The sequential detention method accounts for the inherent decrease in efficiency of two sequential detention facilities versus one facility by considering the released runoff from one facility to be equivalent to runoff from an incremental area tributary to the second facility. Thus, the storage volume of the second facility is increased to accommodate the incremental area runoff. By minimizing the second detention facility's release rate, the volumes of any additional sequential facilities are minimized.

Sequential detention facilities are to be designed using Standard Form SF-11. The form is divided into two parts: Singular Detention and Sequential Dentention. The singular detention part is for listing and computing the parameters associated with a single detention facility. Each facility is analyzed using the "equation detention method" criteria and the "compensating detention procedure" criteria, if required.

The sequential detention part of the form evaluates the combined effect of the detention facilities. The results of the second part computations will yield the minimum volume required and the maximum release rates allowed for each detention facility. The description of Standard Form SF-11 is as follows:

Col. 1: Facility Number: Designated number of the detention facility being analyzed.

Col. 2: Basin Area: Area of basin (sub-basin) tributary to the detention facility not including any area tributary to an upstream detention facility.

Col. 3: (Q-sub I): Peak inflow in cfs from the area described in Column 2.

Col. 4: IMP %: Percent imperviousness of the area described in Column 2 to be used in Equations 1202 and 1203.

Col. 5: K: K-factor calculated from Equations 1202 and 1203 and the percent imperviousness (IMP %) in Column 4.

Col. 6: (Q-sub I/A): Peak inflow (Q-sub I) in Column 3 divided by the area (A) in Column 2.

Col. 7: ΣQ: Peak inflow into detention facility computed by summation of the peak inflow in Column 3 and the maximum release rate from the detention facilities just upstream in Column 10.

Col. 8: Z: Equivalent inflow area computed by dividing Column 7 by Column 6 ($\Sigma Q/(Q_I/A)$).

Col. 9: Minimum S-sub m: Minimum allowed storage volume for the respective detention facility computed using Equation 1201 and the parameters in Column 5 (K-factor) and Column 8 (Z = A).

Col. 10: Maximum Q-sub m: Maximum allowed release rate for the respective detention facility computed using Equations 1204, 1205, and the Z parameter in Column 8.

An example of the sequential detention method is given in Section 1204.3.

1203.2 Regional Detention

Two methods are allowed for calculating the minimum required volumes and maximum allowable release rates for regional detention facilities. The equation detention method and the hydrograph detention method. If the rational runoff method is chosen to calculate the peak runoff from the basin (see Section 600), then the equation method is to be used for determining the storage volumes and release rates for the detention facility. If the CUHP runoff method is chosen, then the hydrograph detention method is to be used to compute the detention facility parameters.

1. Equation Detention Method
The equation detention method uses the equations and methods described in the "Local Detention" Section 1202.1. However, for the detention facility(s) which detain offsite flows, the basin area (A) and percent imperviousness (I) parameters in Equations 1201, 1204, and 1205 are to include the total offsite and onsite area tributary to the detention facility. The required release rates and volumes shall be computed without the benefit of offsite detention (if any) when using the equation detention method.

2. Hydrograph Method
The hydrograph method uses routed hydrographs computed from CUHP to determine the minimum storage volume required for each detention facility. The CUHP hydrographs are routed using the methods discussed in Sections 605 and 606. When including offsite basins that discharge from offsite detention facilities, the CUHP hydrographs are routed through the facilities using the as-built storage volumes and release rates for the facility. The maximum allowable release rates for the onsite detention facilities shall be equal to the CUHP historic peak runoff at the respective design points. The minimum required storage volumes for the onsite detention facilities shall be the storage volumes computed from routing of the CUHP hydrographs with the maximum release rate limited to the historic peak runoff at the respective design points.

1203.3 Detention Method Selection

Presented on Figure-1204 is a detention method selection flowchart. The flowchart is presented as a guide for selection of the applicable detention method(s) for a given site. The flowchart starts with selection of a rainfall/runoff method (Rational versus CUHP) since the selection of this method will determine which detention method(s) may be used. Shown along with the method titles are the MANUAL section numbers where detailed information on the methods is given. Consulting this flowchart should help in the understanding and selection of the proper detention design method.

1204 DESIGN EXAMPLES

1204.1 Equation Detention Method

Example No. 23: Equation Detention Method

Given: A basin that has the following characteristics:

Basin Area (A) = 23 acres

Basin Imperviousness (I) = 55%

Offsite Area = 0 Acres

Undetained Area = 0 acres

One detention facility

Required: 100-year and 10-year storage volumes and release rates.

Solution:

Step 1: Determine K_{100} using Equation 1202

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

$= (1.78\,(55) - 0.002(55)^2 - 3.56)/1000$

$= 0.0883$

Step 2: Determine K_{10} using Equation 1203

$K_{10} = (0.95I - 1.90)/1000$

$= (0.95 \times 55 - 1.90)/1000$

$= 0.0504$

Step 3: Determine minimum required 100-year storage volume using Equation 1201

$V = KA$

$= 0.0883 \times 23$

$= 2.03$ acre-feet (88,500 ft^3)

Step 4: Repeat Step 3 for 10-year storage

$V = KA$

$= 0.0504 \times 23$

$= 1.16$ acre-feet (50,500 ft^3)

Step 5: Determine maximum allowed 100-year release rate

$Q_{100} = 1.00\ A$

$= 1.00 \times 23$

$= 23$ cfs

Step 6: Repeat Step 5 for 10-year release rate

$Q_{10} = 0.24A$

$= 0.24 \times 23$

$= 5.5$ cfs

1204.2 <u>Compensating Detention Method</u>

<u>Example No. 24</u>: <u>Compensating Detention Method</u>

<u>Given</u>: Total Basin Area (A) = 23 acres

Basin Imperviousness = 55%

Offsite Area = 0 acres

Undetained Area = 0.8 acres

10-year Peak Runoff from Undetained Area = 2.4 cfs

100-year Peak Runoff from Undetained Area = 4.2 cfs

One Dentention Facility

<u>Required</u>: 100-year and 10-year storage volumes and release rates

<u>Solution</u>:

Step 1: Compare the undetained area to the allowable undetained area:

Allowable undetained area = 5% of total area (Section 1203.1.2)

$= 0.05 \times 23 = 1.15$ acres

$= 0.8$ acres < 1.15 acres - acceptable

Step 2: Determine minimum required 100-year and 10-year storage volumes. Some as Step 1 and 4 in Example No. 23.

$V_{100} = 2.03$ acre-feet

$V_{10} = 1.16$ acre-feet

Step 3: Determine 100-year and 10-year allowable release rates from the total site.

$Q_{100} = 1.00$ A $\quad Q_{10} = 0.24A$

$= 1.00 \times 23 \quad = 0.24 \times 23$

$= 23$ cfs $\quad = 5.5$ cfs

Step 4: Determine maximum allowable 100-year release rate from the detention facility

Q (detention) = Q (total site) - Q (undetained)

= 23 - 4.2

= 18.8 cfs

Step 5: Repeat Step 4 for 10-year release rate

Q (detention) = Q (total site) - Q (undetained)

= 5.5 - 2.4 = 3.1 cfs

1204.3 Sequential Detention Method

Example No. 25: Sequential Detention Procedure

Given: Drainage basin shown on Figure-1205. The following sub-basin parameters:

SUB-BASIN	AREA ACRES	% IMP	Q_{10} CFS	Q_{100} CFS
A-1	11	40	21.0	47.0
A-2	7	70	23.0	41.0
A-3	10	40	17.0	37.0
A-4	16	50	29.0	57.0
B-1	9	45	23.0	47.0

Undetained Area = 0 acres

Offsite flow from B-1 is routed around the development.

Required: 10-year and 100-year storage volumes and release rates for all detention facilities.

Solution:

Step 1: Using Standard Form SF-11, fill in the given 10-year sub-basin parameters in Columns 1, 2, 3, and 4 for the uppermost detention facility.

Step 2: Compute K_{10} as shown in Example 23 and enter the result in Column 5

$$K_{10} = (0.95I - 1.90)/1000$$
$$= (0.95\ (40) - 1.90)/1000$$
$$= 0.0361$$

Step 3: Divide Column 3 by Column 2 and enter the result in Column 6

$Q_I/A = 21/11 = 1.909$ cfs/acre

Step 4: Compute the 10-year peak inflow to the detention facility. For this facility, the peak inflow is equal to the peak inflow from sub-basin A-1 or 21.0 cfs. Enter the result in Column 7.

Step 5: Divide Column 7 by Column 6 and enter the result in Column 8

$Z = \text{sum of } (Q/(Q_I/A))$

$= 21.0/1.909$

$= 11.0$ acres

Step 6: Compute the minimum required 10-year storage volume as shown in Example 23 using Z = A and K_{10} from Column 5. Enter the result in Column 9.

$V = KZ$

$= 0.0361\ (11.0) = 0.40$ acre-feet (17,300 ft^3)

Step 7: Compute the minimum allowable 10-year release rate as shown in Example 23 using Z = A and enter the result in Column 10.

$Q_{10} = 0.24Z$

$= 0.24\ (11.0)$

$= 2.6$ cfs

Step 8: Repeat Steps 1 through 3 for the next detention facility

$K_{10} = 0.0646$

$Q_I/A = 3.286$

Step 9: Repeat Step 4 but include the peak outflow from detention facility A-1.

$Q = 23 + 2.6$

$= 25.6$ cfs

Step 10: Repeat Steps 5 through 7

$Z = 7.8$

$S_m = 0.50$ acre-feet

$Q_m = 1.9$ cfs

Step 11: Repeat Steps 1 through 7 for the remaining detention facilities for both the 10-year and 100-year floods.

1205 <u>WATER QUALITY</u>

Storm water runoff usually contains many organic and inorganic substances. The effect of detention storage for removal of inorganic substances such as debris and sediment may be substantial (see Section 1300). However, the effect of detention storage for removal of organic substances is minimal at best. If the proposed detention facility is designed with a permanent pool, water quality due to organic substances may be a problem. These detention facilities should be designed with provisions for aeration and may require an algicide if algae growth is a problem.

STANDARD FORM SF-11
SEQUENTIAL DETENTION CALCULATION

SUBDIVISION Example No 25

CACULATED BY AJL **DATE** Feb. 24, 1984

	FACILITY NUMBER (1)	SINGULAR DETENTION: BASIN AREA (A) Ac (2)	Q_i CFS (3)	IMP % (4)	K Ft (5)	Q_i/A CFS/Ac (6)	SEQUENTIAL DETENTION: ΣQ CFS (7)	Z Ac (8)	S_m Ac-Ft (9)	Q_m CFS (10)
10-YEAR	A-1	11	21	40	0.0361	1.909	21.0	11.0	0.40	2.6
	A-2	7	23	70	0.0646	3.286	25.6	7.8	0.50	1.9
	A-3	10	17	40	0.0361	1.700	17.0	10.0	0.36	2.4
	A-4	16	29	50	0.0456	1.813	33.3	18.4	0.84	4.4

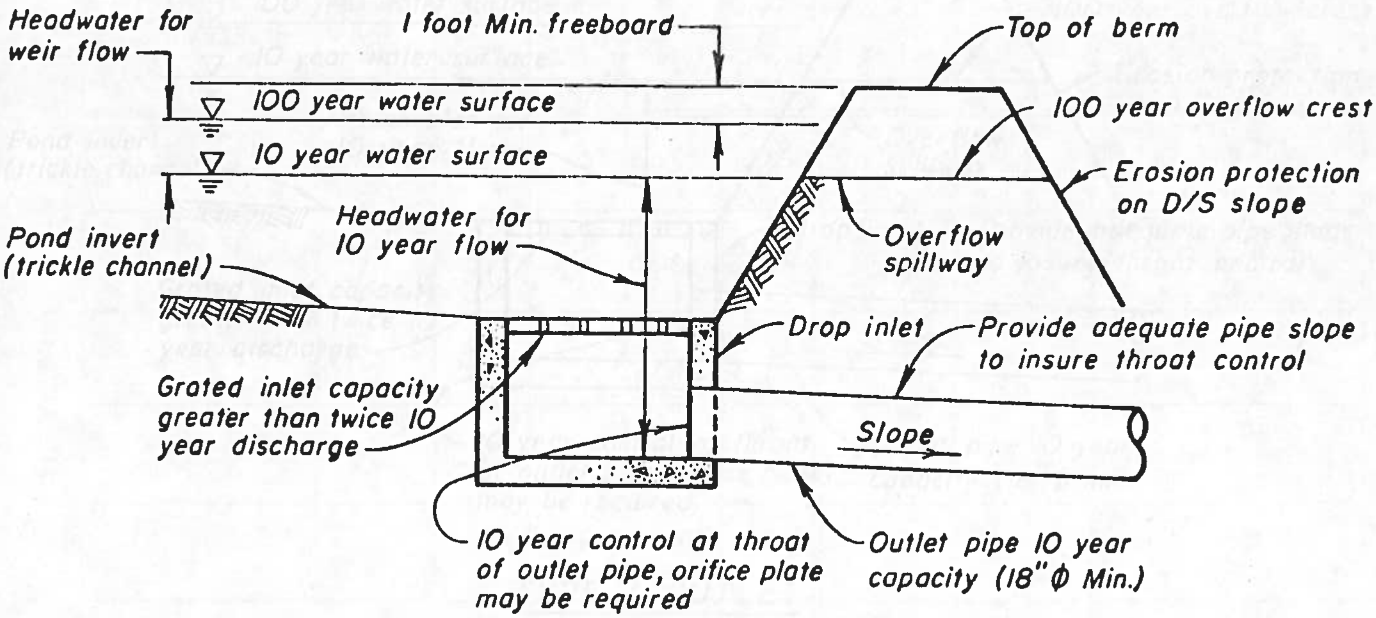
100-YEAR	A-1	11	47	40	0.0644	4.272	47.0	11.0	0.71	11.0
	A-2	7	41	70	0.1112	5.857	52.0	8.9	0.99	8.9
	A-3	10	37	40	0.0644	3.700	37.0	10.0	0.64	10.0
	A-4	16	57	50	0.0804	3.563	75.9	21.3	1.71	21.3

$\Sigma Q = Q_i +$ Previous Q_m

$Z = \Sigma Q/(Q_i/A)$

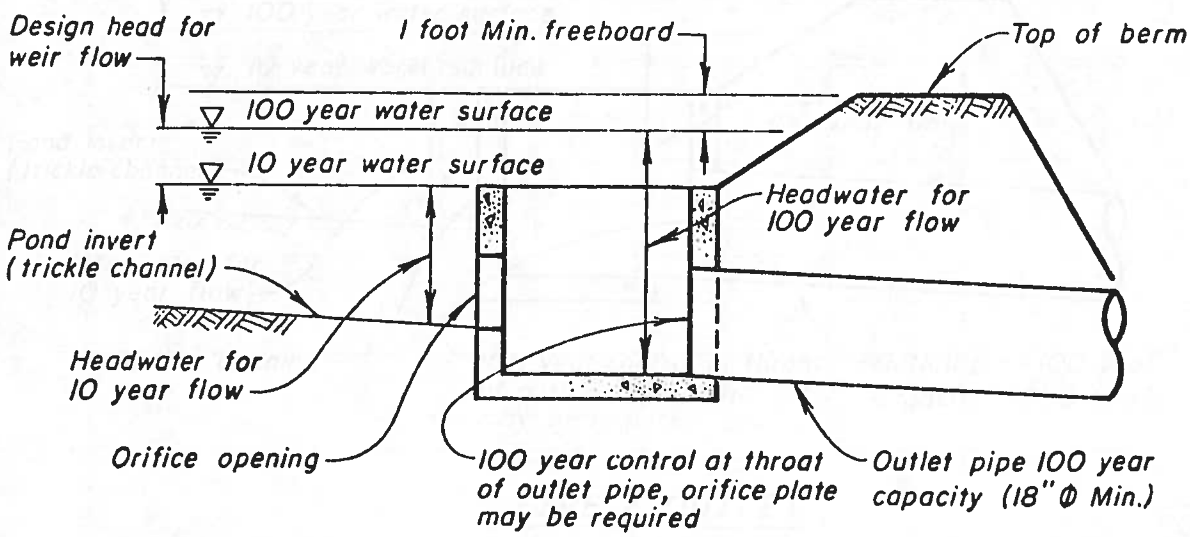
$S_m = KZ$

DETENTION POND OUTLET CONFIGURATIONS



TYPE I OUTLET

No Scale

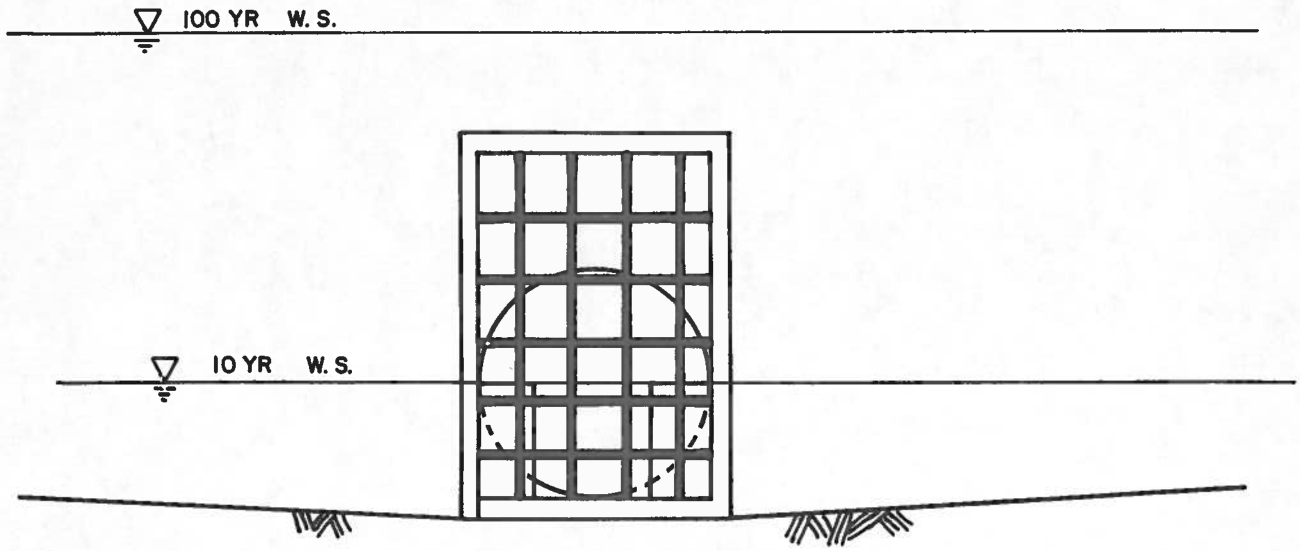


TYPE 2 OUTLET

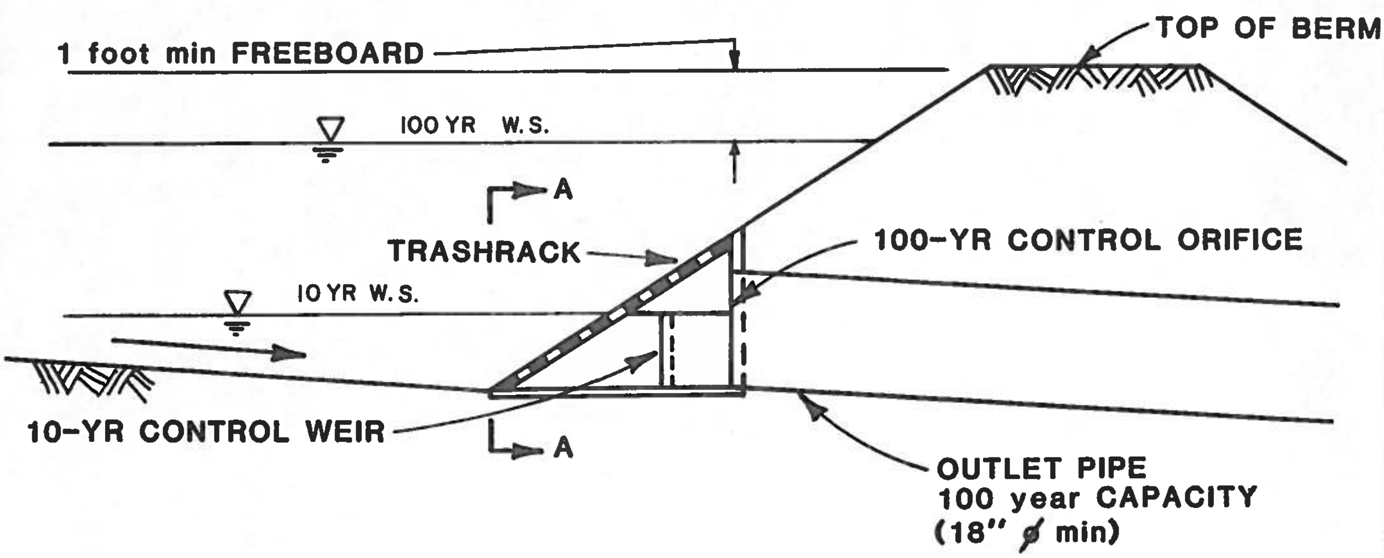
No Scale

WRC ENG.	REFERENCE:

DETENTION POND OUTLET CONFIGURATIONS



SECTION A-A



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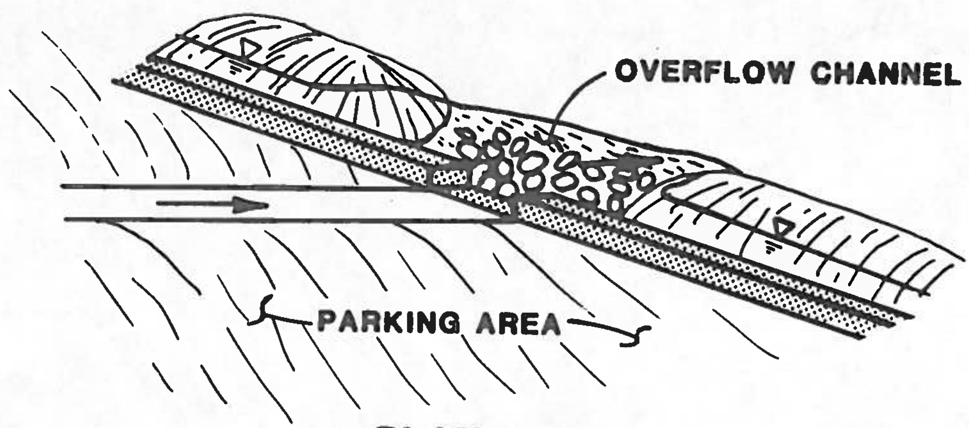
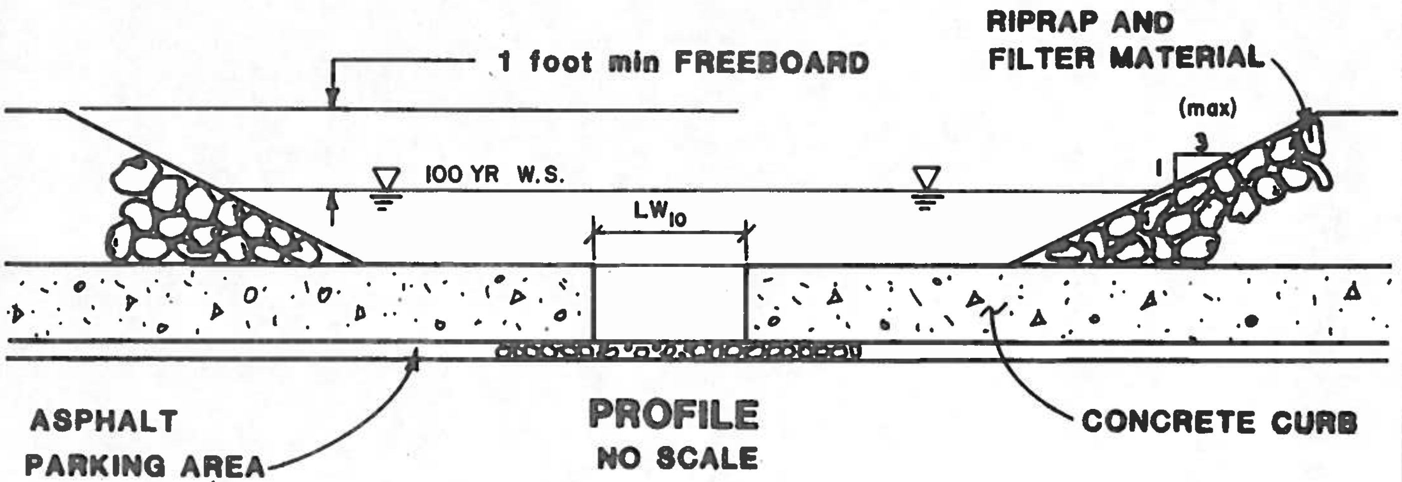
DETENTION POND OUTLET CONFIGURATIONS



PLAN

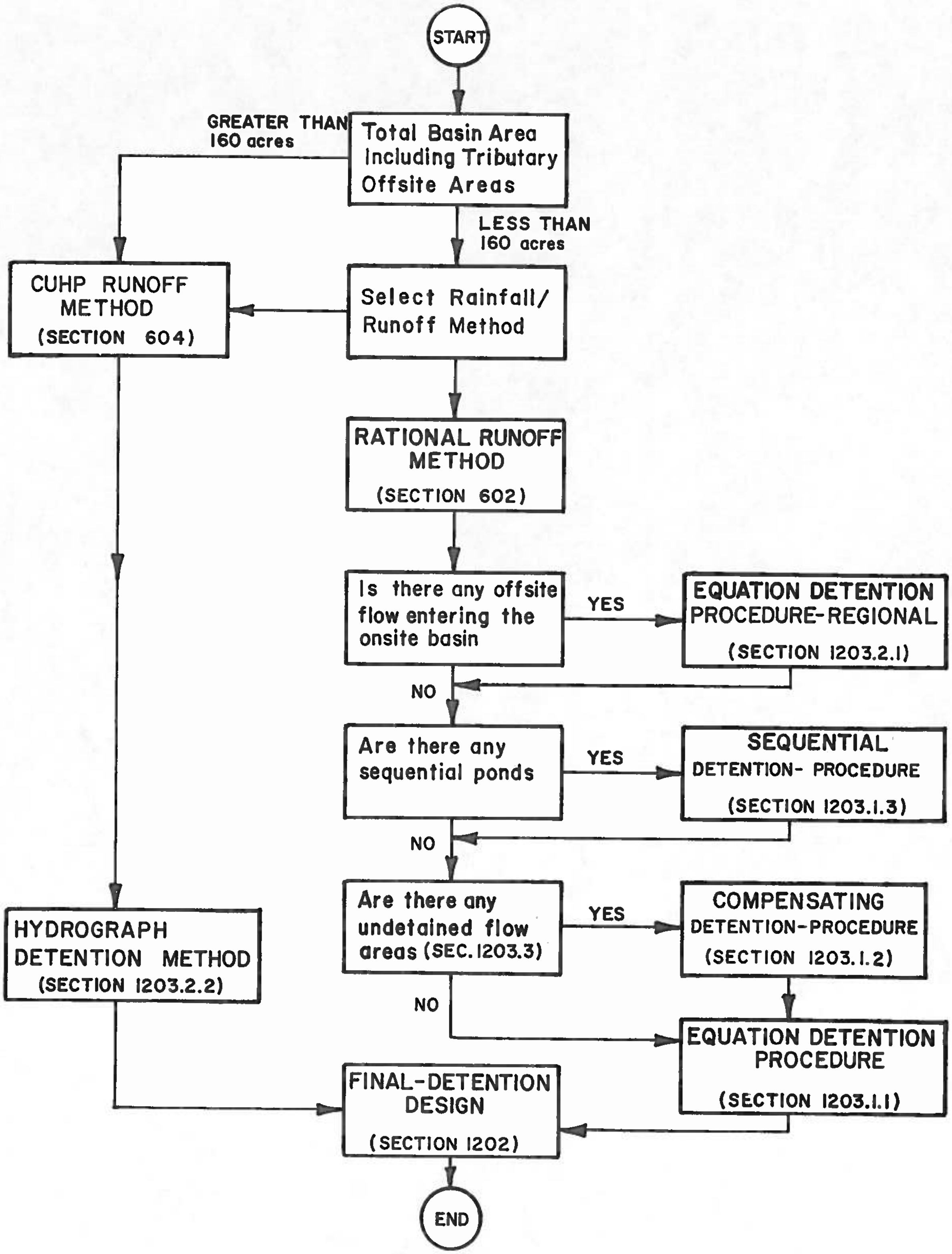


PROFILE
NO SCALE

TYPE 4 OUTLET

WRC ENG. | REFERENCE:

DETENTION METHOD SELECTION
FLOW CHART



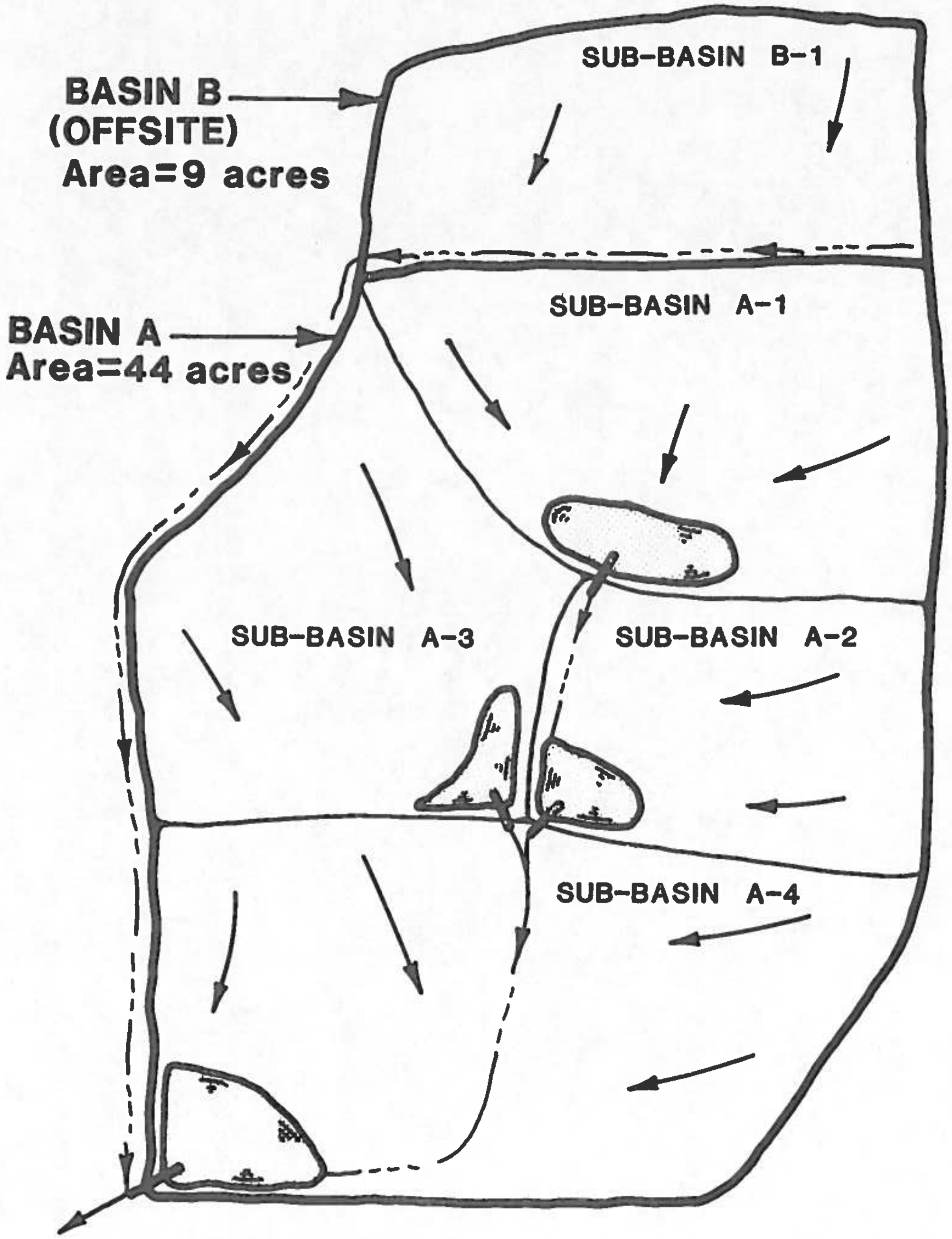
WRC ENG

REFERENCE: See discussion in Section 1202.3

BOULDER COUNTY
STORM DRAINAGE CRITERIA MANUAL

FIGURE 1205

EXAMPLE NO. 25
SEQUENTIAL DETENTION METHOD



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