Chapter 8
Drainage Part 2

Roof Consultant Institute

Advanced Roof Consulting

Introduction

- Brief outline about chapter
- Brief outline about presenter

Charts Used in Design

Figure 1 - Chart 1 of SMACNA

CHART 1
DESIGN AREAS FOR PITCHED ROOFS

PITCH	*B
Level to 3 in./ft	1.00
4 to 5 in./ft	1.05
6 to 8 in./ft	1.10
9 to 11 in./ft	1.20
12 in./ft	1.30

*To determine the design area, multiply the plan area by the factor in column B.

Charts Used in Design

Figure 2 - Chart 2 of SMACNA

RAINFALL DATA AND DRAINAGE FACTORS

AREA	A STORMS WHICH SHOULD BE EXCEEDED ONLY ONCE IN 5 YEARS		B STORMS WHICH SHOULD BE EXCEEDED ONLY ONCE IN 10 YEARS		C MAXIMUM STORMS	
	Intensity in in/hr lasting 5 minutes	Sq ft of calculated roof drained per sq in. of down-spout area	Intensity in in./hr lasting 5 minutes	Sq ft of calculated roof drained per sq in. of down-spout area	Intensity in in/hr lasting 5 minutes	Sq ft of calculated roof drained per sq in. of down-spout area
Alabama: Birmingham	7	175	7	175	9	130
Arizona: Phoenix	4	300	5	250	7	175
Arkansas: Little Rock	6	200	7	175	9	130
California: Los Angeles	3	400	4	300	6	200
Sacramento	3	400	3	400	5	250
San Diego	3	400	4	300	5	250
San Francisco	3	400	3	400	5	250
Colorado: Denver	5	250	6	200	11	110
Connecticut: Hartford	6	200	7	175	9	130
District of Columbia	7	175	7	175	10	120
Florida: Jacksonville	7	175	8	150	10	120
Miami	7	175	8	150	10	120
Tampa	8	150	9	130	13	95
Georgia: Atlanta	7	175	8	150	11	110
Illinois: Chicago	6	200	7	175	10	120
Indiana: Indianapolis	6	200	7	175	10	120
Iowa: Des Moines	6	200	7	175	10	120
Kansas: Witchita	6	200	7	175	10	120
Kentucky: Louisville	6	200	7	175	10	120
Louisiana: New Orleans	8	150	8	150	12	100
Maine: Portland	4	300	5	250	7	175
Maryland: Baltimore	7	175	8	150	11	110
Massachusetts: Boston	5	250	6	200	8	150
Michigan: Detroit	6	200	7	175	10	120
Minnesota: Minneapolis	6	200	7	175	10	120
Missouri: Kansas City	7	175	8	150	10	120
St. Louis	6	200	8	150	11	110
Montana: Helena	4	300	4	300	6	200
Nebraska: Omaha	6	200	7	175	12	100

Charts Used in Design

Nevada: Reno	3	400	4	300	6	200
New Jersey: Trenton	6	200	7	175	9	130
New Mexico: Albuquerque	4	300	4	300	6	200
New York: Albany	6	200	7	175	9	130
Buffalo	5	250	6	200	10	120
New York City	6	200	8	150	9	130
North Carolina: Raleigh	7	175	8	150	10	120
North Dakota: Bismarck	6	200	7	175	10	120
Ohio: Cincinnati	6	200	7	175	10	120
Cleveland	6	200	7	175	10	120
Oklahoma: Oklahoma City	6	200	7	175	10	120
Oregon: Portland	3	400	3	400	5	250
Pennsylvania: Philadelphia	6	200	7	175	10	120
Pittsburgh	6	200	7	175	9	130
Rhode Island: Providence	5	250	5	250	7	175
South Carolina: Charleston	7	175	7	175	9	130
Tennessee: Memphis	6	200	7	175	10	120
Knoxville	5	250	6	200	9	130
Texas: Fort Worth	6	200	7	175	9	130
Houston	7	175	8	150	11	110
San Antonio	7	175	8	150	11	110
Utah: Salt Lake City	3	400	4	300	6	200
Virginia: Norfolk	6	200	7	175	9	130
Washington: Seattle	3	400	3	400	4	300
Spokane	3	400	3	400	6	200
West Virginia: Parkersburg	6	200	7	175	10	120
Wisconsin: Madison	6	200	6	200	9	130
Milwaukee	6	200	7	175	10	120
Wyoming: Cheyenne	5	250	6	200	8	150

Charts Used in Design

Figure 3 - Chart 3 of SMACNA

DIMENSIONS OF STANDARD DOWNSPOUTS

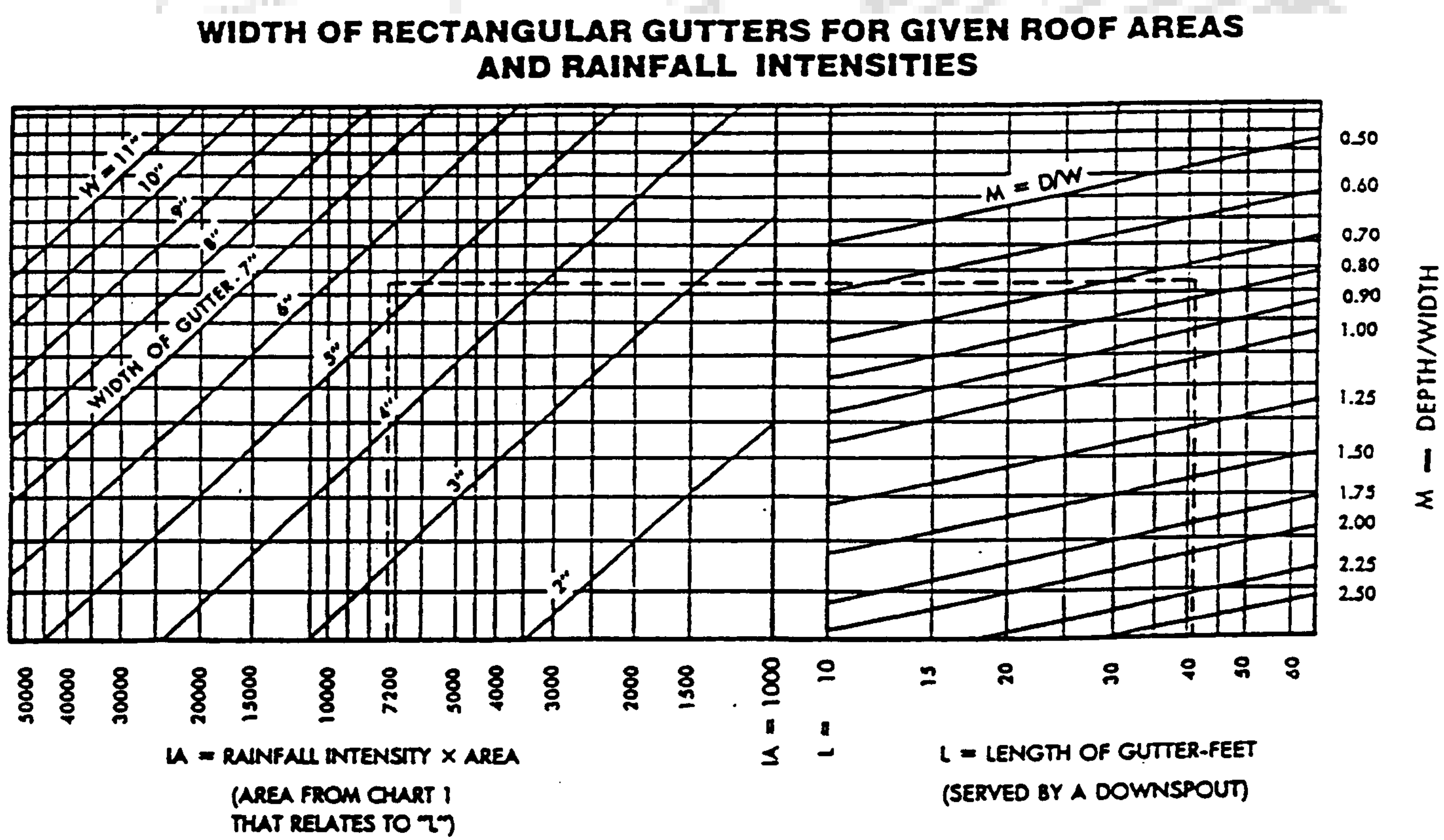
TYPE	Area (sq in.)	"A" (sq in.)	Nominal Size (in.)	Actual Size (in.)
Plain Round	7.07	5.94	3	3
	12.57	11.04	4	4
	19.63	17.71	5	5
	28.27	25.95	6	6
	50.24	47.15	8	8
Corrugated Round	5.94		3	3
	11.04		4	4
	17.72		5	5
	25.97		6	6
Plain Rectangular	3.94	3.00	2	1¾ x 2¼
	6.00	4.80	3	2 x 3
	12.00	10.31	4	3 x 4
	20.00	15.75	5	3¾ x 4¾
	24.00	21.56	6	4 x 6
Rectangular Corrugated	3.80	3.00	2	1¾ x 2¼
	7.73	6.38	3	2⅜ x 3¼
	11.70	10.00	4	2¾ x 4¼
	18.75	16.63	5	3¾ x 5

"A" = area of 1/4" undersized inlet

See Plates 31 and 32 for gage

Figure 4 - Chart 4 of SMACNA

Charts Used in Design

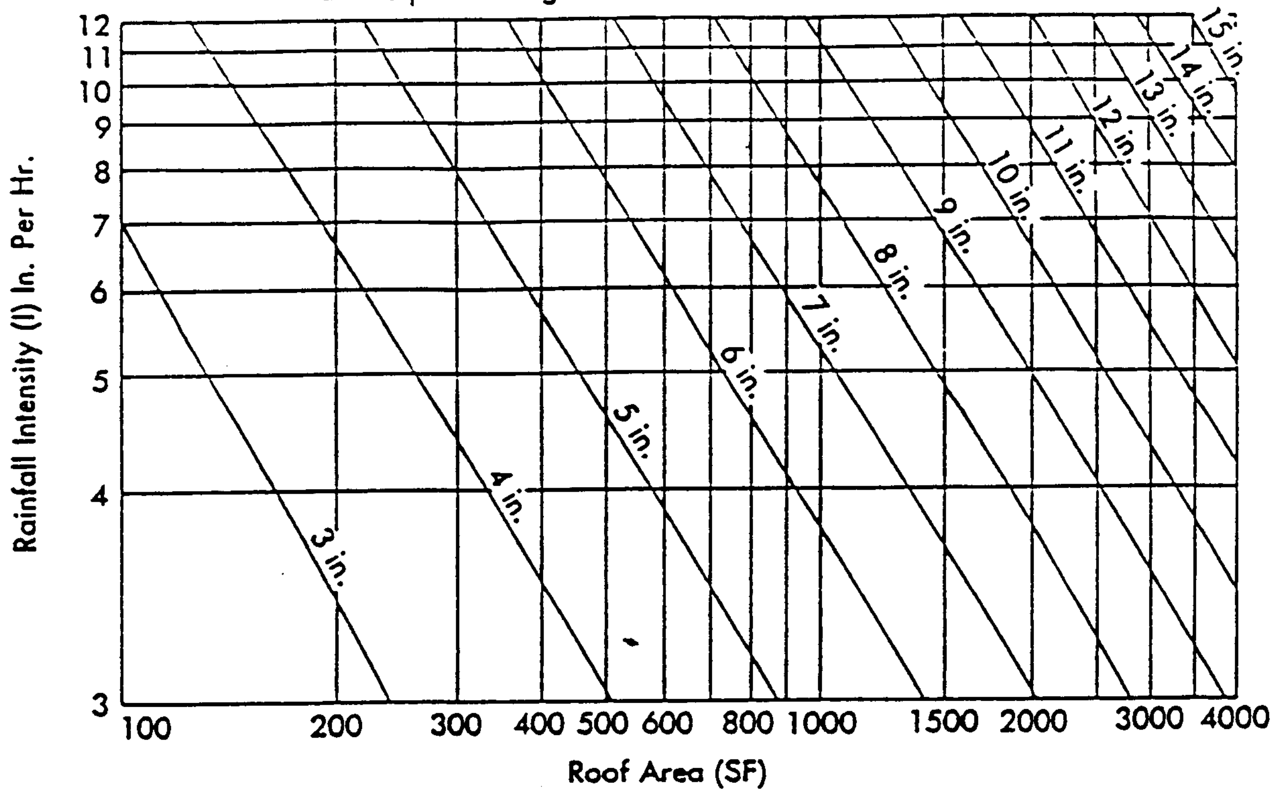


Charts Used in Design

Figure 5 - Chart 5 of SMACNA

HALF ROUND GUTTER SELECTION

Width required for given roof areas and rainfall intensities.



Charts Used in Design

Figure 6 - Chart 6 of SMACNA

SLOPED ROOF GUTTERS

Diameter* of gutter inches	C.S. Area Sq. In.	Maximum Roof Area For Gutters					
		Level		1/8 in. per Ft. Slope		1/4 in. per Ft. Slope	
		Sq. Ft.	gpm	Sq. Ft.	gpm	Sq. Ft.	gpm
3	3.5	680	7	960	10	1,360	14
4	6.3	1,440	15	2,040	21	2,880	30
5	9.8	2,500	26	3,520	37	5,000	52
6	14.1	3,840	40	5,440	57	7,680	80
7		5,520	57	7,800	81	11,040	115
8	25.1	7,960	83	11,200	116	14,400	165
10	39.1	14,400	150	20,400	212	28,800	299

Charts Used in Design

Table 5. Flow Capacity for Roof Drains and Piping[1]

English Units:

Diameter of Drain or Pipe in.	Roof Drains and Vertical Leaders gpm	Horizontal Drainage Piping, gpm Slopes— in. per ft		
		⅛ Slope	¼ Slope	½ Slope
3	90	34	48	69
4	180	78	110	157
5	360	139	197	278
6	540	223	315	446
8	[2]1170	479	679	958
10	—	863	1217	1725
12	—	1388	1958	2775
15	—	2479	3500	4958

Metric Units:

Diameter of Drain or Pipe mm	Roof Drains and Vertical Leaders cu dm/min	Horizontal Drainage Piping, cu dm/min Slopes— percentages		
		1% Slope	2% Slope	4% Slope
75	340	130	180	260
100	680	295	415	595
125	1360	525	745	1050
150	2040	845	1190	1690
200	[2]4420	1815	2570	3625
255	—	3265	4605	6530
305	—	5255	7410	10,500
380	—	9385	13,245	18,770

[1]To ensure achieving these flow capacities, roof drains must be placed at mid-bay, or the roof surfaces must be sloped toward the roof drains (see Sections 3.3.5 and 3.3.7).

[2]Design flow of this capacity is impractical; water must build up approximately 4.5 in. (113 mm) to achieve this flow.

Drainage Design Problem 1

PROBLEM 1.

The entrance to a Mall in Chicago is at the bottom of the valley of a standing seam (roll-locked) metal roof as shown, it has a slope of 3 in 12. The downspouts are to be placed 20 ft o.c., with the first one 10 ft away from the valley in both directions. Design the gutter and downspout sizes for maximum storms.

Drainage Design Problem 1

PROBLEM 1.

Location: Chicago
Storm which exceeds one in ten year
Chicago = 7"

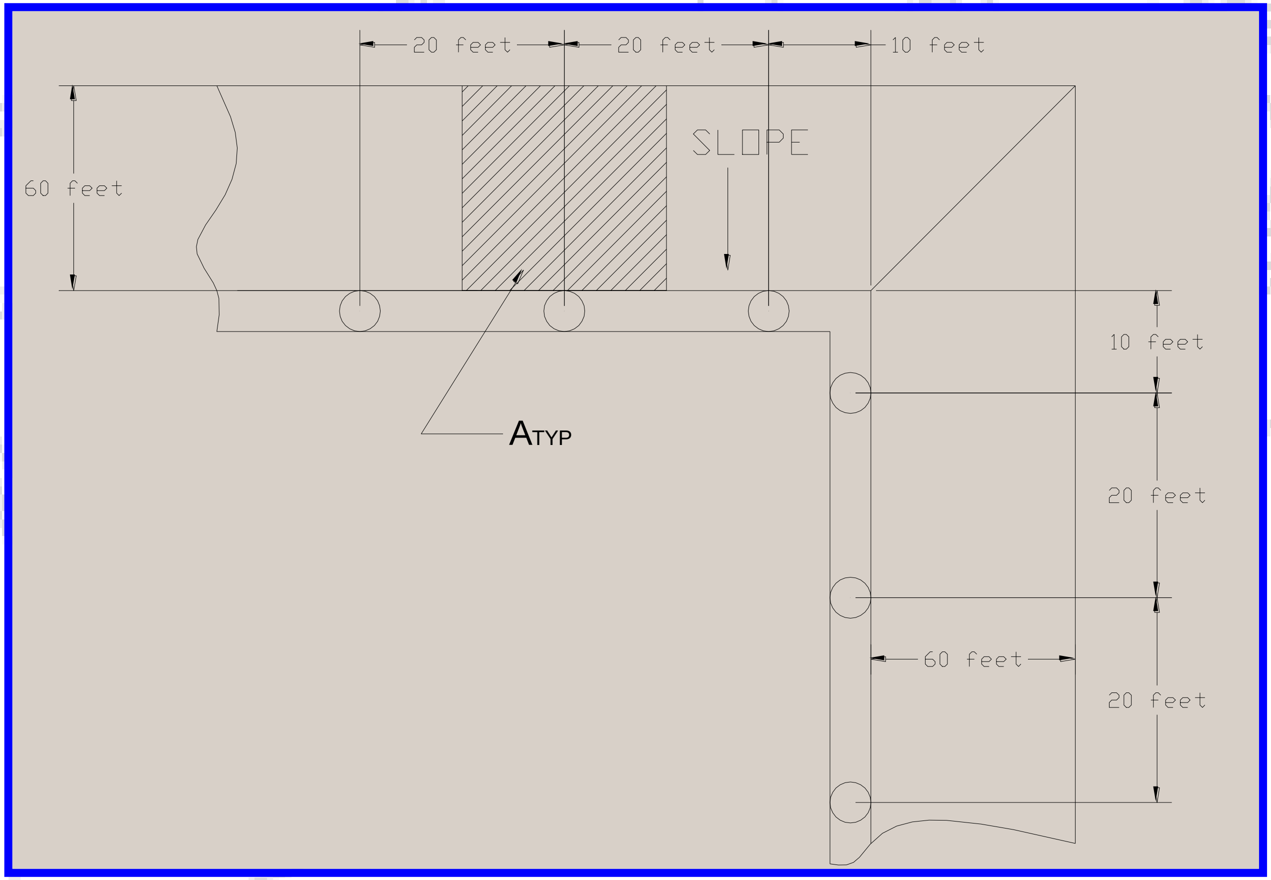
175 ft^2 = Q Downspout Sq. ft. of roof area per sq. in of downspout area

STEP A:
Tributary area for downspout:
A_{typ} = 60 x 20 = 1200

No correction factor 3:12 (see chart 1)

Drainage Design Problem 1

PROBLEM 1.



Drainage Design Problem 1

PROBLEM 1.

Assume gutter ration of 0.75
M = D/W = 0.75
A = 1200 x 7 = 8400
Gutter length is 20'

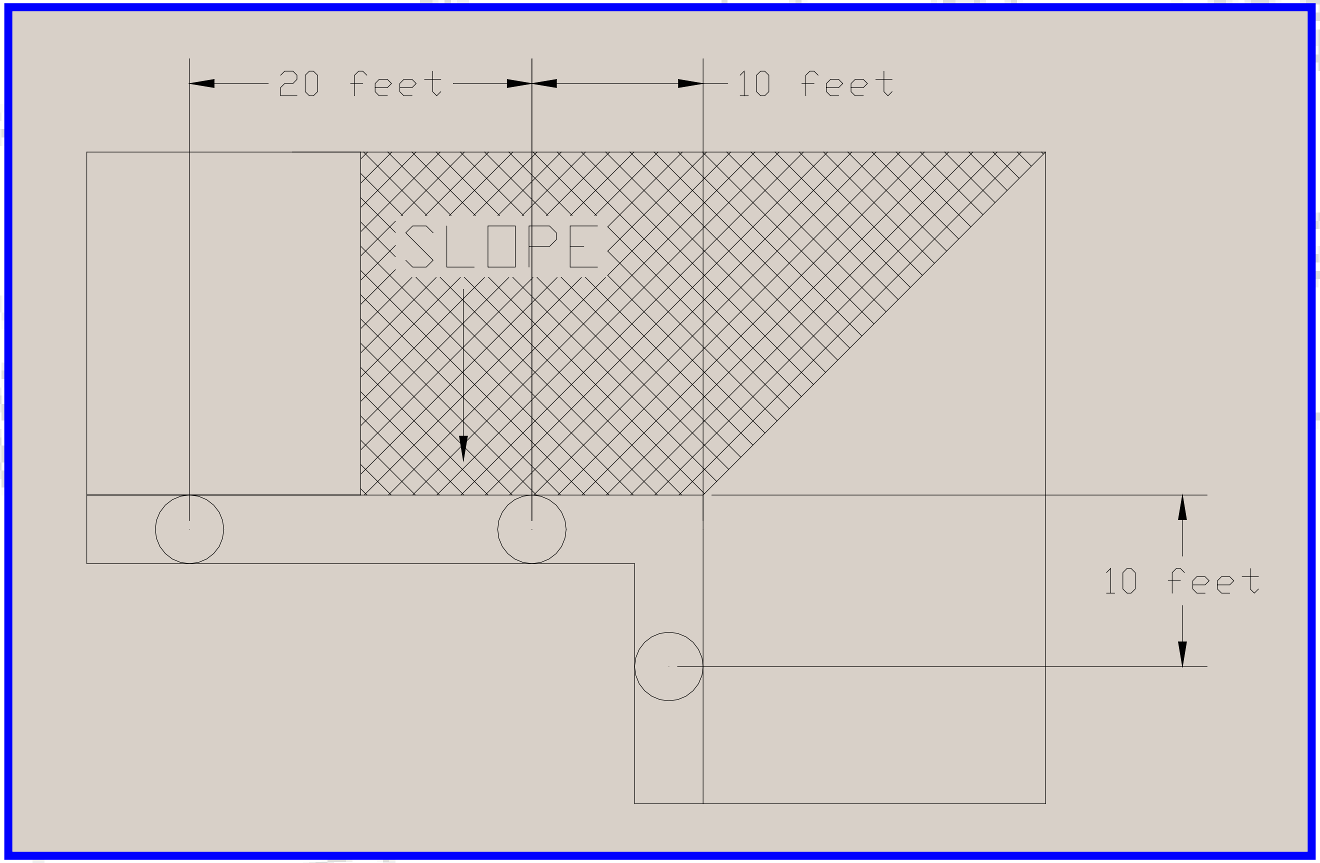
From Chart 4
Assume 6" width of gutter

Depth is 0.75 x 6 = 4.5"
Downspout dimension = 1200/175 = 6.875

Use a nominal 4" gutter

Drainage Design Problem 1

PROBLEM 1.



Drainage Design Problem 1

PROBLEM 1.

$A = 60 \times 20 + (60 \times 60)/2$

$= 60(20 + 30)$

$= 3000\ ft^2$

L = 20 feet

$A = 3000 \times 7 = 21000\ ft^2$

Assume D/W = M = 0.75

7" gutter = width

0.75 x 7 = 5.25

Downspout is 21000/(7 x 175) = 120/7 = 17.14 sq. in.

Drainage Design Problem 2

PROBLEM 2.

A similar situation occurs in Los Angeles with an entrance below the valley. This asphalt shingle roof has a slope of 6 in 12. A large downspout is planned with a diagonal gutter receiver at the base of the valley. Determine the size of the downspout at the base of the valley for maximum storms. The downspouts to the sides are 20 feet o.c. starting 10 feet from each side of the valley. What are the sizes of these downspouts and gutters ?

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Drainage Design Problem 2

PROBLEM 2.

Tributary Area Calculations:-

Slope = 6:12 => Chart 1 factor 1.10

Tributary Area for 20 foot down spout

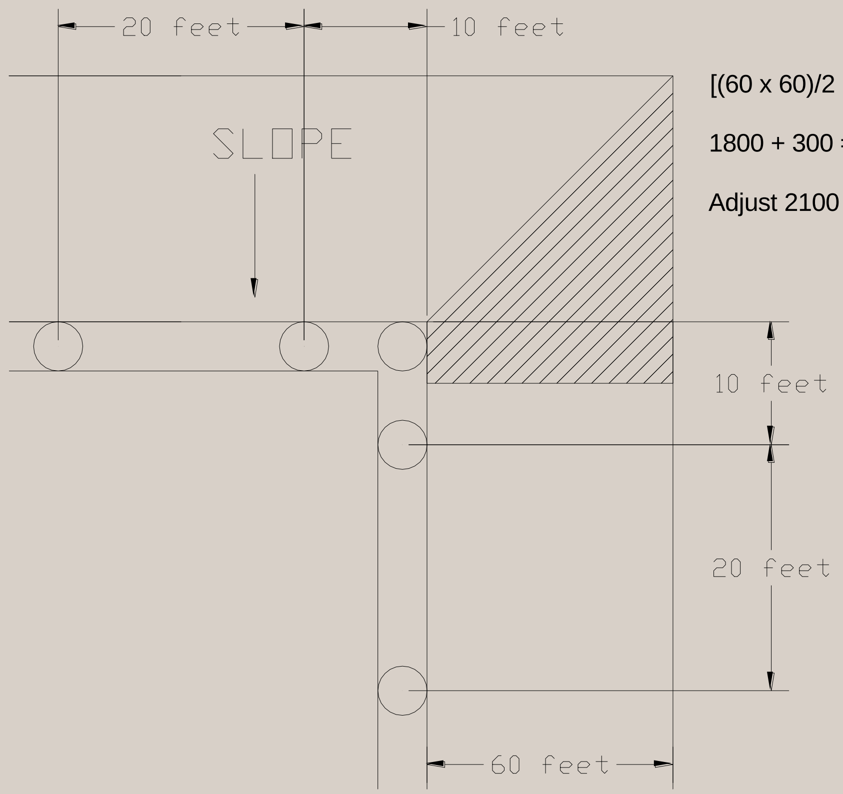
$A_{20} = 20 \times 60 \times 1.10 = 1320\ ft^2$

Tributary Area for 10 foot down spout

$A_{10} = (10 + 5)(60)(1.10) = 990\ ft^2$

Drainage Design Problem 2

PROBLEM 2.



[(60 x 60)/2 = 5 x 60]

1800 + 300 = 2100

Adjust 2100 x 1.10 = 2310 ft^2

Drainage Design Problem 2

PROBLEM 2.

Corner Downspout: (see figure before)

A_{big} = 2(2310) = 4620 ft^2

Intensity of rainfall i = 6" (Maximum Storm)

Downspout roof area = 200 ft^2 for 1" of downspout

Assume M = depth/Width = 0.75

Drainage Design Problem 2

PROBLEM 2.
Calculation for Gutter Sizing:

20 foot gutter L = 20 feet
iA = 6 x 1320 = 7920 ft^2

Check chart width of gutter between 5" and 6"
Assume 6"

10 foot gutter L = 15 feet
iA = 6 x 990 = 5940 ft^2

Check chart width of gutter between 4" and 5"
Assume 5"

Drainage Design Problem 2

PROBLEM 2.

Large gutter L = 10 feet

iA = 6 x 4620 = 27720 ft^2

Check chart width of gutter between 7" and 8"

Assume 8"

Drainage Design Problem 2

PROBLEM 2.

Conclusions:

Use 6" gutter for 20 ft and 10 ft downspouts
Depth = 6 x 0.75 = 4.5"

Use 8" gutter for large downspouts
Depth = 8 x 0.75 = 6"

Both depths do not match other depth for 10 ft. and 20 ft., recompute

Drainage Design Problem 2

PROBLEM 2.

Try M = 4.5/9 = 0.5

Check chart width of gutter between 8" and 9"

Assume 9"

Size Downspouts

1. For large downspout:

A = 4620

A_{spout} = 4620/200 = 23.1 in^2

Use 6" round plain

Drainage Design Problem 2

PROBLEM 2.

2. For 10 foot downspout:

A = 990

A_{spout} = 990/200 = 4.95 in^2

Use 4" rectangular

3. For 20 foot downspout:

A = 1320

A_{spout} = 1320/200 = 6.60 in^2

Use 4" rectangular

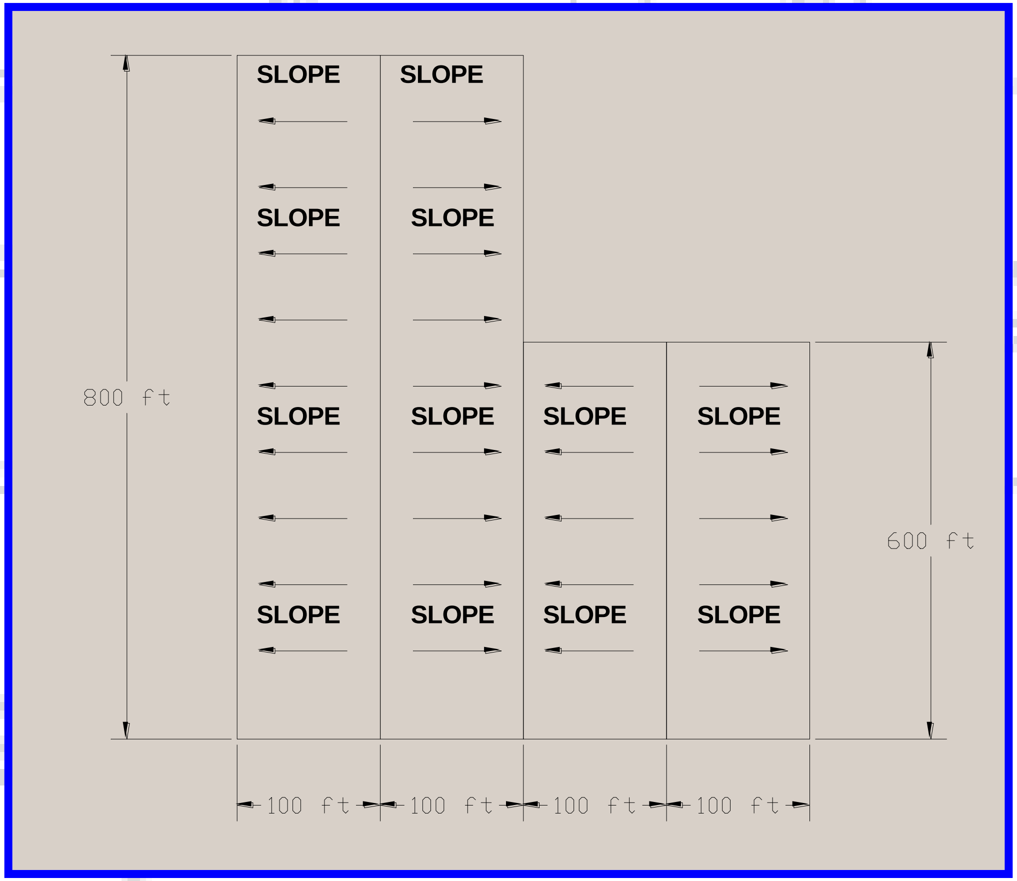
Drainage Design Problem 4

PROBLEM 3.

A warehouse in Boston was 200' x 800' and it had another 200' x 600' building added to. Both the addition and original have a roll locking standing seam metal roof with a slope towards each other as shown and have a common gutter. An 6" by 8" gutter was installed with 6" round outlet 30" o.c. A 6" PVC horizontal drain was run at 1/8" per foot slope to each end of the building. Design for maximum storms. The owner has had leaking at the gutter and you are called in to find out the problem and to design a remedy at the lowest possible cost. The gutter was lined with a single ply membrane, so leaking is not at the gutter joints.

Drainage Design Problem 3

PROBLEM 3.



Drainage Design Problem 3

PROBLEM 3.

Check Design:

Gutter size 8" x 8"
6" round outlets at 30" o.c.

Location is Boston Maximum storm is i =8"

Downspout area 150 ft^2 per 1 in^2 of downspout area

Drainage Design Problem 3

PROBLEM 3.
STEP 1 Check Gutter Design

Tributary Area = 2 x 100 x 30 = 6000 ft^2
Adjust for slope 1 : 12 Factor 1.00
6000 x 1.00 = 6000

M = D/W = 8/8 = 1.00 L= 30 ft

iA = 6000 x 8 = 48000

Check dimensions from chart
Verify 8" x 8" OK
Gutter Design is adequate

Drainage Design Problem 3

PROBLEM 3.

STEP 2 Check Downspout Design

Each downspout takes up 6000 ft^2

$6000/150 = 40\ in^2$

Downspout is inadequate REJECT

Drainage Design Problem 3

PROBLEM 3.

STEP 3 Redesign

6" downspout is 25.95 in^2

Compute excess capacity for each downspout

Number of Downspout 600/30 = 20

Total area drainage:

20 x 25.95 x 150 = 77850 ft^2

Total Roof Area is

2 x (100 x 600) = 120000 ft^2

Drainage Design Problem 3

PROBLEM 3.

Excess capacity to drain is 120000 - 77850 = 42150 ft^2 of roof

Number of downspouts needed is:

42150/150 = 281.06 in^2

Requires additional downspouts;

281/25.95 = 10.8 of 6" downspouts

Drainage Design Problem 3

PROBLEM 3.

Compute maximum capacity of the 6" sloped drain;

6" pipe @ $^{1}/_{8}$ slope = 223 GPM

Compute total rainfall on roof:

120,000 x 0.0104 x 8 = 9984 GPM

Excess water capacity from outlets:

42150 x 0.0104 x 8 = 3506.88 GPM

Add extra outlets 6 on each side of the building

Drainage Design Problem 3

PROBLEM 3.

NOTE:

As an alternate solution , increase the size of the outlet to 8"

Check Design:

20 + 12 = 32 - 6" outlets

32 x 150 x 25.95 = 124560 ft^2 > 120,000 ft^2

Check capacity of 6" PVC pipe per downspout;

0.0104 x 8 x 30 x 200 = 499.20 GPM

Capacity of a 6" downspout is 563 GPM vertical

Design is OK

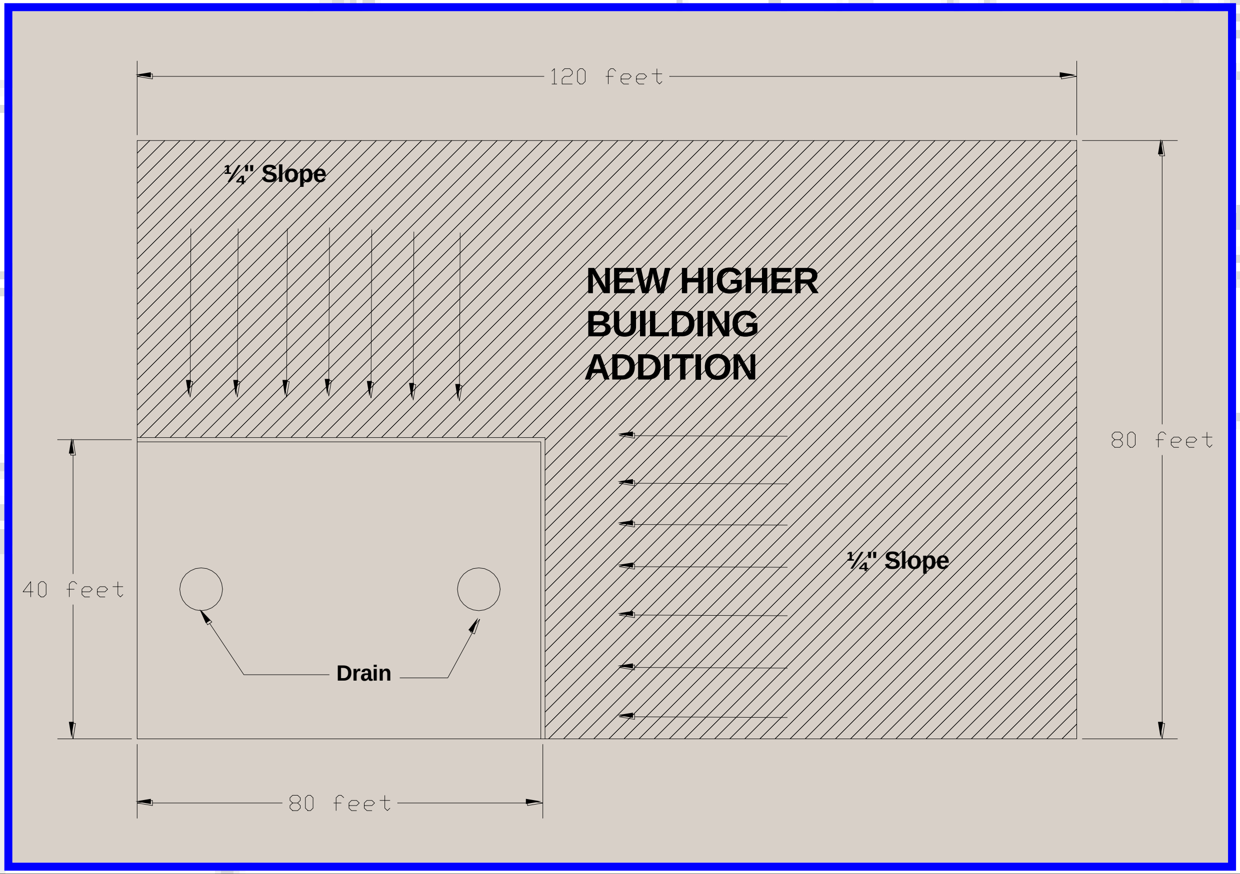
Drainage Design Problem 4

PROBLEM 4. HOMEWORK PROBLEM

A 40' x 80' roof has 2 drains as shown. When an addition was constructed, the new roof which is 10' higher, slopes 1/4" per foot towards the old roof and the water is collected with gutters and the water is dropped to the original roof by a number of downspouts. This building is in Raleigh, NC. Your task is to find the size of the 2 drains needed for maximum storms. The 2 drains are to be connected to a single drain line. Also compute the horizontal drain line size and its slope.

Drainage Design Problem 4

PROBLEM 4. HOMEWORK PROBLEM



Drainage Design Problem 5

PROBLEM 5. HOMEWORK PROBLEM

The problem is to illustrate how tapered decks can be installed. The top portion of this roof has a steel deck that is flat. The joist span is 40". 1/4" per foot tapered insulation board is to be run the 2 directions towards the drains that are at mid-span of the joists. Tapered crickets are installed to force the water to the drains. if the insulation is to be a minimum thickness of 2" at the drains, how thick would it be at the perimeter and center beam?

The lower portion of the roof illustrates a lightweight pour over a flat steel deck. In this case, the 1/4" per foot slope is in all 4 directions towards each drain.

If this building was in Dallas, what size drains would be required for maximum storms?

Drainage Design Problem 5

PROBLEM 5. HOMEWORK PROBLEM