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SECTION V - STORMWATER DETENTION

5.1 GENERAL

Stormwater runoff and the velocity of discharge are considerably increased through development and growth of the City. Prior to the development of land, surface conditions provide a high percentage of permeability and a longer time of concentration. With the construction of buildings, parking lots, etc., permeability and the time of concentration are significantly decreased. These modifications may create harmful effects on properties downstream.

Criteria for differential runoff and detention guidelines are set out below to attempt to decrease the possible effects of development on downstream properties due to increased runoff.

<u>Downstream Conditions</u>: A field study of the downstream capacity of all drainage facilities and the effects from the area to be improved shall be submitted which includes an area equal to twenty (20) times the project area or one-half (1/2) mile minimum distance along the drainage path.

1. No increase in peak flow discharge from the one hundred (100) year precipitation event down to and including the two (2) year event shall be allowed into areas within the City of Bentonville, Arkansas, or the city's planning jurisdiction, except as provided in item 2 below.
2. A waiver of detention may be requested if circumstances exist.
3. An acceptable solution must be presented to the Planning Commission as a part of the PROJECT DRAINAGE PLAN, which may include detention design and/or other on-site and/or off-site improvements as required to meet the intent of these regulations and have no negative impact on adjacent property or watersheds.

5.2 VOLUME OF DETENTION

Volumes of detention shall be evaluated according to the following methods:

A. Volume of detention for basins with total drainage areas of less than 25 acres may be evaluated by the "Modified Rational Hydrograph Method".

B. For basins with total drainage areas larger than 25 acres, the City Engineer retains the right to require submittal of proposed method of evaluation for the sizing of the retention basin or detention basin. The method will be evaluated for a professional acceptance, applicability, and reliability by the City Engineer.

5.3 DESIGN CRITERIA

Stormwater detention ponds shall be designed to limit the peak stormwater discharge rate of the 2, 10, 25, 50, and 100 year storm frequencies after development to predevelopment rates.

5.4 METHOD OF DETENTION

The following conditions and limitations shall be observed in selection and use of the method of detention:

5.4.1 GENERAL LOCATION

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. Conditions for general location of detention facilities are identified in the following sections.

5.4.2 DRY RESERVOIRS

Wet weather ponds or dry reservoirs shall be designed with proper safety, stability, and ease of maintenance facilities, and shall not exceed eight (8) feet in depth. Maximum side slopes for grass reservoirs shall not exceed one (1) foot vertical for three (3) feet horizontal (3:1) unless adequate measures are included to provide for the above noted features. In no case shall the limits of maximum ponding elevation be closer than twenty (20) feet horizontally from any building and less than one and a half (1.5) feet vertically below the lowest sill or floor elevation. The entire reservoir area shall be sodded as required prior to final plat approval or issuance of certificate of occupancy. The reservoir area shall include bottom, all side slopes (interior and exterior), and top of berm/embankment. Any area susceptible to, or designed as, overflow by higher design intensity rainfall shall be sodded or paved depending upon the outflow velocity. Concrete trickle channel shall be constructed from all inlets into pond to discharge.

5.4.3 DETENTION IN OPEN CHANNELS

Open channels may be used as detention areas provided that the limits of the maximum ponding elevation are not closer than twenty (20) feet horizontally from any buildings, and not less than one and a half (1.5) feet below the lowest sill or floor elevation of any building. No ponding will be permitted within public road right-of-way unless approval is given in writing by the City Engineer. Maximum depth of detention in open channels shall be four (4) feet. Minimum flow line grade shall be 1.0 percent for grass or untreated bottoms or 0.5 percent for paved channels.

For trapezoidal sections, the maximum side slopes of the channel used for detention shall not exceed one (1) foot vertical for three (3) feet horizontal (3:1). For design of other typical channel sections, the features of safety, stability, and ease of maintenance shall be observed by the Design Engineer.

Unless concrete lined, the entire reservoir area of the open channel shall be sodded as required in the original design. The hydraulic or water surface elevations resulting from channel detention shall not adversely effect adjoining properties.

5.4.4 PERMANENT LAKES OR RETENTION PONDS/WET PONDS

Permanent lakes with fluctuating volume controls may be used as detention areas provided that the limits of maximum ponding elevations are no less than one and a half (1.5) feet below the lowest sill or floor elevation of any building.

Maximum side slopes for the fluctuating area of permanent lakes shall be one (1) foot vertical to three (3) feet horizontal (3:1) unless provisions are included for safety, stability, and ease of maintenance.

Special consideration such as fencing, shoreline slope, depth of water, and abrupt change of grade in inundated areas of two (2) feet or more depth, etc., shall be given to the safety of small children and the public in design of permanent lakes in residential areas.

The entire fluctuating area of the permanent reservoir shall be sodded. Also, calculations must be provided to ensure adequate "live storage" is provided for the 100 year storm. Any area susceptible to or designed as overflow by higher design intensity rainfall (100-year frequency) shall be sodded or paved, depending on the design velocities. An analysis shall be furnished of any proposed earthen dam construction soil. A boring of the foundation for the earthen dam may be requested by the City

Engineer. Earthen dam structures shall be designed by a Professional Engineer.

Aeration devices required for lakes/ponds less than 10-acre water surface area.

5.4.5 PARKING LOTS

Detention is permitted in parking lots to maximum depths of 12 inches. In no case should the maximum limits of ponding be designed closer than twenty (20) feet from a building.

The minimum freeboard and the maximum ponding elevation to the lowest sill or floor elevation shall be one and a half (1.5) feet for the 100 year precipitation event.

5.4.6 OTHER METHODS

Underground detention is acceptable if designed conditions warrant. Parking lots and associated curb and gutter is to serve as the overflow and/or freeboard area. Freeboard is used to account for issues such as sedimentation, clogged discharge, factor of safety, etc. If a parking lot or overflow area is available on site, there is no need for additional storage. If a parking lot or overflow area is not available on site, and/or any overflow would immediately discharge to adjacent property, extra storage/volume should be provided (designed for 105%).

Other methods of detention such as seepage pits, French drains, etc., are discouraged. If other methods are proposed, proper documentation of soil data, percolation, geological features, etc., will be needed for review and consideration.

5.4.7 VERIFICATION OF ADEQUACY

Projects shall provide documented verification of adequacy according to the scope and complexity of design signed originally and certified as-built by the same Arkansas registered professional engineer, if feasible.

5.4.8 CONTROL STRUCTURES

Detention facilities shall be provided with effective control structures. Plan view and sections of the structure with adequate details shall be included in Plans.

The structure selected shall have documented evidence that it will control the 2, 10, 25, 50, and 100 year storms.

The overflow opening or spillway shall be designed to accept the total peak runoff of the improved tributary area. Conveyance for any off-site drainage shall also be provided for.

5.4.9 DISCHARGE SYSTEMS

For site-specific runoff, the effectiveness of local detention structures can be acknowledged in the design of any on-site downstream drainage facilities assuming that the detention facilities comply with all criteria and that they are properly constructed and maintained.

In the case of regional detention basins, sizing of the system below the control structure shall be for the total improved peak runoff tributary to the structure with no allowance for detention unless approved in writing by the City Engineer.

In the event the Engineer desires to incorporate the flow reduction benefits of existing upstream detention ponds, the following field investigations and hydrologic analysis <u>will be required</u>: (Please note that under no circumstances will the previously approved construction plans of the upstream pond suffice as an adequate analysis. While the responsibility of the individual site or subdivison plans rests with the Engineer of Record, any subsequent engineering analysis must assure that all the incorporated ponds work collectively.)

1. A field survey of the existing physical characteristics of both the outlet structure and ponding volume. Any departure from the original engineer's design must be accounted for. If a dual use for the detention pond exists, (e.g., storage of equipment), then this too should be accounted for.

2. A comprehensive hydrologic analysis which simulates the attenuation of the contributing area ponds. This should not be limited to a linear additive analysis, but rather a network of hydrographies which considers incremental timing of discharge and potential coincidence of outlet peaks.

5.4.10 OWNERSHIP OF STORMWATER DETENTION PONDS

The ownership of stormwater detention ponds shall remain with the DEVELOPER, his/her successors or assigns, or the PROPERTY OWNER, or a Property Owners Association (POA). The City assumes no responsibility for ownership or maintenance of stormwater detention ponds unless currently owned by the City.

5.4.11 EASEMENTS

Easements shall be provided in Plans for detention facilities.

Easements shall be dedicated in conjunction with platting of subject property, or by separate document in the case of existing platted property. In either case, document to be approved by City Engineer prior to execution.

All detention and retention facilities within a subdivision shall be shown on the final plat as an individual lot and said lot shall be a drainage easement to allow for inspection and maintenance of outfall structure by the City.

Access to the detention facility shall be provided by a minimum 20' wide unobstructed drainage/access easement between public street and facility when the facility and associated easement is not located adjacent to a public right-of-way.

A detention facility located on an individual commercial development does not require a drainage easement unless the detention is shared or located off-site. In this case, the detention facility shall be enclosed within a drainage easement along with necessary access easement.

5.4.12 MAINTENANCE

a. Detention facilities, when mandatory, are to be built in conjunction with the storm sewer installation and grading. Since these facilities are intended to control increased runoff, they must be partially or fully operational soon after the initial clearing of vegetation.

b. Silt and debris connected with early construction shall be removed periodically from the detention area and control structure in order to maintain close to full storage capacity.

c. The responsibility of maintenance of detention facilities in residential subdivision projects shall remain with the DEVELOPER, PROPERTY OWNER, or POA.

d. The responsibility of maintenance of detention facilities in commercial developments shall be the responsibility of the PROPERTY OWNER.

e. Regarding the responsibility of maintenance for detention facilities, if the Developer, property owner, or POA fail to provide a reasonable degree of maintenance and the detention facilities become inoperative or ineffective, the City of Bentonville, Arkansas, may perform remedial work and assess the OWNER the cost of repair and maintenance. (Ord. No. 86-31, Sec. 7)

f. The responsibility of 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.

5.5 DETENTION BASIN DESIGN PROCEDURE
(Using the Modified Rational Method)

Computer generated computations and output are accepted and subject to review by City Engineer.

1. Compute existing (predevelopment) and proposed (developed) site characteristics:

   A. Drainage Area
   B. Composite Runoff Coefficient
   C. Time of Concentration (use Figures 2.2 and/or 2.4)

2. Determine rainfall intensity for existing conditions (2 through 100 year storm) from City of Bentonville Rainfall Intensity-Duration Curves (Figure 2.5).

3. Compute existing peak runoff rates using Rational Formula Q=CiA - These will also be the maximum allowable release rates from the detention basin.

4. Determine inflow hydrograph using Modified Rational Method (see Figure 5.2 and Example).

5. Find estimated detention volume using Modified Rational Method.

6. Size detention basin based on estimated required volume. Develop stage-storage curve for the detention basin.

7. Size release structure based on allowable release flow. Develop stage-discharge curve for the release structure.

8. Route the inflow hydrographs (developed using Modified Rational Method for the 2 through 100 year storms) through the detention basin using Modified Puls Method. (See Exhibit 5.1).

9. Check routed hydrographs to insure flows do not exceed predevelopment peaks. Adjust detention basin and release structure, if necessary.

5.5.1 MODIFIED RATIONAL METHOD DETENTION BASIN DESIGN PROCEDURE EXAMPLE

Given: A 10 acre site currently agricultural use is to be developed for townhouses. The entire area is the drainage area of the proposed detention basin.

Determine: Maximum Release rate and required detention storage.

Solution:

Step 1:

Determine 100-year peak runoff rate prior to site development. This is the maximum release rate from site after development.

NOTE: Where a basin is being designed to provide detention for both its drainage area and a bypass area; the maximum release rate is equal to the peak runoff rate prior to site development for the total of the areas minus the peak runoff rate after development for the bypass area. This rate for the bypass area will vary with the duration being considered.

Present Conditions $Q = CiA$

$C = .30$
$Tc = 20$ min.
$i100 = 7.0$ in./hr.
$Q100 = .30 (7.0) 10 = 21.0$ cfs (Maximum release rate)

Step 2:

Determine inflow hydrograph for storms of various durations in order to determine maximum volume required with release rate determined in Step 1.

NOTE: Incrementally increase durations by 10 minutes to determine maximum required volume. The duration with a peak inflow less than the maximum release rate or where required storage is less than storage for the prior duration is the last increment.

Future Conditions (Townhouses)

C = .80
Tc = 15 min.
i100 = 7.0 in./hr.
Q100 = .80 (7.7) 10 = 56.0 cfs

Check various duration storms

20 min.	i = 7.0	Q = .80	(7.0)	10 = 56.0 cfs
30 min.	i = 5.8	Q = .80	(5.8)	10 = 46.4 cfs
40 min.	i = 5.0	Q = .80	(5.0)	10 = 40.0 cfs
50 min.	i = 4.4	Q = .80	(4.4)	10 = 35.2 cfs
60 min.	i = 4.0	Q = .80	(4.0)	10 = 32.0 cfs
70 min.	i = 3.7	Q = .80	(3.7)	10 = 29.6 cfs
80 min.	i = 3.4	Q = .80	(3.4)	10 = 27.2 cfs
90 min.	i = 3.1	Q = .80	(3.1)	10 = 24.8 cfs

NOTE: Rainfall intensities are for illustrative purposes only and do not represent actual values for the City of Bentonville.

Maximum Storage Volume is determined by deducting the volume of runoff released during the time of inflow from the total inflow for each storm duration. See Figure 5.1.

V = time x Qin x 60 sec/min - 0.5 x Qout x (Time +Tc) x 60 sec/min.

15 min. Storm Inflow 15 (61.6) 60 sec/min =	55,440 cf
Outflow (0.5) 30 (21.0) 60 sec/min =	18,900 cf
Storage	36,540 cf
20 min. Storm Inflow 20 (56.0) 60 sec/min =	67,200 cf
Outflow (0.5) 35 (21.0) 60 sec/min =	22,050 cf
Storage	45,150 cf

30 min. Storm Inflow 30 (46.4) 60 sec/min =	83,520 cf
Outflow (0.5) 45 (21.0) 60 sec/min =	28,350 cf
Storage	55,170 cf
40 min. Storm Inflow 40 (40.0) 60 sec/min =	96,000 cf
Outflow (0.5) 55 (21.0) 60 sec/min =	34,650 cf
Storage	61,350 cf
50 min. Storm Inflow 50 (35.2) 60 sec/min =	105,600 cf
Outflow (0.5) 65 (21.0) 60 sec/min =	40,950 cf
Storage	64,650 cf
60 min. Storm Inflow 60 (32.0) 60 sec/min =	115,200 cf
Outflow (0.5) 75 (21.0) 60 sec/min =	47,250 cf
Storage	67,950 cf
70 min. Storm Inflow 70 (29.6) 60 sec/min =	124,320 cf
Outflow (0.5) 85 (21.0) 60 sec/min =	53,550 cf
Storage	70,770 cf
80 min. Storm Inflow 80 (27.2) 60 sec/min =	130,560 cf
Outflow (0.5) 95 (21.0) 60 sec/min =	59,850 cf
Storage	70,710 cf
90 min. Storm Inflow 90 (24.8) 60 sec/min =	133,920 cf
Outflow (0.5) 105 (21.0) 60 sec/min =	66,150 cf
Storage	67,770 cf

Step 3:

Route design storm hydrograph through the detention basin using the Modified Puls Routing Method or another approved method, based on final detention basin and release structure design. Computer programs to accomplish this task are readily available. See Exhibit 5.1 for typical required output format.

<u>EXHIBIT 5.1</u>

D E T A I N v1.0 -- Copyright (c) 1992 by -Mate Software

JOB DESCRIPTION: Sample Project for DETAIN v1.0
DATE: 05-18-1992
TIME: 01:00:00

D R A I N A G E R E P O R T

<u>INPUT/OUTPUT FILENAMES:</u>

Report output filename: REPORT.OUT
Intensity/duration curve filename: INT_100.DAT

<u>DRAINAGE BASIN CHARACTERISTICS:</u>

Drainage area = 1.50 acres
Length of overland flow = 500.0 feet
Average overland slope = 3.50%
Existing runoff coefficient = 0.40
Developed runoff coefficient = 0.80

<u>CHANNEL CHARACTERISTICS:</u>

Length of channel flow = 300.0 feet
Average channel slope = 0.0050 ft/ft
Average channel width = 4.0 feet
Average channel depth = 1.00 feet
Manning's "n" value = 0.040
Average channel velocity = 2.01 ft/sec

<u>FLOW COMPUTATIONS:</u>

Q = C * i * A (Runoff in cfs)
C = Average runoff coffecient
i = Average rainfall intensity (in/hr)
A = Drainage area (ac)

DESCRIPTION	EXISTING INTENSITY (in/hr)	DEVELOPED INTENSITY (in/hr)	EXISTING RUNOFF (cfs)	DEVELOPED RUNOFF (cfs)	RUNOFF INCREASE (cfs)
100 Year Storm	6.30	8.39	3.78	10.07	6.29
50 Year Storm	5.76	7.66	3.45	9.19	5.73
25 Year Storm	5.20	6.94	3.12	8.32	5.21
10 Year Storm	4.49	5.99	2.69	7.19	4.50
5 Year Storm	3.98	5.38	2.39	6.45	4.06
2 Year Storm	3.29	4.51	1.97	5.41	3.43

JOB DESCRIPTION: Sample Project for DETAIN v1.0
DATE: 05-18-1992
TIME: 01:00:00

T I M E O F C O N C E N T R A T I O N

TIME OF CONCENTRATION (OVERLAND FLOW):

$$To = \frac{1.8 * (1.1 - C) * L^{0.5}}{S^{0.33}}$$

C = Average runoff cofficient
L = Length of basin (ft)
S = Average basin slope (%)

Existing time of concentration = 18.6 minutes
Developed time of concentration = 8.0 minutes

TIME OF TRAVEL (CHANNEL FLOW):

$$Tt = \frac{L}{V}$$

L = Length of channel
V = Average channel velocity

Time of travel = 2.5 minutes

TOTAL TIME OF CONCENTRATION:

Tc = To + Tt

Existing time of concentration = 21.0 minutes
Developed time of concentration = 10.4 minutes

JOB DESCRIPTION: Sample Project for DETAIN v1.0
DATE: 05-18-1992
TIME: 01:00:00

C O M P O S I T E   R U N O F F   C O E F I C I E N T S

PREDEVELOPMENT AREAS:

DESCRIPTION	AREA (ac)	C
Predevelopment Area No. 1	0.5	.6
Predevelopment Area No. 2	1.0	.3

TOTAL AREA = 1.50 ACRES; AVERAGE RUNOFF COEFFICIENT = 0.40

POSTDEVELOPMENT AREAS:

DESCRIPTION	AREA (ac)	C
Postdevelopment Area No. 1	1.0	.9
Postdevelopment Area No. 2	0.5	.6

TOTAL AREA = 1.50 ACRES; AVERAGE RUNOFF COEFFICIENT = 0.80

D E T E N T I O N   C O M P U T A T I O N S

MODIFIED RATIONAL METHOD:

Volume = Time * Qin * 60 sec/min - 0.5 * Qout * (Time + Tc) * 60 sec/min
Time = Storm duration (min)
Qin = Peak runoff from storm (cfs)
Qout = Maximum discharge (cfs)
Tc = Time of concentration (min)

STORM DURATION (min)	AVERAGE INFLOW (cfs)	MAXIMUM RELEASE (cfs)	REQUIRED DETENTION (cu ft)
10	10.20	3.78	3802.56
11	9.90	3.78	4103.18
12	9.50	3.78	4298.69
13	9.24	3.78	4549.63
14	8.94	3.78	4738.65
15	8.69	3.78	4934.88
16	8.46	3.78	5123.90
17	8.28	3.78	5334.52
18	8.08	3.78	5497.63
19	7.86	3.78	5622.57
20	7.72	3.78	5808.00
21	7.56	3.78	5961.02
22	7.52	3.78	6253.72
23	7.30	3.78	6277.15
24	7.12	3.78	6342.33
25	7.02	3.78	6511.91
26	6.90	3.78	6632.54
27	6.78	3.78	6738.76
28	6.66	3.78	6830.59
29	6.55	3.78	6928.89
30	6.46	3.78	7035.83
31	6.36	3.78	7131.26
32	6.24	3.78	7169.08
33	6.14	3.78	7240.02
34	6.05	3.78	7299.45
35	5.98	3.78	7397.75
36	5.88	3.78	7435.58
37	5.80	3.78	7488.52
38	5.74	3.78	7586.10
39	5.64	3.78	7592.25
40	5.54	3.78	7586.87
41	5.50	3.78	7688.05
42	5.40	3.78	7662.52
43	5.32	3.78	7656.42
44	5.28	3.78	7766.97
45	5.20	3.78	7743.59
46	5.14	3.78	7776.37
47	5.06	3.78	7768.12
48	5.02	3.78	7820.34
49	4.94	3.78	7796.24
50	4.90	3.78	7835.51
51	4.84	3.78	7832.29

STORM DURATION (min)	AVERAGE INFLOW (cfs)	MAXIMUM RELEASE (cfs)	REQUIRED DETENTION (cu ft)
52	4.78	3.78	7821.88
53	4.70	3.78	7766.10
54	4.66	3.78	7779.44
55	4.60	3.78	7747.43
56	4.56	3.78	7788.85
57	4.50	3.78	7743.88
58	4.44	3.78	7691.70
59	4.40	3.78	7717.28
60	4.34	3.78	7652.15
61	4.31	3.78	7663.26
62	4.27	3.78	7669.91
63	4.23	3.78	7672.09
64	4.20	3.78	7669.81
65	4.16	3.78	7663.07
66	4.12	3.78	7651.86
67	4.08	3.78	7636.19
68	4.05	3.78	7616.05
69	4.01	3.78	7591.45
70	3.97	3.78	7562.38
71	3.94	3.78	7569.75
72	3.92	3.78	7573.81
73	3.89	3.78	7574.55
74	3.86	3.78	7571.98
75	3.83	3.78	7566.10
76	3.81	3.78	7556.91
77	3.78	3.78	7544.41 X
78	3.75	3.78	7528.59 X
79	3.72	3.78	7509.46 X

END OF COMPUTATIONS -- MAXIMUM VOLUME = 7835.51; AT TIME = 50

JOB DESCRIPTION: Sample Project for DETAIN v1.0
DATE: 05-18-1992
TIME: 01:00:00

D E T E N T I O N H Y D R O G R A P H

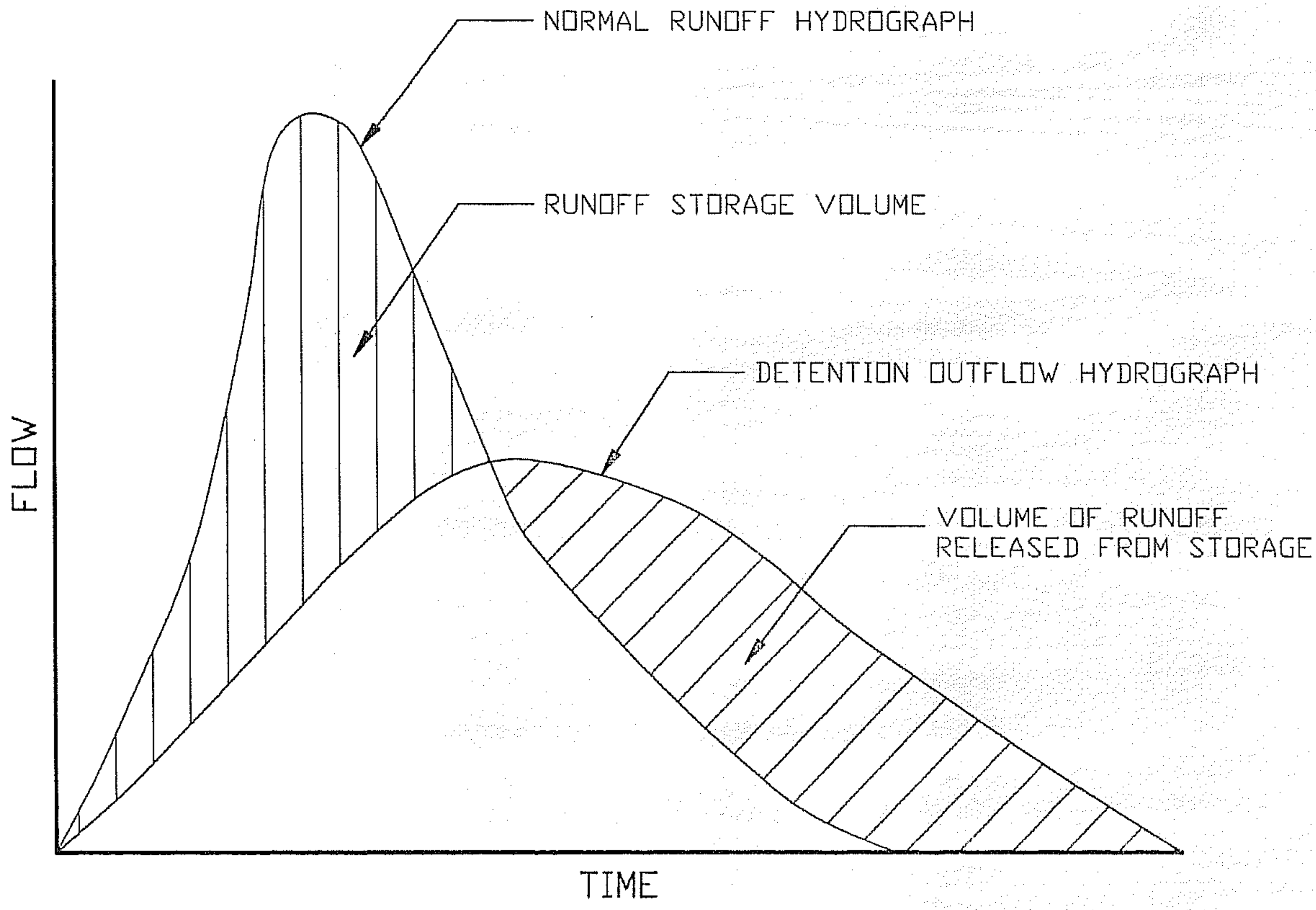
INPUT/OUTPUT FILENAMES:

Inflow hydrograph filename: INFLOW.DAT
Stage/storage curve filename: STORAGE.DAT
Stage/discharge curve filename: OUTFLOW.DAT

TIME (min)	INFLOW (cfs)	STAGE (ft)	OUTFLOW (cfs)	VOLUME (cu ft)
0	0.00	0.00	0.00	0.00
1	0.47	0.02	0.05	13.28
2	0.94	0.08	0.19	48.92
3	1.41	0.12	0.30	104.16
4	1.88	0.16	0.40	182.01
5	2.34	0.21	0.51	280.15
6	2.81	0.24	0.60	401.46
7	3.28	0.29	0.71	545.20
8	3.75	0.33	0.80	710.98
9	4.22	0.37	0.89	899.39
10	4.69	0.41	0.99	1109.87
11	4.90	0.45	1.09	1338.47
12	4.90	0.49	1.18	1564.33
13	4.90	0.52	1.29	1784.28
14	4.90	0.55	1.41	1997.04
15	4.90	0.58	1.52	2202.77
16	4.90	0.61	1.64	2401.70
17	4.90	0.64	1.75	2593.95
18	4.90	0.66	1.85	2779.72
19	4.90	0.71	2.02	2957.67
20	4.90	0.75	2.14	3126.53
21	4.90	0.80	2.27	3287.93
22	4.90	0.84	2.38	3442.21
23	4.90	0.88	2.49	3589.68
24	4.90	0.92	2.60	3730.64

TIME (min)	INFLOW (cfs)	STAGE (ft)	OUTFLOW (cfs)	VOLUME (cu ft)
25	4.90	0.96	2.70	3865.38
26	4.90	1.00	2.80	3994.17
27	4.90	1.03	2.84	4118.69
28	4.90	1.06	2.88	4240.61
29	4.90	1.09	2.93	4360.00
30	4.90	1.12	2.97	4476.91
31	4.90	1.15	3.01	4591.39
32	4.90	1.18	3.05	4703.49
33	4.90	1.20	3.09	4813.26
34	4.90	1.23	3.12	4920.75
35	4.90	1.26	3.16	5026.00
36	4.90	1.28	3.20	5130.09
37	4.90	1.31	3.23	5230.99
38	4.90	1.33	3.27	5329.80
39	4.90	1.36	3.30	5426.55
40	4.90	1.38	3.33	5521.30
41	4.90	1.40	3.37	5614.07
42	4.90	1.43	3.40	5704.92
43	4.90	1.45	3.43	5793.87
44	4.90	1.47	3.46	5880.98
45	4.90	1.49	3.49	5966.28
46	4.90	1.51	3.53	6049.54
47	4.90	1.52	3.58	6129.82
48	4.90	1.53	3.63	6207.14
49	4.90	1.54	3.68	6281.63
50	4.89	1.54	3.72	6353.36
51	4.42	1.55	3.76	6408.37
52	3.95	1.55	3.77	6433.75
53	3.49	1.55	3.77	6430.59
54	3.02	1.55	3.75	6399.93
55	2.55	1.54	3.72	6342.80
56	2.08	1.53	3.66	6260.16
57	1.61	1.52	3.60	6152.97
58	1.14	1.50	3.52	6022.11
59	0.67	1.47	3.45	5867.58
60	0.20	1.42	3.39	5688.46

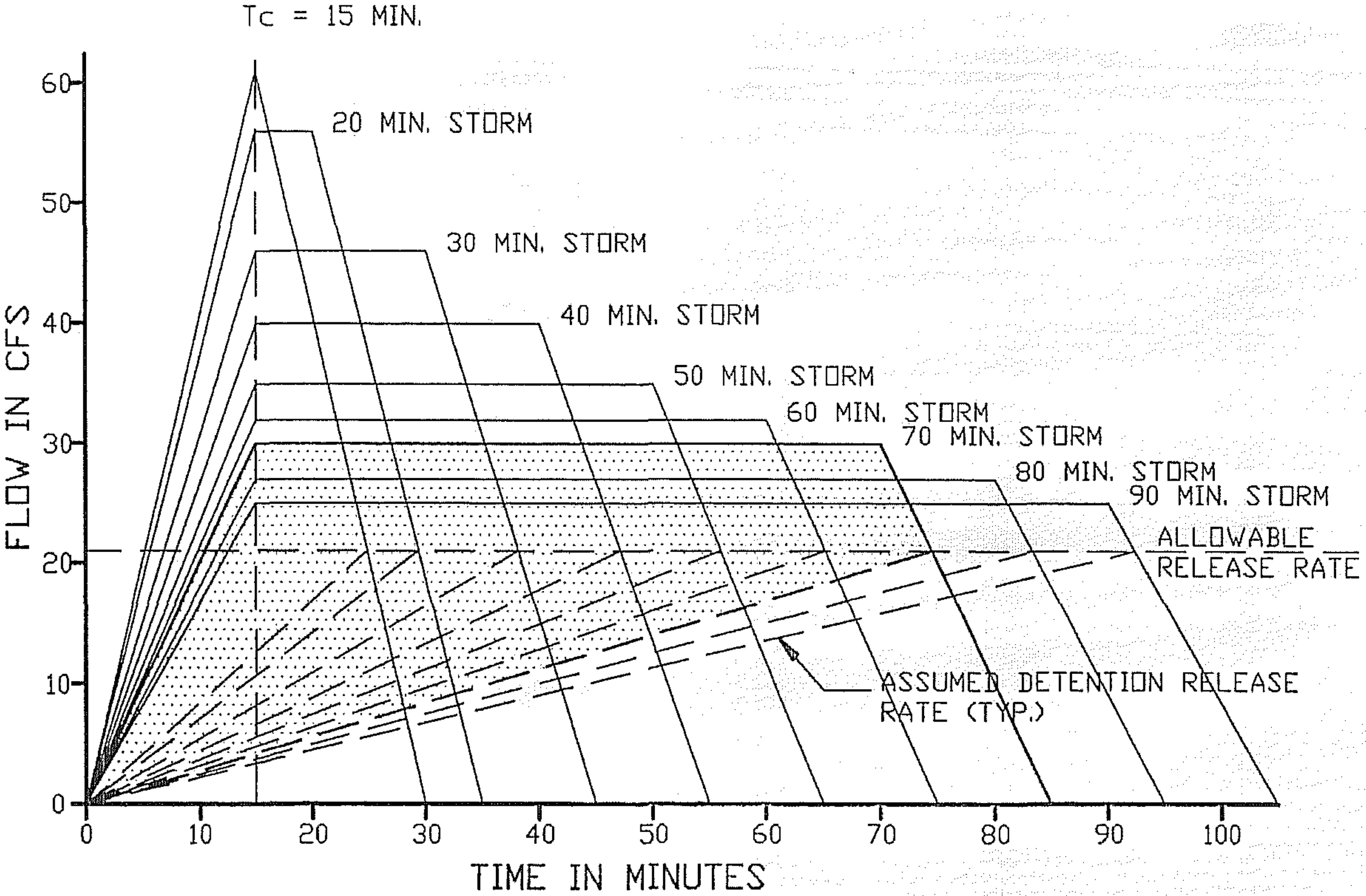
END OF SIMULATION -- MAXIMUM VOLUME = 6433.75; AT TIME = 52



CONCEPT OF DETENTION

CONCEPT OF DETENTION POND

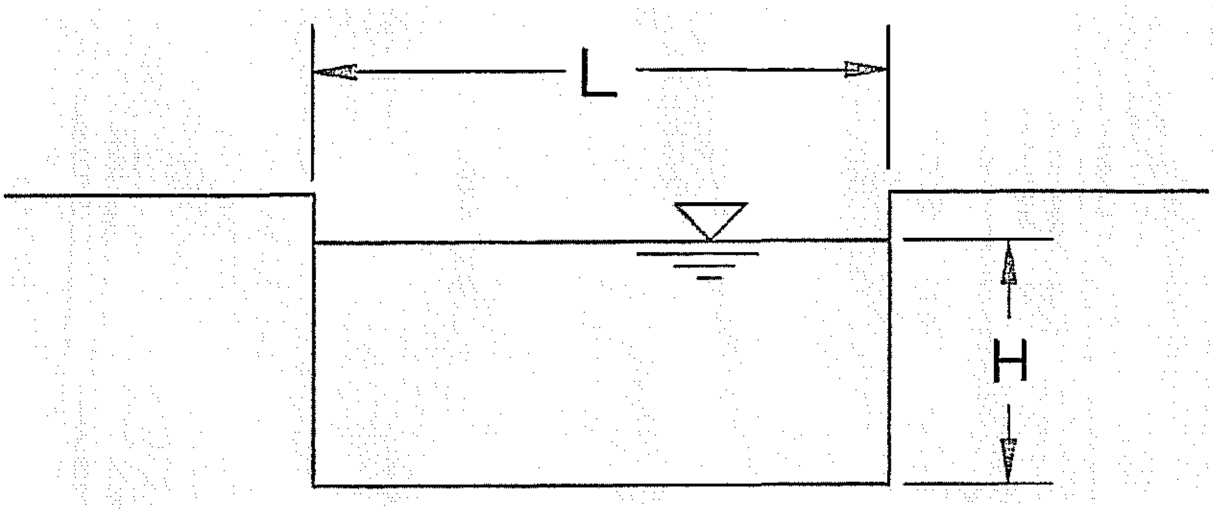
Figure 5.1



MODIFIED RATIONAL METHOD EXAMPLE

EXAMPLE OF MODIFIED RATIONAL METHOD

Figure 5.2



RECTANGULAR WEIR FLOW EQUATION

$$Q = CLH^{3/2}$$

where

Q = Weir discharge in CFS
C = Weir coefficient
L = Horizontal length of the weir in feet
H = Head on the weir in feet

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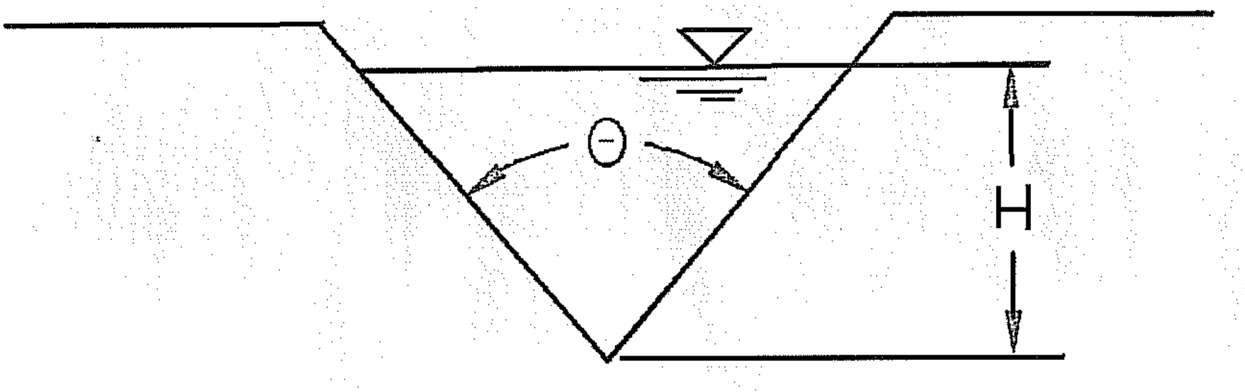
RECTANGULAR WEIR

Figure 5.3

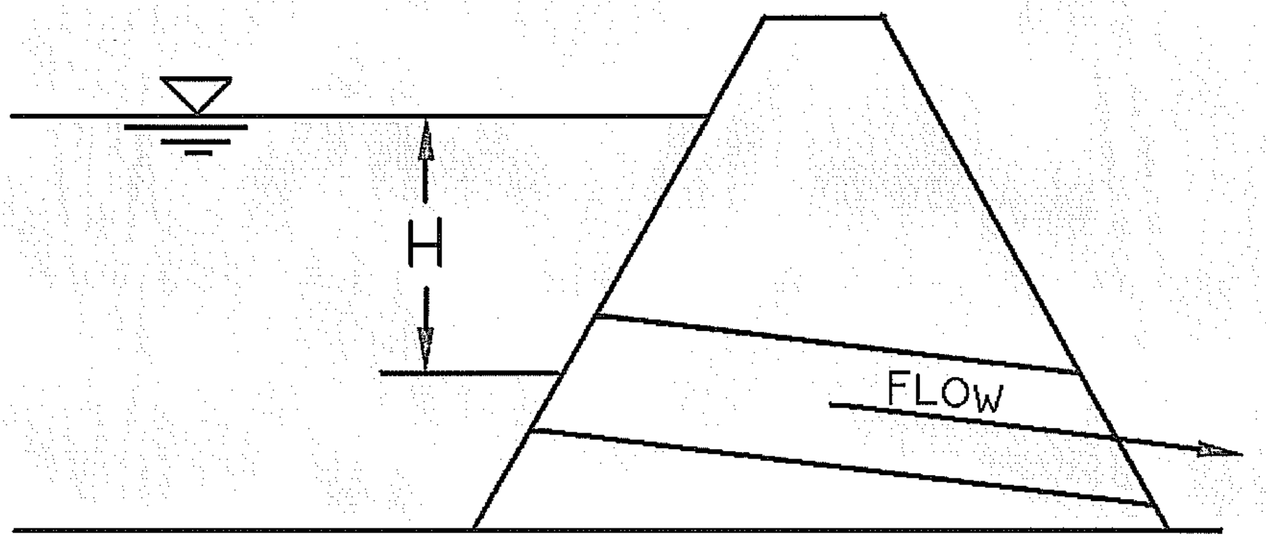


V-NOTCH WEIR FLOW EQUATION

$$Q = C \tan(\theta/2) H^{5/2}$$

where

Q = Weir discharge in CFS
C = Weir coefficient
θ = Angle of the weir notch in degrees
H = Head on the weir in feet



ORIFICE FLOW EQUATION

$$Q = CA\,(2gH)^{1/2}$$

where

Q = Orifice discharge in CFS
C = Orifice coefficient
A = Area of orifice in square feet
g = Gravitational constant (32.2 FT/S^2)
H = Head on the orifice measured from the centerline in feet

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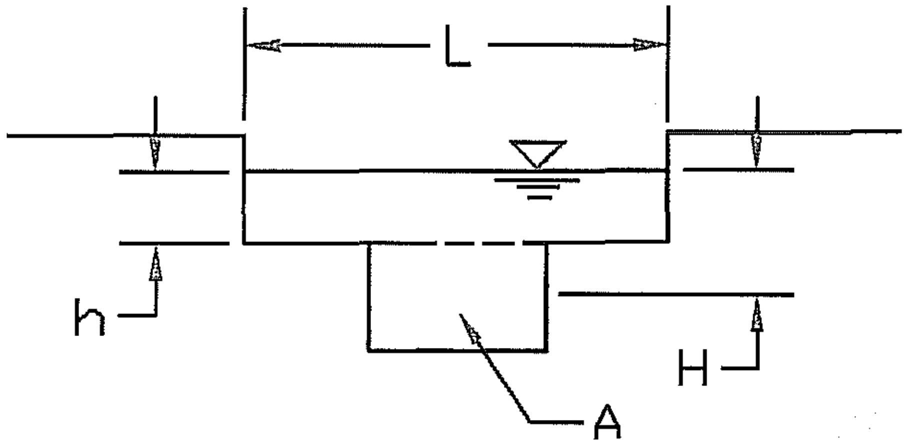
ORIFICE DESIGN

Figure 5.5

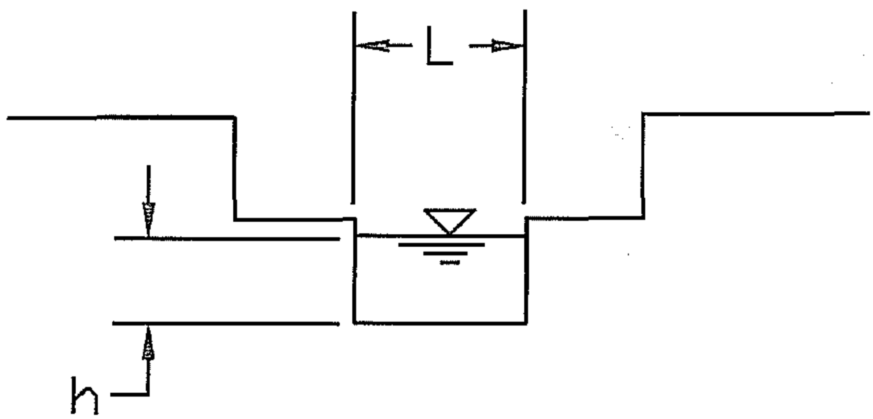


RECTANGULAR WEIR AND ORIFICE FLOW

$$Q_W = C_W L h^{3/2}$$
$$Q_O = C_O A (2gH)^{1/2}$$

where

Q_W = Weir discharge in CFS
Q_O = Orifice discharge in CFS
C_W = Weir coefficient
C_O = Orifice Coefficient
A = Area of orifice in square feet
L = Horizontal length of the weir in feet
h = Head on the weir in feet
H = Head on the orifice in feet



RECTANGULAR WEIR FLOW ONLY

$$Q_W = C_W L h^{3/2}$$

where

Q_W = Weir discharge in CFS
C_W = Weir coefficient
L = Horizontal length of the weir in feet
h = Head on the weir in feet

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MULTISTAGE RELEASE STRUCTURES

Figure 5.6