32

Urban Drainage

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32.1 Introduction

Urbanization drastically alters the hydrologic and meteorological characteristics of watersheds. Because of the changes in surface and heat retention characteristics brought about by buildings and roads, heat islands develop in urban areas. Increases in nucleation and photoelectric gases due to urbanization result in higher smog, precipitation and related activities, and lower radiation in urban areas compared to the surrounding rural areas. Some of these meteorologic effects of urbanization are discussed by Lowry (1967) and Landsberg (1981).

When an area is urbanized, trees and vegetation are removed, the drainage pattern is altered, conveyance is accelerated and the imperviousness of the area is increased because of the construction of residential or commercial structures and roads. Increased imperviousness decreases infiltration with a consequent increase in the volume of runoff. Improvements in a drainage system cause runoff to leave the urbanized area faster than from a similar undeveloped area. Consequently, the time for runoff to reach its peak is shorter for an urban watershed than for an undeveloped watershed. The peak runoff from urbanized watersheds, on the other hand, is larger than from similar undeveloped watersheds. The effects of urbanization on runoff are summarized in Table 32.1.

Urban stormwater drainage collection and conveyance systems are designed to remove runoff from urbanized areas so that flooding is avoided and transportation is not adversely affected. A schematic diagram of a typical urban storm water drainage collection and conveyance system is shown in Fig. 32.1. The cost of this and similar systems is directly dependent on the recurrence interval of rainfall used in the design. Rainfall with 5 to 10 year recurrence intervals is most often used in the sizing and design of the urban stormwater drainage collection and conveyance systems. To accomodate areas that encounter frequent floods or high losses due to flooding and to reduce the potential for downstream flooding, stormwater storage facilities are developed to temporarily store the stormwater and to release it after a storm has passed over the area. Examples of large-scale facilities are the Tunnel and Reservoir Plan (TARP) of the Metropolitan Water Reclamation District of Greater Chicago and the deep tunnel project in Milwaukee. The website for the TARP project is: *www.mwrgdc.dst.il.us/engineering/ourcommunityflooding/OCFAppendix1.htm*. Smaller scale facilities to temporarily detain and release stormwater to the storm

TABLE 32.1 Potential Hydrologic Effects of Urbanization

Urbanizing Influence	Potential Hydrologic Response
Removal of trees and vegetation	Decrease in evapotranspiration and interception; increase in stream sedimentation
Initial construction of houses, streets, and culverts	Local relief from flooding; concentration of floodwaters may aggravate flood problems downstream
Complete development of residential, commercial, and industrial areas	Increased imperviousness reduces time of runoff concentration thereby increasing peak discharges and compressing the time distribution of flow; volume of runoff and flood damage potential greatly increased
Construction of storm drains and channel improvements	Decrease infiltration and lowered groundwater table; increased storm flows and decreased base flows during dry periods

Source: American Society of Civil Engineers Tech. Memo 24 (1974).

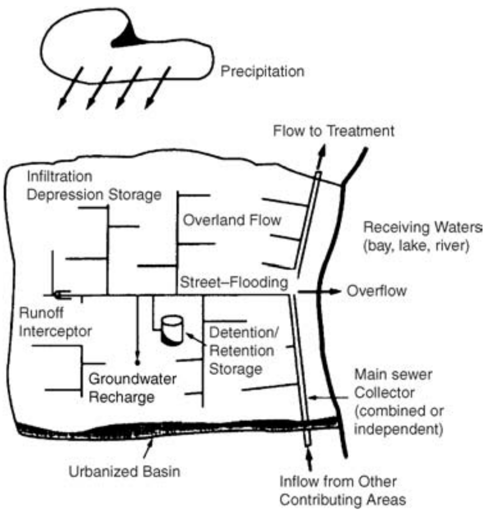

FIGURE 32.1 Schematic diagram of an urban storm-drainage system.

sewer system after the passage of storms (detention facilities) or to retain it and let the water infiltrate or evaporate (retention facilities) are commonly used in suburban flood control projects and are often required for a new development. Detention basins are commonly used to prevent downstream flooding and are often designed to increase the aesthetic appeal of areas in which they are placed.

For many watersheds, models such as TR-20 (SCS, 1982) developed by the Soil Conservation Service of the U.S. Department of Agriculture and HEC-1 (HEC, 1985), developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers are commonly used by designers. These models are used to size collection and conveyance systems as well as stormwater storage facilities, investigate alternative scenarios, and evaluate existing drainage systems.

In this chapter, commonly used formulas and methods to compute peak discharge and runoff hydrographs, such as the rational method and the SCS method are discussed first. Methods for sizing of detention basins are discussed next, followed by a discussion of detention storage layout.

32.2 The Rational Method

The rational method is widely used to determine peak discharges from a given watershed. It was first introduced by Kuichling (1889) into the U.S.; a large majority of the engineering offices which deal with storm drainage work in the U.S. use the rational method. This popularity is due to its simplicity and perhaps to tradition.

In the rational method, the peak rate of surface flow from a given watershed is assumed to be proportional to the watershed area and the average rainfall intensity over a period of time just sufficient for all parts of the watershed to contribute to the outflow. The rational formula is shown in Eq. (32.1)

$$Q = CiA \tag{32.1}$$

where Q = the peak discharge (cfs)
C = the ratio of peak runoff rate to average rainfall rate over the watershed during the time of concentration (runoff coefficient)
i = the rainfall intensity (inches/hour)
A = the contributing area of the watershed (acres).

It should be noted that C has units.

The rational method is usually applied to drainage basins less than 200 acres in area, but should be used carefully for basins greater than five acres. The basic assumptions used in the rational formula are as follows: (1) The rainfall is uniform over the watershed. (2) The storm duration associated with the peak discharge is equal to the time of concentration for the drainage area. (3) The runoff coefficient C depends on the rainfall return period, and is independent of storm duration and reflects infiltration rate, soil type and antecedent moisture condition. The coefficient C, the rainfall intensity i and, the area of the watershed, A, are estimated in order to use the rational method.

Runoff Coefficient

The runoff coefficient C reflects the watershed characteristics. Values of the runoff coefficient C are found in drainage design manuals (Burke et. al., 1994, ASCE, 1992) and in textbooks (Chow et al. 1988). If a watershed has different land uses, a weighted average C based on the actual percentage of lawns, streets, roofs, etc. is computed and used. Values of C must be carefully selected. The C values usually found in manuals and textbooks are valid for recurrence intervals up to 10 years. These values are sometimes altered when higher rainfall frequencies are used.

Rainfall Intensity

Rainfall intensity-duration-frequency curves are used to determine rainfall intensities used in the rational method. Local custom or drainage ordinances dictate the use of a particular return period. In the design of urban drainage collection and conveyance systems, a return period of 5 to 10 years is generally selected. In high value districts (commercial and residential) and in flood protection works, a 50 or 100 year frequency is used. When more than one return period is used, the costs and risks associated with each return period must be scrutinized. In the rational method, the storm duration is equal to the time of concentration. Further details on risk/reliability models for design are found in Tung et al. (2001).

Time of Concentration and Travel Time

The *time of concentration* t_c is the time taken by runoff to travel from the hydraulically most distant point on the watershed to the point of interest. The *time of travel* T_t is the time taken by water to travel from one point to another in a watershed. The time of concentration may be visualized as the sum of the travel times in components of a drainage system. The different components include overland flow, shallow concentrated flow and channel flow. As an area is urbanized, the quality of flow surface and conveyance facilities are improved, and the times of travel and concentration generally decrease. On the other hand ponding and reduction of land slopes which may accompany urbanization increase times of travel and concentration.

Overland flows are assumed to have maximum flow lengths of about 300 ft. From about 300 ft. to the point where the flow reaches well-defined channels, the flow is assumed to be of the shallow concentrated type. After the flow reaches open channels it is characterized by Manning's formula.

TABLE 32.2 Equations for Overland Flow Travel Time

Name	Equation for t_t	Notes
Regan (1972)	$t_t = \frac{L^{0.6}\, n^{0.6}\, K}{i^{0.4}\, S^{0.3}}$	n is Manning's roughness coefficient
Kerby (1959)	$t_t = 0.827\left(\frac{NL}{\sqrt{S}}\right)^{0.467}$	$L < 1200$ ft,
Federal Aviation Agency (1956)	$t_t = 1.8(1.1 - C)\frac{L}{\sqrt{100S}}$	Airport areas C = runoff coefficient
Izzard (1946)	$t_t = \frac{2}{60}\,\frac{.0007i + c}{S^{1/3}}\, L\left(\frac{iL}{43200}\right)^{-2/3}$ or $t_t = \frac{41\, cL^{1/3}}{(Ci)^{2/3}\, S^{1/3}}$	$iL < 500$,
Overton and Meadows (1970)	$t_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\, S^{0.4}}$	

where t_t = the overland flow time (min), L is the basin length (ft),
S = the basin slope (ft/ft), i is the rainfall intensity (in./hr),
c = the retardance coefficient and C is the runoff coefficient,
n = Manning's n,
P_2 = the 2 year-24 hr rainfall (in)
$K = 56$
N = a roughness coefficient

Some commonly used formulas employed in the determination of the overland flow travel time are shown in Table 32.2. Most of these equations relate the overland time of travel to the basin length, slope and surface roughness. Two equations, by Izzard and Regan, include rainfall intensity as a factor, which necessitates an iterative solution.

The average velocities for shallow concentrated flow are estimated by Eqs. (32.2) and (32.3) for unpaved and paved areas respectively, where V is the average velocity in ft/sec. and S is the slope of the land surface in ft/ft. (SCS, 1986).

$$\text{unpaved:} \quad V = 16.13\,(S)^{0.5} \tag{32.2}$$

$$\text{paved:} \quad V = 20.33\,(S)^{0.5} \tag{32.3}$$

Flows in open channels are characterized by Manning's formula. In sewered watersheds, the time of concentration is calculated by estimating the overland flow travel time, which is called the *inlet time*, the gutter flow time and the *time of travel in sewers*. Often, the *inlet time*, which is the time taken by water to reach inlets, is assumed to be between 5 and 30 min. In flat areas with widely spaced street inlets, an inlet time of 20 to 30 min is assumed (ASCE, 1992). These inlet times are added to the flow time in the sewer or channel to determine the travel time at a downstream location.

The flow time in sewers is usually calculated by choosing a pipe or channel configuration and calculating the velocity. The time is then found by:

$$t = \frac{L}{60V} \tag{32.4}$$

where t = the travel time in the sewer (min.)
L = the length of the pipe or channel (ft)
V = the velocity in the sewer (ft/sec)

TABLE 32.3 Typical Velocities in Natural Waterways (AASHTO, 1991)

Average Slope of waterway (%)	Velocity In: Natural Channel (not well defined) (ft/sec)	Velocity In: Shallow Channel (ft/sec)	Velocity In: Main Drainage Channel (ft/sec)
1–2	1.5	2–3	3–6
2–4	3.0	3–5	5–9
4–6	4.0	4–7	7–10
6–10	5.0	6–8	—

Mannings' formula is commonly used to estimate the travel times in sewers. The sewer is assumed to flow full and a velocity is computed. Manning's n values commonly used for this purpose are found in Chow (1959). Sometimes, natural channels are used to convey storm runoff. In these cases the velocities given in Table 32.3 (AASHTO, 1991) may be used in Eq. (32.4). The drainage area, A, used in the rational formula is determined from topographic maps and field surveys.

Application of the Rational Method

The choice of parameters in the rational method is subjective. Consequently, variations occur in designs. Since rainfall intensity values are derived from statistical analyses and may not represent actual storm events, it is impossible to have a storm of a specified design intensity and duration associated with the results from the rational method. The procedure for the application of the rational method is as follows: (1) The contributing basin area A (acres) is determined by using maps or plans made specifically for the basin. (2) By using the land use information, appropriate C values are determined. If the land has multiple uses, a composite C value is estimated by Eq. (32.5):

$$C_{comp} = \frac{\left(C_1 A_1 + C_2 A_2 + \cdots \; C_n A_n\right)}{A} \tag{32.5}$$

where $C_1, C_2 \ldots C_n$ = the runoff coefficients associated with the $A_1, A_2 \ldots A_n$ respectively
A = the sum of $A_1, A_2 \ldots A_n$

(3) The time of concentration is estimated by summing the travel time components. (4) The rainfall intensity is determined by using an intensity-duration-frequency diagram and the time of concentration as the storm duration. (5) The peak runoff (cfs) is computed by multiplying C, i and A. (6) If there is another basin downstream, the time of concentration from the upstream basin is added to the travel time in the channel. This time of concentration is compared to the time of concentration of the second basin and the larger of two is used as the new time of concentration. Examples of the application of rational method are found in Burke et al. (1994). Because of the assumptions and the simplistic approach on which rational method is based, its application is not recommended for watersheds larger than five acres.

32.3 The Soil Conservation Service Methods

The Soil Conservation Service has developed a method to estimate rainfall excess P_e from total rainfall P, based on the total ultimate abstraction S. In this method, P_e is given by Eq. (32.6), where P must be greater than 0.2S, which is the initial storage capacity I_a (in.).

$$P_e = \frac{\left(P - 0.2S\right)^2}{P + 0.8S} \tag{32.6}$$

TABLE 32.4 Soil Classification Table (SCS, 1972)

Name	Class	Name	Class	Name	Class
Abscota	A	Bewleyville	B	Check to Waga	D
Digby	B	Door	B	Cincinnatic	C
Ade	A	Birds	(C/D)	Chetwynd	B

TABLE 32.5 Runoff Curve Numbers for Selected Land Uses

	Hydrologic Soil Group			
Land Use Description	A	B	C	D
Cultivated land[a]: without conservation treatment with	72	81	88	91
conservation treatment	62	71	78	81
Pasture or range land: Poor condition good condition	68	79	86	89
	39	61	74	80
Meadow: good condition	30	58	71	78
Wood or forest land: thin stand, poor cover, no mulch	45	66	77	83
good cover[2]	25	55	70	77
Open Spaces, lawns, parks, golf courses, cemeteries, etc.	39	61	74	80
good condition: grass cover on 75% or more of the area	49	69	79	84
fair condition: grass cover on 50% to 75% of the area				
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential				
Average lot size — Average% impervious				
1/8 acre or less — 65	77	85	90	92
1/4 acre — 38	61	75	83	87
1/3 acre — 30	57	72	81	86
1/2 acre — 25	54	70	80	85
1 acre — 20	51	68	79	84
Paved parking lots, roofs, driveways, etc.	98	98	98	98
Streets and roads:				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89

Antecedent moisture condition II, $I_a = 0.2S$.
Source: SCS (1972).

If P is less than 0.2S, P_e is assumed to be zero. The rainfall excess P_e has units of inches. In this method, the abstraction S is related to the "curve number" CN as in Eq. (32.7)

$$S = \frac{1000}{CN} - 10 \tag{32.7}$$

The curve number CN is also related to soil types and land uses. Soils are divided into four classes A through D, based on infiltration characteristics. Type A soils have the maximum and D soils the minimum infiltration capacity with B and C soils falling in between. Tables containing soil names and types are available in SCS (1972) and a portion of this table is shown in Table 32.4. Curve numbers for selected land use and Antecedent Moisture Condition (AMC (II) (SCS, 1972) are shown in Table 32.5.

Application of the SCS Method

In order to use this method, the area A is subdivided into subareas $A_1, A_2,\ldots A_n$ so that each of the subareas has a uniform land use. By identifying the soil types and land uses in each of these subareas, the CN values for the subareas are estimated from Table 32.5. The rainfall excess P_e is computed by Eq. (32.6). A rainfall excess hyetograph may then be computed by using the Huff curves as discussed in

Section 31.2. The rainfall excess hyetograph thus generated may be used with the SCS - unit hydrograph method to compute a direct runoff hydrograph. The direct runoff hydrograph can be used to size collection and conveyance systems and to estimate detention storage volumes, Mays (2001).

32.4 Detention Storage Design

The increased runoff volume produced by the urbanization of watersheds can result in downstream flooding. Storage facilities are designed to receive runoff from developed upstream watersheds and release it downstream at a reduced rate. This reduced rate is determined by using parameters fixed by local ordinance or by calculating the available capacity of the downstream storm sewer network. Some of the methods used to compute the required storage volumes of detention storages are discussed in this section.

Types of Storage Facilities

Storage facilities can be divided into two general categories as *detention* and *retention*. These are also called as dry or wet detention ponds. Detention storage is the temporary storage of the runoff that is in excess of that released. After a storm ends, the facility is emptied and resumes its normal function. Ponds, parking lots, rooftops and parks are common detention facilities, which may be designed to temporarily store a limited amount of runoff.

Retention facilities are designed to retain runoff for an indefinite period of time. Water level in retention facilities changes only due to evaporation and infiltration. Ponds and lakes are examples of retention facilities that are used in subdivisions to enhance the overall project.

Computation of Detention Storage Volumes

The primary goal in the design of detention facilities is to provide the necessary storage volume. If infiltration and evaporation are neglected during the runoff period, the continuity equation for a detention pond may be written as in Eq. (32.8),

$$I(t) - O(t) = \frac{\Delta S}{\Delta t} \tag{32.8}$$

where $I(t)$ = inflow to the pond from the sewer network at time (t) (cfs)
$O(t)$ = outflow from the pond into the downstream drainage network at time (t) (cfs)
ΔS = change in storage (ft^3) in time interval Δt (sec)
Δt = time interval

Equation (32.8) may also be written as:

$$\left(I_1 + I_2\right)\frac{\Delta t}{2} - \left(O_1 + O_2\right)\frac{\Delta t}{2} = S_2 - S_1 \tag{32.9}$$

where subscripts 1 and 2 denote the flows and storages at times t_1 and t_2.

When inflow and outflow hydrographs are known, the largest value of $S_2 - S_1$ found in Eq. (32.9) is the required storage. The following is a discussion of some of the methods used to estimate detention storage volumes. For retention facilities the outflow rate is equal to the sum of the evaporation and infiltration rates. These are negligible during a storm and the required volume is therefore equal to the runoff volume.

Storage Determination By Using the Rational Method

The rational method discussed previously is extended to compute detention storage volumes by multiplying the peak flow rate by the storm duration. The allowable peak flow rate (release rate) leaving the

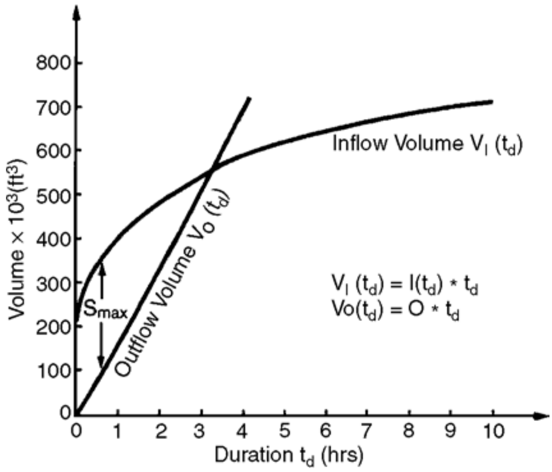

FIGURE 32.2 Graphical representation of storage volumes as determined by the rational method.

detention pond, $O(t)$, is calculated by using the contributing undeveloped area, A_U, the runoff coefficient applicable for undeveloped condition C_U, and rainfall intensity, i_U, associated with the time of concentration of the undeveloped basin. The return period for the intensity i_U is normally fixed by local ordinances or is based on the design parameters of the larger downstream drainage network. The allowable outflow rate is assumed to remain constant for all storm durations, t_d. Therefore the volume corresponding to t_d, $v(t_d)$, is the product of $O(t)$ and t_d. This is illustrated in Fig. 32.2 where the lines $V_I(t_d)$ and V_0 (t_d) are the inflow and outflow volumes at times t_d.

The rate of inflow to the detention basin, $I(t)$, is calculated by using the contributing developed area, A_D, the developed runoff coefficient, C_D, and a rainfall intensity, i_D, corresponding to storm duration, t_d, and the return period. Thus, for various durations, the peak flow and the volume of runoff are computed. The maximum difference between the inflow and outflow volumes is the required detention pond storage. This is shown in Fig. 32.2 as S_{max}. The method may also be expressed as in Eq. (32.10),

$$S\left(t_d\right) = \left[C_D i_D A_D - C_u i_u A_u\right] \frac{td}{12} \tag{32.10}$$

where $S(t_d)$ = the required storage (acre - ft)
t_d = the storm duration in hours.

Various storm durations, t_d, are selected and the largest value of $S(t_d)$ is selected as the required volume of the detention pond.

The procedure to size detention storage facility by using the rational method is as follows: (1) The area, A_U, runoff coefficient, C_U, and time of concentration for the undeveloped site are determined. By using the appropriate intensity-duration-frequency curve, the intensity, i_U, corresponding to the return period for the allowable outflow rate is estimated. (2) The runoff (O) from the undeveloped site ($O = C_U\ i_U\ A_U$) is computed. (3) The runoff coefficient corresponding to the developed conditions, C_D is estimated. (4) The rainfall intensities (i_d) for various durations, (t_d) are obtained for different return periods. Recommended durations are 10, 20, 30, 40, 50 min. and 1, 1.5, 2, 3, 4, 5, 6, 7, 8, 9 and 10 hours. (5) The inflow rate to the detention pond, $I(t_d) = C_D\ i_d\ A_D$ is computed. (6) The required storage for each duration, is calculated. (7) The largest volume $S(t_d)$ is selected as the design volume.

Various agencies have set guidelines for selection of i_U, i_D, C_U and C_d. For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC), uses the criteria that i_U should be is based on a 3-year return period, i_d is based on a 100-year return period, C_U should be less than or equal to 0.15 and C_D should be 0.45 for pervious areas and 0.9 for impervious areas.

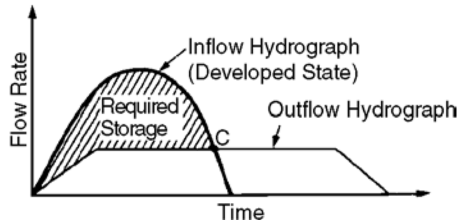

FIGURE 32.3 Inflow and outflow hydrographs for a hypothetical detention pond.

It may be impossible to collect and convey all of the runoff from a given watershed under certain conditions. The result is that some runoff is discharged directly into the downstream drainage network without being detained. To compensate for this unrestricted release, the allowable release rate, O, is reduced by that amount.

Soil Conservation Service Hydrograph Method

Methods were discussed in Section 32.3 by which the stormwater runoff hydrographs can be estimated by the SCS method. These hydrographs are used to compute detention storage volume.

As previously described, the difference between the inflow from the developed watershed and the allowable outflow from a detention pond is the required storage volume. The outflow is determined by using characteristics of the undeveloped watershed and a rainfall frequency equal to or less than that which a receiving system can handle, or is prescribed by local ordinance.

Figure 32.3 shows an inflow and a outflow hydrographs. The difference between the hydrographs, which is the required storage, is shown as the shaded region. At point C, the detention pond inflow rate is equal to the outflow rate when it will start to empty. In Fig. 32.3 the outflow rate is assumed to remain constant. The outflow rate will depend upon the depth of water in the pond and the type of outlet structure (i.e., weir, orifice or pipe). It should also be noted that for a detention pond, the inflow and outflow volumes are equal.

The following is an outline of the procedure used to determine the required storage volume by the SCS hydrograph method. (1) Calculate the curve numbers for the basin in developed and undeveloped condition. (2) Find the time of concentration t_c for the basin in undeveloped and developed condition. (3) From t_c, calculate the duration of the unit hydrograph ΔD, t_p and q_p for the developed and undeveloped basins. (4) Determine the coordinates of the inflow and outflow unit hydrographs. (5) From the design storm duration, depth, time distribution and frequency, calculate the cumulative rainfall at ΔD intervals for both the undeveloped and developed states. (6) Using the basin curve number and ultimate abstraction S, calculate the cumulative runoff, $P_e(t_d)$ at each ΔD interval by using the rainfall data in Step 5. (7) Calculate the storm hydrographs by using the effective rainfall and direct runoff data. (8) Using the peak flow from the undeveloped state as the peak outflow, calculate the outflow hydrograph as determined by the type of outflow structure. (9) Calculate the required storage by using the developed hydrograph and outflow data or by using routing methods.

Detention Storage Layout

Once the amount of detention storage is determined, a storage facility must be designed to accommodate the inflow of runoff and control the release rate. Typical detention storage layout consists of providing a detention pond with the inflow on one side of the pond and the outlet on the other side of the pond. The first criterion in sizing a detention pond is to determine the outlet elevation that is usually controlled by the elevation of the downstream receptor. The downstream receptor may be a storm sewer, water body (i.e., pond, lake, stream or channel) field tile or culvert. The hydraulic conditions of the downstream receptor must be analyzed to determine if there will be any tailwater effects (depending on the design conditions) on the outlet of the detention storage facility. Knowing the outlet elevation of the downstream receptor will give a good approximation of the elevation of the detention pond restrictor elevation. The

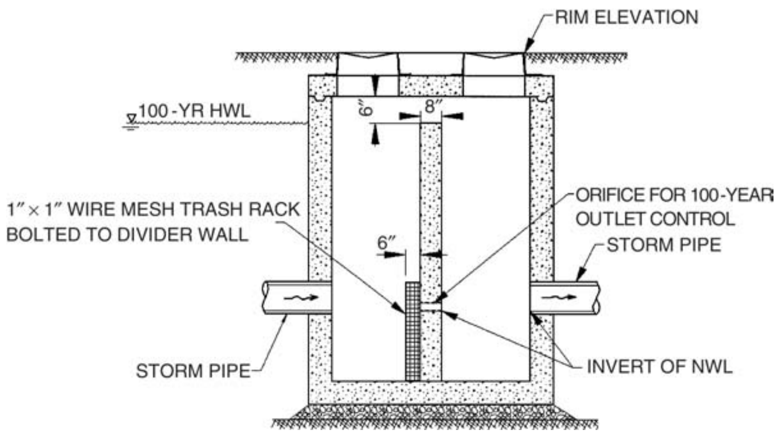

FIGURE 32.4 Detention basin control structure for single release rate.

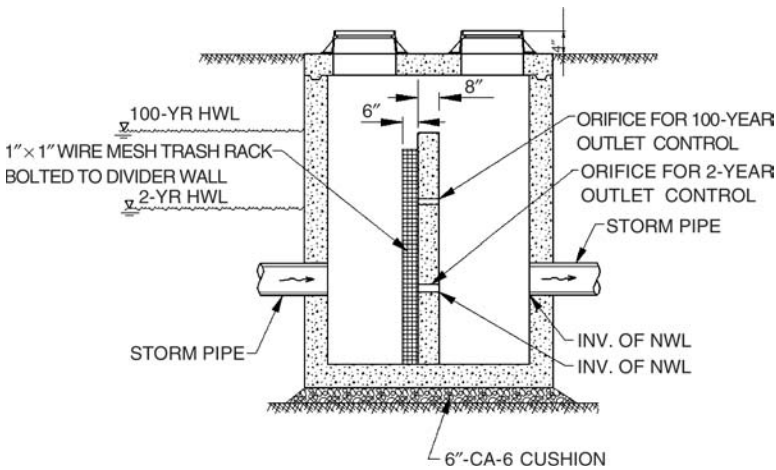

FIGURE 32.5 Detention basin control structure with concrete wall for dual release rate. NWL is the normal water level.

designer needs to decide whether the pond will be wet bottom or dry bottom depending on site characteristics (i.e., groundwater table, soil characteristics, surrounding land use, etc.). The detention pond size and layout can then be determined accounting for the site topography and available area.

The next step in designing the detention pond is to determine the restrictor size. When the regulations require a single outlet release rate for a given storm event and duration, a restrictor size is determined using the orifice equation. The restrictor is placed at the bottom elevation of the pond. Or, in the case of a wet bottom pond, at the normal water level. Figure 32.4 shows an example of a restrictor drilled through a wall constructed inside a manhole. Some regulatory agencies require a 2-stage restrictor outlet control. For example, the 2-year release rate is set at 0.04 cfs per tributary acre and the 100-year release rate is set at 0.15 cfs/acre. In this situation the 2-year release rate restrictor is set at the bottom of the pond and the 100-year release rate restrictor is set at the 2-year high water elevation. Figures 32.5 and 32.6 show two examples for the 2-stage restrictor outlet controls.

Because the controlled rate is often low, it is not uncommon to have a very small restrictor size, even in the range of 1 to 2 in. for smaller tributary areas and 5 to 6 ft of bounce (elevation between the design normal water level and high water level. Some regulatory agencies require a minimum restrictor size of 4 in. For those agencies that do not have a minimum and where the restrictor size is small, it is important to protect the opening from being blocked and provide for an overflow weir that conveys the overtopping

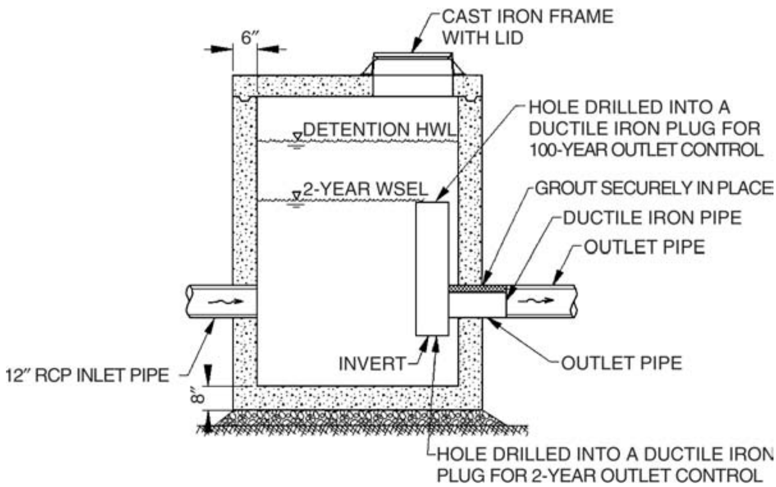

FIGURE 32.6 Detention basin control structure with ductile iron plug for dual release rate.

water to the downstream receptor. Figure 32.5 has a trash rack to collect any debris from blocking the restrictor and an overflow weir set at the high water level.

In areas where the value of the land is high enough that it is too costly to use a sizeable portion of the project site for a detention storage pond there are several alternatives. The first alternative is to refine the pond layout by using retaining walls on some or all sides of the detention pond. Another more costly alternative is to provide underground storage.

Underground storage is expensive but an economic decision that the property owner may choose to consider. The storage is usually obtained by providing laterals of storm sewers laid next to each other or by providing an underground storage vault, which could consist of concrete box culverts. The choice of storm sewer material for underground storage is one of either concrete, corrugated metal or high-density polyethylene. Pipe manufacturers have recently come out with some more efficient layouts that maximize the amount of storage provided for each lateral. There are benefits and concerns for each of the three types of storm sewers that provide underground detention that must be weighed by the design engineer for the circumstances of the particular application. Some things for the design engineer to consider when selecting the underground storage option are: conflicts with existing or proposed utilities, the experience of the contractor installing the system and the loads on top of the storm sewer system.

Defining Terms

Rational method — A method to estimate peak runoff from small watersheds.

Time of concentration — Time taken by runoff to travel from the hydraulically most distant point on the watershed to the point of interest.

Inlet time — Time taken by water to reach inlets.

Detention storage — Storage used to temporarily store storm water and to release it gradually after the storm is over.

Retention storage — A facility to store storm water. The stored water is allowed to infiltrate and evaporate.

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