Storm Drainage Systems

Answers

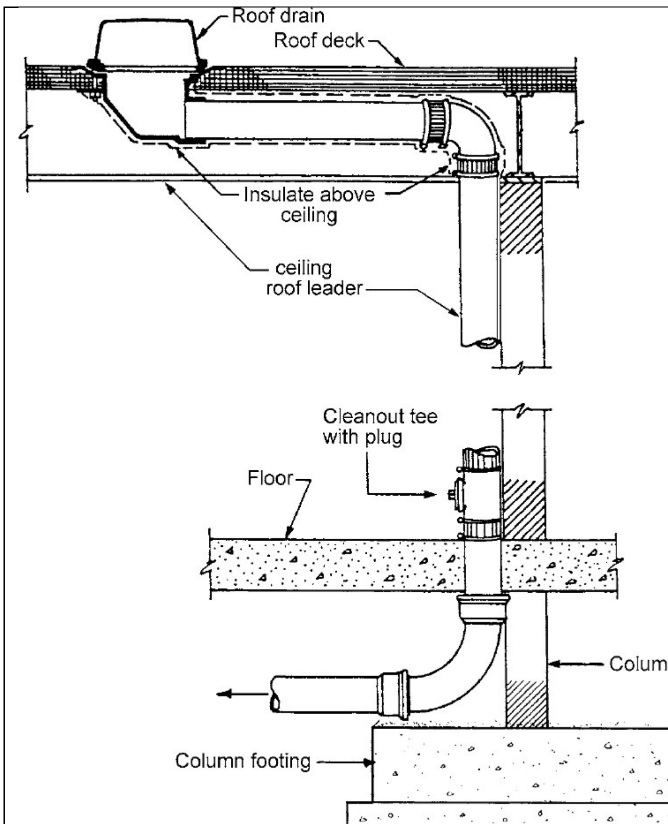
Purpose: Convey rainwater from building roof drains, area drains, subsoil drains, and foundation drains to a point of discharge, subsurface dispersal, or reuse.

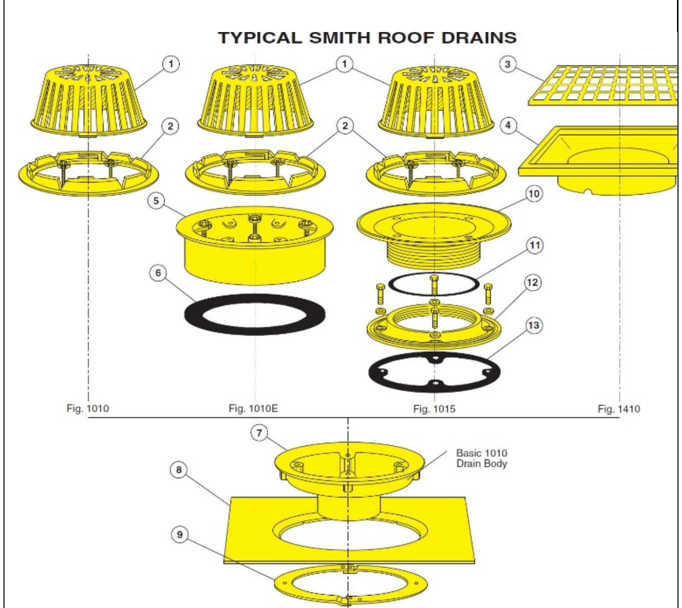
Authority Having Jurisdiction (AHJ) Regulates the Discharge Point:
Municipal Sewer
Combined Sewer
Ground Surface
Subsurface

Codes, Standards, and Regulations
Environmental protection laws establish the requirements for groundwater and surface-water protection.
Environmental agencies regulate watersheds based on specific locations.
Local codes, ordinances and laws are the primary requirements used and must be obtained from the local AHJ.
Clean Water Act (CWA)
U.S. Environmental Protection Agency (EPA)
National Pollutant Discharge Elimination System (NPDES)

Materials
Stormwater system components include piping, fittings, bedding, backfill, supports and hangers, fixtures, and treatment devices. Must be approved by the AHJ

Interior Building Drainage System
Based on local code requirements. All designs must meet or exceed the local code requirements.





ROOF DRAIN PARTS LIST

NO.	DESCRIPTION	NO.	DESCRIPTION
1	High Density Polyethylene Dome	7	Drain Body
2	Combined Cast Iron Flashing Clamp and Gravel Stop	8	Sump Receiver
3	Secured Square Hole Grate	9	Underdeck Clamp
4	Flashing Clamp for Square Grate	10	Adjustable Extension Sleeve
5	Fixed Extension	11	O-Ring Gasket
6	Fixed Extension Gasket	12	Reversible Collar
		13	Neoprene Gasket

Typical Roof Drain and Roof Leader

Sizing Roof Drainage System

The sizing of the roof drainage system must consider all components: the rain storm, the flow of rainwater on the roof surface, the ability of the roof drain to move the water from the roof to the piping, the vertical piping, the horizontal piping and the connection to the point of discharge.

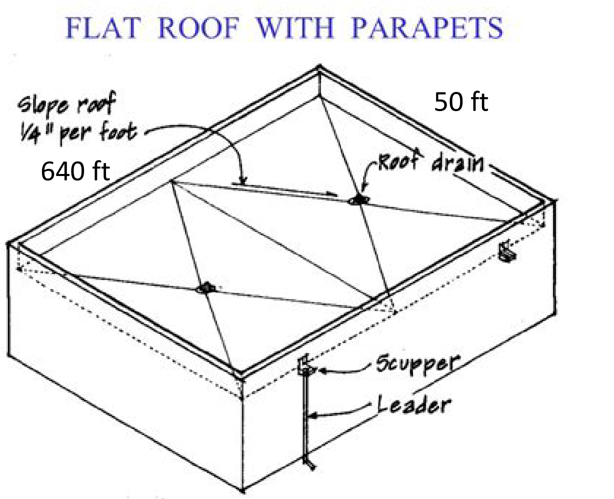
Four Steps to Sizing Roof Drains on a Building

1. Determine 100-year, 1-hour rainfall rate used for location of building
2. Select number of roof drains and calculate the roof area sloped to each drain
3. Size horizontal storm drainage piping
4. Size vertical storm drainage piping

2016 California Plumbing Code - Appendix D Sizing Storm Water Drainage Systems provides maximum rates of rainfall for U.S. various cities based on inches per hour that may fall during a storm of one-hour duration and a 100-year return period. In other words, a storm so severe and with so much rain it will only occur once in 100 years. The goal is to plan for the absolute worst and be able to easily accommodate the typical rainfall amounts.

Example 1.

The building shown is in Redding, California. Determine the minimum size drain, horizontal drainage pipe and leader that can be used for the drainage design shown.



Roof Area = 50 ft x 640 ft = 32.000 ft^2

16,000 ft^2 per drain

1. Appendix D – Table D 101.1 1.5 inches per hour

TABLE D 101.1
MAXIMUM RATES OF RAINFALL FOR VARIOUS CITIES* (continued)

STATES AND CITIES	STORM DRAINAGE 60-MINUTE DURATION, 100-YEAR RETURN	
	inches per hour	gallons per minute per square foot
CALIFORNIA	–	–
Eureka	1.5	0.016
Lake Tahoe	1.3	0.014
Los Angeles	2.0	0.021
Lucerne Valley	2.5	0.026
Needles	1.5	0.016
Palmdale	3.0	0.031
Redding	1.5	0.016
San Diego	1.5	0.016
San Francisco	1.5	0.016
San Luis Obispo	1.5	0.016

2. Two Drains, 1/4" per 12" slope
   Size the Drain: For 1.5 inches per hour use Note 2.

   34 600 / 1.5 = 23 067 → 5" drain required

TABLE 1101.12
SIZING ROOF DRAINS, LEADERS, AND VERTICAL RAINWATER PIPING[2, 3]

SIZE OF DRAIN, LEADER, OR PIPE	FLOW	MAXIMUM ALLOWABLE HORIZONTAL PROJECTED ROOF AREAS AT VARIOUS RAINFALL RATES (square feet)											
inches	gpm[1]	1 (in/h)	2 (in/h)	3 (in/h)	4 (in/h)	5 (in/h)	6 (in/h)	7 (in/h)	8 (in/h)	9 (in/h)	10 (in/h)	11 (in/h)	12 (in/h)
2	30	2880	1440	960	720	575	480	410	360	320	290	260	240
3	92	8800	4400	2930	2200	1760	1470	1260	1100	980	880	800	730
4	192	18 400	9200	6130	4600	3680	3070	2630	2300	2045	1840	1675	1530
5	360	34 600	17 300	11 530	8650	6920	5765	4945	4325	3845	3460	3145	2880
6	563	54 000	27 000	17 995	13 500	10 800	9000	7715	6750	6000	5400	4910	4500
8	1208	116 000	58 000	38 660	29 000	23 200	19 315	16 570	14 500	12 890	11 600	10 545	9600

For SI units: 1 inch = 25 mm, 1 gallon per minute = 0.06 L/s, 1 inch per hour = 25.4 mm/h, 1 square foot = 0.0929 m^2

Notes:

[1] Maximum discharge capacity, gpm (L/s) with approximately 1¾ inch (44 mm) head of water at the drain.

[2] For rainfall rates other than those listed, determine the allowable roof area by dividing the area given in the 1 inch per hour (25.4 mm/h) column by the desired rainfall rate.

[3] Vertical piping shall be round, square, or rectangular. Square pipe shall be sized to enclose its equivalent roundpipe. Rectangular pipe shall have not less than the same cross-sectional area as its equivalent round pipe, except that the ratio of its side dimensions shall not exceed 3 to 1.

3. Size the Horizontal Drainage Pipe

   30 200 / 1.5 = 20 133 → 6" pipe is required

TABLE 1101.8
SIZING OF HORIZONTAL RAINWATER PIPING[1, 2]

SIZE OF PIPE	FLOW (⅛ inch per foot slope)	MAXIMUM ALLOWABLE HORIZONTAL PROJECTED ROOF AREAS AT VARIOUS RAINFALL RATES (square feet)					
inches	gpm	1 (in/h)	2 (in/h)	3 (in/h)	4 (in/h)	5 (in/h)	6 (in/h)
3	34	3288	1644	1096	822	657	548
4	78	7520	3760	2506	1880	1504	1253
5	139	13 360	6680	4453	3340	2672	2227
6	222	21 400	10 700	7133	5350	4280	3566
8	478	46 000	23 000	15 330	11 500	9200	7670
10	860	82 800	41 400	27 600	20 700	16 580	13 800
12	1384	133 200	66 600	44 400	33 300	26 650	22 200
15	2473	238 000	119 000	79 333	59 500	47 600	39 650

SIZE OF PIPE	FLOW (¼ inch per foot slope)	MAXIMUM ALLOWABLE HORIZONTAL PROJECTED ROOF AREAS AT VARIOUS RAINFALL RATES (square feet)					
inches	gpm	1 (in/h)	2 (in/h)	3 (in/h)	4 (in/h)	5 (in/h)	6 (in/h)
3	48	4640	2320	1546	1160	928	773
4	110	10 600	5300	3533	2650	2120	1766
5	196	18 880	9440	6293	4720	3776	3146
6	314	30 200	15 100	10 066	7550	6040	5033
8	677	65 200	32 600	21 733	16 300	13 040	10 866
10	1214	116 800	58 400	38 950	29 200	23 350	19 450
12	1953	188 000	94 000	62 600	47 000	37 600	31 350
15	3491	336 000	168 000	112 000	84 000	67 250	56 000

4. Size the Vertical Drainage Pipe
   Table 1101.12

   34 600 / 1.5 = 23 067 → 5" pipe is required

   The size of a storm water drainage pipe shall not be reduced in the direction of flow.
   → 6" leader pipe is required

What are the minimum requirements for the scupper?

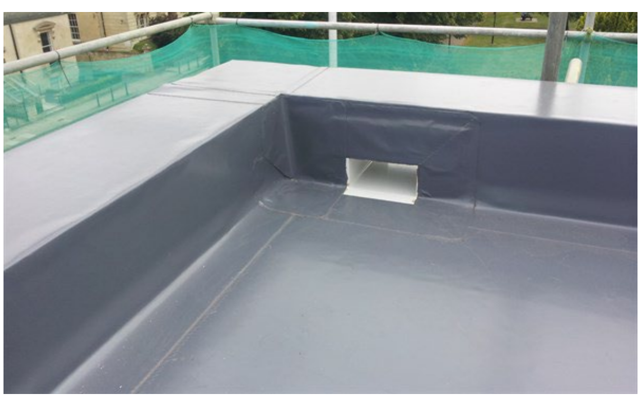
1101.12.2 Secondary Drainage. Secondary (emergency) roof drainage shall be provided by one of the methods specified in Section 1101.12.2.1 or Section 1101.12.2.2.

1101.12.2.1 Roof Scuppers or Open Side. Secondary roof drainage shall be provided by an open-sided roof or scuppers where the roof perimeter construction extends above the roof in such a manner that water will be entrapped. An open-sided roof or scuppers shall be sized to prevent the depth of ponding water from exceeding that for which the roof was designed as determined by Section 1101.12.1. Scupper openings shall be not less than 4 inches (102 mm) high and have a width equal to the circumference of the roof drain required for the area served, sized in accordance with Table 1101.12.

Opening – not less than 4 inches high

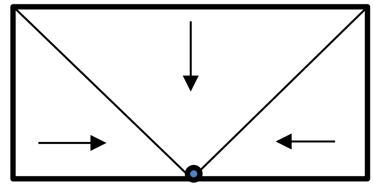
Width – equal to the circumference of the roof drain required for the area served

Height – not less than 2 inches above the roof surface
(prevent ponding) - structural



Example 2.
Size a horizontal roof drain serving 14,000 square feet of roof area on a building in Minneapolis, MN.

1. Appendix D – 2016 California Plumbing Code Table D101.1 (60 min, 100 yr)
   Minneapolis MN – Always Check Code Amendments
   Minnesota Plumbing Code — 1101.11 Roof Drainage
   1101.11.1 Primary Roof Drainage
   "Shall be sized on a basis of a rate of rainfall at a minimum 4 inches per hour."
2. Number of drains and area sloped to each drain. 1 drain



3. Size Horizontal Drainage Pipe Required pipe size is 10"

TABLE 1101.7
SIZING OF HORIZONTAL RAINWATER PIPING[1, 2]

SIZE OF PIPE	FLOW (1/8 inch per foot slope)	MAXIMUM ALLOWABLE HORIZONTAL PROJECTED ROOF AREAS AT VARIOUS RAINFALL RATES (square feet)					
inches	gpm	1 (in/h)	2 (in/h)	3 (in/h)	4 (in/h)	5 (in/h)	6 (in/h)
3	34	3288	1644	1096	822	657	548
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12	1384	133 200	66 600	44 400	33 300	26 650	22 200
15	2473	238 000	119 000	79 333	59 500	47 600	39 650

4. Size the Vertical Drainage Pipe Minimum size of Leader pipe size is 8"

TABLE 1101.11
SIZING ROOF DRAINS, LEADERS, AND VERTICAL RAINWATER PIPING[2, 3]

SIZE OF DRAIN, LEADER, OR PIPE	FLOW	MAXIMUM ALLOWABLE HORIZONTAL PROJECTED ROOF AREAS AT VARIOUS RAINFALL RATES (square feet)											
inches	gpm[1]	1 (in/h)	2 (in/h)	3 (in/h)	4 (in/h)	5 (in/h)	6 (in/h)	7 (in/h)	8 (in/h)	9 (in/h)	10 (in/h)	11 (in/h)	12 (in/h)
2	30	2880	1440	960	720	575	480	410	360	320	290	260	240
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Notes:

1 Maximum discharge capacity, gpm (L/s) with approximately 1¾ inch (44 mm) head of water at the drain.

2 For rainfall rates other than those listed, determine the allowable roof area by dividing the area given in the 1 inch per hour (25.4 mm/h) column by the desired rainfall rate.

3 Vertical piping shall be round, square, or rectangular. Square pipe shall be sized to enclose its equivalent roundpipe. Rectangular pipe shall have not less than the same cross-sectional area as its equivalent round pipe, except that the ratio of its side dimensions shall not exceed 3 to 1.

1106.3 Reduction in Size Prohibited. Except for siphonic roof drainage systems, storm drain piping shall not reduce in size in the direction of flow, including changes in direction from horizontal to vertical.

Leader pipe must be 10"

Designing a Stormwater Harvesting System

General rule of thumb when sizing a cistern to capture rainfall is that 1-inch rainfall from a 1000 square foot roof will generate approximately 600 gallons of runoff.

Cistern Volume

Equation $V = A^2 \times i \times c \times 7.5\ gal/ft^3$

V = volume of rain barrel (gallons)

A^2 = surface area roof (square feet)

i = rainfall (1 inch = 0.08 ft)

c = coefficient of runoff (0.9 for impervious areas)

7.5 = conversion factor (gallons per cubic foot)

Example 3

Calculate the volume of runoff that can be captured from a 3500 square foot roof in Chico, CA.

Historic Average

Home » Local » Historic Averages

Chico, California

Weather Report · Interactive Map · Extended Forecast · Hourly Forecast · Past Observations · Historic Averages

Monthly Averages & Records - °F | °C

Date	Average Low	Average High	Record Low	Record High	Average Precipitation	Average Snow
January	35°	54°	12° (1937)	77° (1920)	5.17"	0.1"
February	39°	60°	16° (1989)	82° (1920)	4.5"	0"
March	42°	65°	23° (1971)	93° (1914)	4.32"	0"
April	45°	72°	27° (1922)	98° (1926)	1.59"	0"
May	51°	80°	30° (1984)	108° (1910)	0.91"	0"
June	57°	88°	38° (1986)	115° (1961)	0.47"	0"
July	61°	93°	40° (1981)	117° (1972)	0.05"	0"
August	59°	92°	38° (1978)	116° (1914)	0.16"	0"
September	55°	88°	35° (1986)	114° (1988)	0.59"	0"
October	47°	79°	23° (1971)	107° (2001)	1.34"	0"
November	40°	63°	20° (1916)	91° (1936)	3.5"	0"
December	35°	54°	11° (1932)	76° (2002)	3.63"	0.1"

Average – 29.76 / 12 = 2.5 inches

Highest Month – 5 inches

Average

$V = 3500\ ft^2 \times 2.5\ in \times 1\ ft/12\ in \times 0.9 \times 7.5\ gal/ft^3 = 3500\ ft^2 \times 0.21\ ft \times 0.9 \times 7.5\ gal/\ ft^3 = 4{,}961$ gallons

Highest Month

$V = 3500\ ft^2 \times 5.0\ in \times 1\ ft/12\ in \times 0.9 \times 7.5\ gal/ft^3 = 3500\ ft^2 \times 0.42\ ft \times 0.9 \times 7.5\ gal/\ ft^3 = 9{,}923$ gallons

Site Drainage and Infiltration
To design stormwater management systems, the science of Hydrology and the calculation of runoff for each particular site are necessary considerations.

The hydrology of a storm event is the basis for all aspects of stormwater management design, including pipe size and selecting appropriate treatment devices and methods.

Methods used to determine volumes and peak flows are historical date.
Precipitation and frequency information can be found on the National Oceanic and Atmospheric Administration's National Weather Service website (nws.noaa.gov).

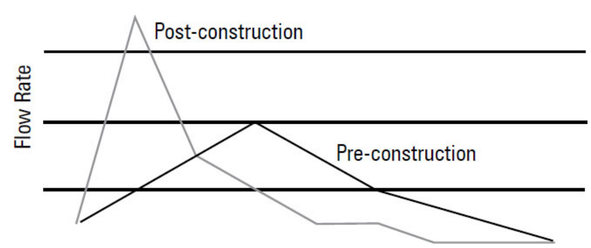
The Rational Method
Many jurisdictions use the Rational Method for calculating peak flow rates.
It translates peak intensity of rainfall directly into peak intensity of runoff.

Q = A c i

Where
Q = Runoff, cfs
A = Drainage area, acres (1 acre = 43,560 square feet)
C = runoff coefficient, dimensionless (see table below)
i = Rainfall intensity, inches per hour
[1 acre-in/hr = 1 acre x 43,560 ft^2/acre x 1 in x 1 ft/12 in x 1 hr/60 min x 1 min/60sec = 43560/43200 = 1.008 cfs]

Table Coefficients for Use with the Rational Method

Type of Surface or Land Use	Runoff Coefficient (c value)
Individual soil covers	
Forest	0.1 – 0.3
Turf or meadow	0.1 – 0.4
Cultivated field	0.3 – 0.4
Steep grassed area (2:1)	0.5 – 0.7
Bare earth	0.2 – 0.9
Gravel or macadam pavement	0.35 – 0.7
Concrete or asphalt pavement	0.8 – 0.9
Composite land uses	
Flat residential, about 30% impervious	0.40
Flat residential, about 60% impervious	0.55
Sloping residential, about 50% impervious	0.65
Flat commercial, about 90% impervious	0.80



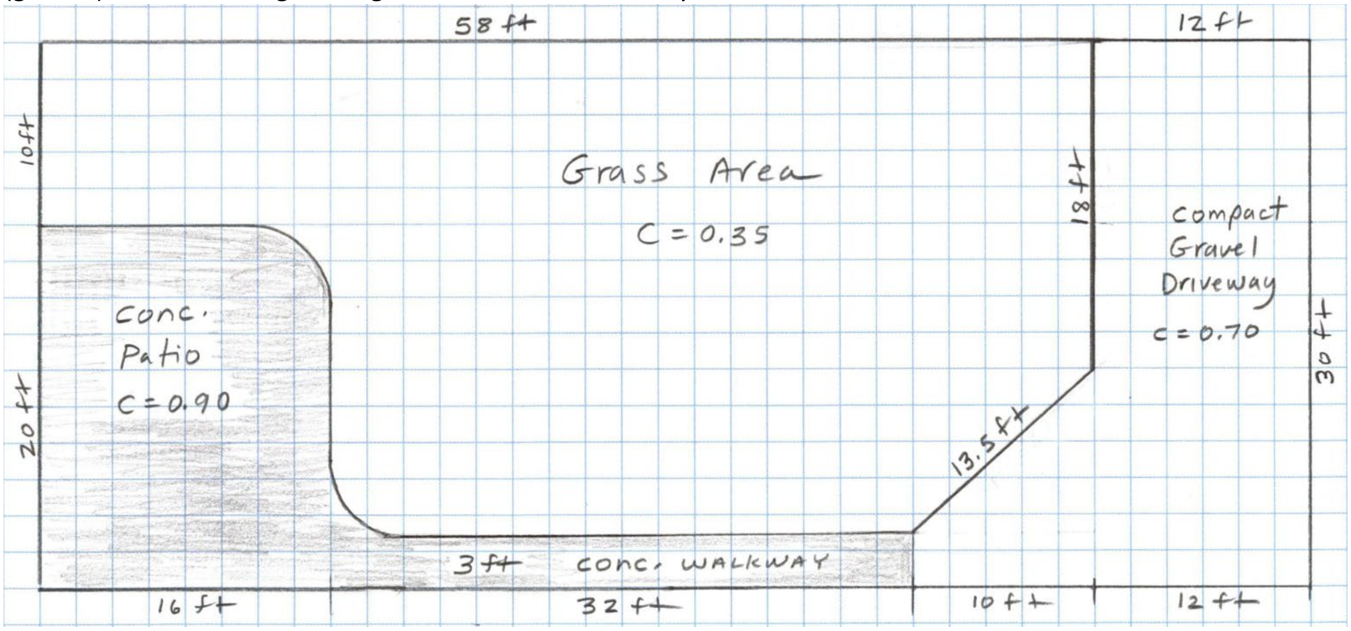
Example 4
Calculate the peak runoff (gpm) for a 1.5-acre site with a concrete or pavement cover and a 4-inches -per-hour rainfall.

Q = A c i
= 1.5-acre x 0.90 x 4 = 5.4 cfs

Convert to gallon per minute (gpm), multiply by 448.8

Q = 5.4 cfs x 448.8 = 2,424 gpm (peak flow rate)
Design must carry the peak flow rate to a treatment device or point of discharge

Example 5
For the residential site shown use the Rational Method to determine the peak runoff rate (gpm) and volume (gallons) for the drainage area given. The rainfall intensity is 4.2 in/hr.



The Rational Method equation is: Q = C x I x A where:
Q = Storm Water Runoff (in cubic feet per second)
C = Coefficient of Runoff
I = Rainfall Intensity (in inches per hour)
A = Area of Drainage Zone (in acres)

The equation above can be modified to give you runoff in gallons per minute.

The modified equation is: Q = (C x I x A) / 96.23 where:
Q = Storm Water Runoff (in gallons per minute, gpm)
C = Coefficient of Runoff
I = Rainfall Intensity (in inches per hour)
A = Area of Drainage Zone (in square feet)

Concrete Area
20 ft x 16 ft + 3 ft x 32 ft = 416 ft^2

Compact Gravel Area
12 ft x 30 ft + ½ x (10 ft x 9 ft) + 3 ft x 10 ft = 435 ft^2

Grass Area
10 ft x 58 ft + 17 ft x 42 ft – 45 ft^2 = 1249 ft^2

Q = [(0.90 x 416) + (0.70 x 435) + (0.35 x 1249) x 4.2] / 96.23 = [(374.4 + 304.5 + 437.15) x 4.2)]/96.23 = 48.7 gpm

Use 60-minute storm:
Volume = 48.7 gpm x 60 min = 2,922 gal