Table of Contents

29.1 General

Wherever practical, bridge drainage should be carried off the structure along the curb or gutter line and collected with roadway catch basins. Floor drains are not recommended for structures less than 200' long and floor drain spacing is not to exceed 500' on any structure. However, additional floor drains are required on some structures due to flat grades, superelevations and the crest of vertical curves. The drains are spaced according to the criteria as set forth in 29.2, which includes acceptable spread of water measured from gutterline as a function of design speed, design storm frequency and duration of rainfall. Additional drains should not be provided other than what is required by design. Utilizing blockouts in parapets to facilitate drainage is not allowed.

Superelevation on structures often creates drainage problems other than at the low point especially if a reverse curve is involved. Water collects and flows down one gutter and as it starts into the superelevation transition it spreads out over the complete width of roadway at the point of zero cross-slope. From this point the water starts to flow into the opposite gutter. Certain freezing conditions can cause traffic accidents to occur in the flat area between the two transitions. To minimize the problem, locate the floor drain as close to the cross over point as practical. Floor drains are installed as near all joints as practical to prevent gutter flow from passing over and/or through the joints.

The Bureau of Structures recommends the Type “GC” floor drain for new structures. Type "GC" floor drains are gray iron castings that have been tested for hydraulic efficiency. Where hydraulic efficiency or girder flange to edge of deck geometry dictates the use of a different floor drain configuration, BOS recommends the Type “WF” floor drain. Steel fabricated floor drains Type “H” provide an additional 6” of downspout clearance and are retained for maintenance of structures where floor drain size modifications are necessary.

All of the floor drains shown on the Standards have grate inlets. When the longitudinal grade exceeds 1 percent, hydraulic flow testing indicates grates with rectangular longitudinal bars are more efficient than grates having transverse rectangular bars normal to flow. However, grates with bars parallel to the direction of traffic are hazardous to bicyclists and even motorcyclists as bar spacing is increased for hydraulic efficiency. As a result, transverse bars sloped toward the direction of flow are detailed for the cast iron floor drains.

Downspouts are to be fabricated from reinforced thermosetting resin (fiberglass) pipe having a diameter not less than 6” for all new structures. Galvanized standard pipe or reinforced fiberglass material may be used for downspouts when adjusting or rehabilitating existing floor drains. Downspouts are required on all floor drains to prevent water and/or chlorides from getting on the girders, bearings, substructure units, etc. Downspouts should be detailed to extend a minimum of 6” below low prestressed girder bottom flange or 1' below low steel to prevent flange or web corrosion. A downspout collector system is required on all structures over grade separations. Reinforced fiberglass pipe is recommended for all collector systems due to its durability and economy. In the design of collector systems, elimination of unnecessary bends and provision for an adequate number of clean outs is recommended.

29.2 Design Criteria

The flow of water in an open channel depends on its cross section, grade, and roughness. Generally, the gutter cross section on a structure is right triangular in shape with the curb, median or parapet forming the vertical leg. For design speeds 45 mph or less, floor drains are spaced at a distance such that the maximum gutter flow is restricted to a spread width of the shoulder plus one-half the adjacent through driving lane for a given design frequency storm. This defines the hypotenuse of the triangle if the shoulder and driving lane slope are equal. For design speeds greater than 45 mph, floor drains are spaced at a distance such that the maximum gutter flow is restricted to a spread width of the shoulder. An increase in longitudinal and transverse slope increases inlet capacity. In design, it is assumed that all of the water passing over the width of the inlet is taken by that inlet, the remaining water (Q bypass) continues to the next inlet.

For design, a storm frequency of 10 years with a duration of 5 minutes is used. This gives a rainfall intensity (i) in inches/hour that can be found for each county in Wisconsin in the *Facilities Development Manual (FDM)* (Sect. 13-10, Attachment 5.4). A run-off coefficient (C) of 0.9 is used for concrete surfaces.

The Rational Method (English Units) converts rainfall intensity for a given design frequency storm to run-off by the following equation:

$$Q = C\,i\,A$$

Where:

Q	=	peak rate of run-off in cfs.
C	=	run-off coefficient for surface type.
i	=	rainfall intensity in inches/hour.
A	=	drainage area in acres = $\frac{LW}{43560}$

Where:

L	=	floor drain spacing in feet.
W	=	contributing structure width in feet.

The Manning equation modified for triangular flow is used to compute Q and Q_{bypass} for the given gutter section. The modified equation is:

$$Q = 0.56\left(\frac{Z}{n}\right)(S_o)^{\frac{1}{2}}(d)^{\frac{8}{3}}$$

Where:

Q	=	discharge in cfs.
Z	=	reciprocal of cross slope.
n	=	Manning's coefficient of roughness, use n = 0.014 for concrete.
S_o	=	longitudinal slope in feet/foot.
d	=	depth of flow at the deepest point (gutter line) in feet.

Refer to Table 29.2-1, Table 29.2-2 and Table 29.2-3 for values of (Z/n) and to Figure 29.2-1 for a nomographic solution to the Manning equation.

CROSS SLOPE, Sc			1/Sc	VALUES OF Z/n				
				n				
in/ft	in/ft	ft/ft	Z	0.012	0.013	0.014	0.015	0.016
	0.0120	0.0010	1000.00	83,333	76,923	71,429	66,667	62,500
1/64	0.0156	0.0013	768.00	64,000	59,077	54,857	51,200	48,000
	0.0240	0.0020	500.00	41,667	38,462	35,714	33,333	31,250
1/32	0.0313	0.0026	384.00	32,000	29,538	27,429	25,600	24,000
	0.0360	0.0030	333.33	27,778	25,641	23,810	22,222	20,833
	0.0480	0.0040	250.00	20,833	19,231	17,857	16,667	15,625
	0.0600	0.0050	200.00	16,667	15,385	14,286	13,333	12,500
1/16	0.0625	0.0052	192.00	16,000	14,769	13,714	12,800	12,000
	0.0720	0.0060	166.67	13,889	12,821	11,905	11,111	10,417
	0.0840	0.0070	142.86	11,905	10,989	10,204	9,524	8,929
3/32	0.0938	0.0078	128.00	10,667	9,846	9,143	8,533	8,000
	0.0960	0.0080	125.00	10,417	9,615	8,929	8,333	7,813
	0.1000	0.0083	120.00	10,000	9,231	8,571	8,000	7,500
	0.1080	0.0090	111.11	9,259	8,547	7,937	7,407	6,944
	0.1200	0.0100	100.00	8,333	7,692	7,143	6,667	6,250
1/8	0.1250	0.0104	96.00	8,000	7,385	6,857	6,400	6,000
	0.1320	0.0110	90.91	7,576	6,993	6,494	6,061	5,682
	0.1440	0.0120	83.33	6,944	6,410	5,952	5,556	5,208
5/32	0.1563	0.0130	76.80	6,400	5,908	5,486	5,120	4,800
	0.1680	0.0140	71.43	5,952	5,495	5,102	4,762	4,464
	0.1800	0.0150	66.67	5,556	5,128	4,762	4,444	4,167
3/16	0.1875	0.0156	64.00	5,333	4,923	4,571	4,267	4,000
	0.1920	0.0160	62.50	5,208	4,808	4,464	4,167	3,906
	0.2000	0.0167	60.00	5,000	4,615	4,286	4,000	3,750
	0.2040	0.0170	58.82	4,902	4,525	4,202	3,922	3,676
	0.2160	0.0180	55.56	4,630	4,274	3,968	3,704	3,472
7/32	0.2188	0.0182	54.86	4,571	4,220	3,918	3,657	3,429
	0.2280	0.0190	52.63	4,386	4,049	3,759	3,509	3,289
	0.2400	0.0200	50.00	4,167	3,846	3,571	3,333	3,125
1/4	0.2500	0.0208	48.00	4,000	3,692	3,429	3,200	3,000
9/32	0.2813	0.0234	42.67	3,556	3,282	3,048	2,844	2,667
19/64	0.2969	0.0247	40.42	3,368	3,109	2,887	2,695	2,526
	0.3000	0.0250	40.00	3,333	3,077	2,857	2,667	2,500

Table 29.2-1

Values of Z/n for Manning's Equation

CROSS SLOPE, Sc			1/Sc	VALUES OF Z/n				
				n				
in/ft	in/ft	ft/ft	Z	0.012	0.013	0.014	0.015	0.016
5/16	0.3125	0.0260	38.40	3,200	2,954	2,743	2,560	2,400
21/64	0.3281	0.0273	36.57	3,048	2,813	2,612	2,438	2,286
11/32	0.3438	0.0286	34.91	2,909	2,685	2,494	2,327	2,182
	0.3600	0.0300	33.33	2,778	2,564	2,381	2,222	2,083
3/8	0.3750	0.0313	32.00	2,667	2,462	2,286	2,133	2,000
	0.4000	0.0333	30.00	2,500	2,308	2,143	2,000	1,875
13/32	0.4063	0.0339	29.54	2,462	2,272	2,110	1,969	1,846
	0.4200	0.0350	28.57	2,381	2,198	2,041	1,905	1,786
7/16	0.4375	0.0365	27.43	2,286	2,110	1,959	1,829	1,714
15/32	0.4688	0.0391	25.60	2,133	1,969	1,829	1,707	1,600
	0.4800	0.0400	25.00	2,083	1,923	1,786	1,667	1,563
1/2	0.5000	0.0417	24.00	2,000	1,846	1,714	1,600	1,500
17/32	0.5313	0.0443	22.59	1,882	1,738	1,613	1,506	1,412
	0.5400	0.0450	22.22	1,852	1,709	1,587	1,481	1,389
9/16	0.5625	0.0469	21.33	1,778	1,641	1,524	1,422	1,333
19/32	0.5938	0.0495	20.21	1,684	1,555	1,444	1,347	1,263
	0.6000	0.0500	20.00	1,667	1,538	1,429	1,333	1,250
5/8	0.6250	0.0521	19.20	1,600	1,477	1,371	1,280	1,200
21/32	0.6563	0.0547	18.29	1,524	1,407	1,306	1,219	1,143
	0.6600	0.0550	18.18	1,515	1,399	1,299	1,212	1,136
11/16	0.6875	0.0573	17.45	1,455	1,343	1,247	1,164	1,091
	0.7000	0.0583	17.14	1,429	1,319	1,224	1,143	1,071
23/32	0.7188	0.0599	16.69	1,391	1,284	1,192	1,113	1,043
	0.7200	0.0600	16.67	1,389	1,282	1,190	1,111	1,042
3/4	0.7500	0.0625	16.00	1,333	1,231	1,143	1,067	1,000
	0.7800	0.0650	15.38	1,282	1,183	1,099	1,026	962
25/32	0.7812	0.0651	15.36	1,280	1,182	1,097	1,024	960
	0.8000	0.0667	15.00	1,250	1,154	1,071	1,000	938
13/16	0.8125	0.0677	14.77	1,231	1,136	1,055	985	923
	0.8400	0.0700	14.29	1,190	1,099	1,020	952	893
27/32	0.8438	0.0703	14.22	1,185	1,094	1,016	948	889
	0.8500	0.0708	14.12	1,176	1,086	1,008	941	882
7/8	0.8750	0.0729	13.71	1,143	1,055	980	914	857

Table 29.2-2
Values of Z/n for Manning's Equation

CROSS SLOPE, Sc			1/Sc	VALUES OF Z/n				
				n				
in/ft	in/ft	ft/ft	Z	0.012	0.013	0.014	0.015	0.016
	0.9000	0.0750	13.33	1,111	1,026	952	889	833
39/32	1.2188	0.1016	9.85	821	757	703	656	615
15/16	0.9375	0.0781	12.80	1,067	985	914	853	800
	0.9500	0.0792	12.63	1,053	972	902	842	789
	0.9600	0.0800	12.50	1,042	962	893	833	781
31/32	0.9688	0.0807	12.39	1,032	953	885	826	774
1	1.000	0.0833	12.00	1,000	923	857	800	750
	1.020	0.0850	11.76	980	905	840	784	735
	1.080	0.0900	11.11	926	855	794	741	694
	1.140	0.0950	10.53	877	810	752	702	658
	1.200	0.1000	10.00	833	769	714	667	625
2	2.000	0.1667	6.000	500	462	429	400	375
	2.400	0.2000	5.000	417	385	357	333	313
3	3.000	0.2500	4.000	333	308	286	267	250
	3.600	0.3000	3.333	278	256	238	222	208
4	4.000	0.3333	3.000	250	231	214	200	188
	4.800	0.4000	2.500	208	192	179	167	156
5	5.000	0.4167	2.400	200	185	171	160	150
6	6.000	0.5000	2.000	167	154	143	133	125
7	7.000	0.5833	1.714	143	132	122	114	107
	7.200	0.6000	1.667	139	128	119	111	104
8	8.000	0.6667	1.500	125	115	107	100	94
	8.400	0.7000	1.429	119	110	102	95	89
9	9.000	0.7500	1.333	111	103	95	89	83
	9.600	0.8000	1.250	104	96	89	83	78
10	10.00	0.8333	1.200	100	92	86	80	75
	10.80	0.9000	1.111	93	85	79	74	69
11	11.00	0.9167	1.091	91	84	78	73	68
	11.50	0.9583	1.043	87	80	75	70	65
12	12.00	1.0000	1.000	83	77	71	67	63

Table 29.2-3
Values of Z/n for Manning's Equation

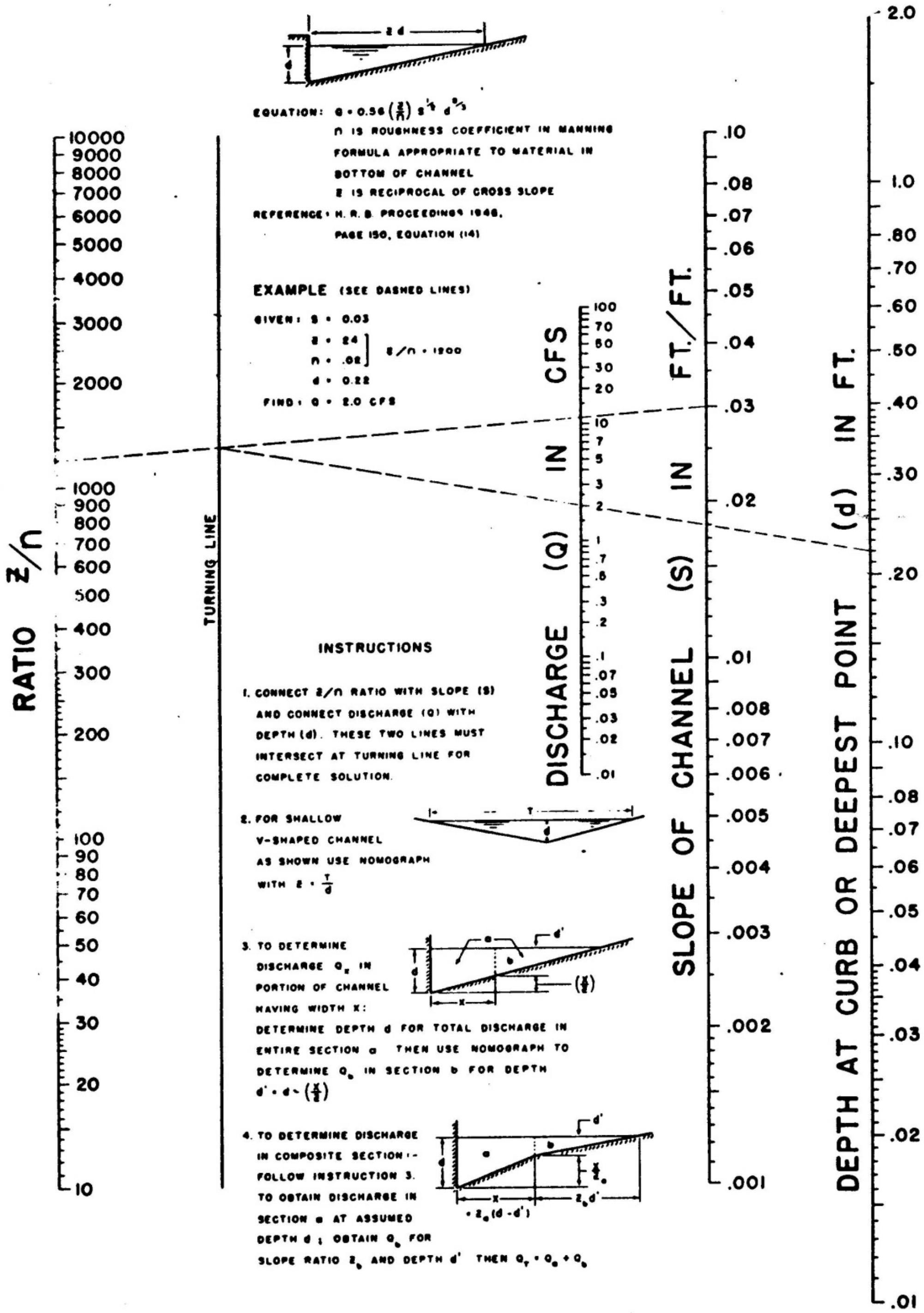

Figure 29.2-1

Nomograph for Flow in Triangular Channels
Modified Manning Solution

29.3 Design Example

The following method is used to compute floor drain spacing by equating net discharge to the Rational Method:

Given: Structure 1200 feet long on a 0.3% grade having a cross slope of 0.02 feet/foot with a contributing structure width of 23'-6". Use Type "GC" floor drain. For a structure in Marathon County, the rainfall intensity (i) from the *FDM* (Sect. 13-10, Attachment 5.4) is 6.60 in./hr.

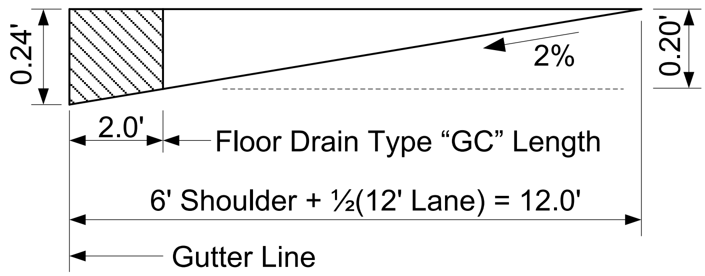

Figure 29.3-1
Cross Section of Flow

Compute: Floor drain spacing

From Table 29.2-1 with a cross slope of 0.02 feet/foot

$(Z/n) = 3571.$

From Figure 29.2-1, $Q = 2.44$ cfs and $Q_{bypass} = 1.50$ cfs.

$$L = \left(Q - Q_{bypass}\right)\frac{43560}{CiW}$$

$L = (2.44 – 1.5) \cdot 43569 / (0.9 \cdot 6.60 \cdot 23.5\}$

$L = 293$ ft

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