GEORGE WANNAMAKER

KING COUNTY DEPARTMENT OF PUBLIC WORKS

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Director

RECOMMENDED PROCEDURES FOR STORM DRAIN AND ROAD CULVERT DESIGN

PREPARED BY

KING COUNTY DIVISION OF HYDRAULICS

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I N D E X

	Page No.
Instructions for Storm Drain and Road Culvert Design	1
Runoff Coefficients	3
Runoff Calculations - Examples	4
Layout Example	8
Overland Flow Time	Fig. 1-2
Runoff Coefficient and Channel Friction Factors	Tables 1-1 & 1-2
Nomograph for Flow in Triangular Channels	Fig. 6
Nomograph for Computing Required Size of Circular Drain	Fig. 8-2
Headwater Depth for Concrete Pipe Culverts	5-17
Headwater Depth for C.M. Pipe Culverts	5-20
Headwater Depth for C.M. Pipe-Arch Culverts	5-21
Capacity of Grate Inlet in Sump	Fig. 9-1
Solution of Manning's Equation (Circular Pipe)	5-22
Solution of Manning's Equation (Pipe Arch)	5-23
Schedule Guide for 12" through 30" Diameter Culvert Pipe	Tables I-IV

Rainfall Intensity-Duration Curves:

Chart 6 - Mayfield
Chart 10 - Renton-Seattle
Chart 12 - Tacoma
Chart 18 - Arlington-Concrete-Cosmos-Deming-Everett-Glacier-Gold Bar-Granite Falls-Hamilton-Lyman-Marblemount-Marysville-Morton-Mossy Rock-North Bend-Packwood-Snohomish-Snoqualmie-Stanwood-Sultan-Warnick-Woodland
Chart 21 - Skykomish
Chart 31 - Cayuse-Chinook-Harts-Stevens-White Passes
Chart 33 - Snoqualmie Pass

Calculation Sheet

INSTRUCTIONS FOR
STORM DRAIN AND ROAD CULVERT DESIGN

Storm drain and road culvert design will be based on an engineering analysis. The design will be reviewed by the Hydraulics Division.

The engineering analysis should include a layout of the entire drainage area, runoff rates, slopes and storm drain or culvert size. The entire drainage system in the development should be shown on a plat map. Off site drainage contributing to the flow in the plat may be shown on a U. S. Geological Survey quadrangle sheet. The engineer should conduct a field inspection or check the existing plats in the County office for off site drainage.

Runoff rates can be determined by the rationale formula:

$$Q = C\ I\ A$$

Q = Runoff in cfs
C = Runoff coefficient
I = Rainfall intensity in inches per hour
A = Contributing area in acres

A runoff coefficient (C) of 0.4 should be used for normal suburban development (see Page 3 for other runoff coefficients). The rainfall intensity (I) will be based on the Rainfall Intensity-Duration Curves, prepared by the U. S. Weather Bureau for the area. The curve that is the closest to the plat will be used (see charts 6, 10, 12, 18, 21, 31, and 33). Where other data of the same nature are used, the engineer should submit the curve along with the design analysis. For drainage areas less than 50 acres or producing a runoff of less than 20 cfs, a 10-year design frequency may be used. For areas greater than 50 acres or producing a runoff greater than 20 cfs, a 25-year design frequency will be used regardless of the size of plat.

The time of concentration for rainfall should be computed for all culverts and pipe systems. An initial collecting time of 10 minutes for unpaved areas and 5 minutes for paved areas may be taken at the most distant point of flow from a catch basin or culvert. From this point, the overland flow time to the nearest ditch, channel or gutter may be computed by assuming a velocity of 1 foot per second for a distance which does not exceed 600 feet in areas zoned for residential or commercial land use. Graph Figure 1-2 may be used for determinations of times of concentrations for flows from areas not zoned for development. In ditches, channels or gutters, the velocity can vary depending on the slope from 1.5 feet

per second to 5 feet per second. Once the runoff has reached a storm drainage system, the concentration time can be computed by the pipe velocity through the system.

The following minimum roughness coefficients will be used:

n = 0.012 for concrete, clay or smooth interior metallic pipes

n = 0.021 for corrugated metal pipe

Storm drain pipe sizes may be selected by nomograph or calculators based on the Manning Formula. Culverts and pipes that are placed in ditches which will pass flows into storm drainage systems should be designed from a booklet entitled Hydraulic Charts for the Selection of Highway Culverts, by the Bureau of Public Roads. Culverts should be designed to carry the design runoff with a headwater depth not greater than 2.0 times the culvert diameter for culverts 18 inches and under, or 1.5 times the culvert diameter for culverts greater than 18 inches. At all times, the computed water surface must be at an elevation which will not saturate the base course under the paving.

The following table of "N" values for friction factors for helical corrugated metal pipes will be used:

PIPE DIAMETER	MANNING "N"
6"	0.013
8"	0.013
12"	0.015
15"	0.016
18"	0.016
21"	0.017
24"	0.018
30"	0.020
36"	0.021
42"	0.023
48"	0.024

RUNOFF COEFFICIENTS

Zone Type	Coefficient
Pavements and Roofs	0.90
Gravel Pavement	0.55
Commercial	0.80
Apartment Dwelling Areas	0.60
Suburban, Normal Residential	0.40
Residential High Density	0.50
Industrial Areas, Light	0.65
Industrial Areas, Heavy	0.75
Park and Cemeteries	0.20
Playgrounds	0.25
School Grounds with Buildings	0.35
Trailer Parks	0.70

EXAMPLES
RUNOFF CALCULATIONS

AREA 1 C = 0.4 A = 5.0 AC

Pt. "A" to Road Ditch 420 feet V = 1.0 ft/sec.

Road Ditch Culvert "A" 165 feet V = 2.0 ft/sec.

$$\text{Time} = \frac{420}{(60)(1)} + \frac{165}{(60)(2)} + 10 = 7+1.4+10 = 18.4 \text{ min.}$$

I = 1.15

Q = (.4)(5.0(1.15) = 2.30 cfs

From Hydraulic Charts for the selection of Highway Culverts by Bureau of Public Roads:

12 inch concrete for Q = 2.3 cfs

$\frac{HW}{D} = 0.95 < 2.0$ OK

12 inch CMP for Q = 2.3 cfs

$\frac{HW}{D} = 1.1 < 2.0$ OK

Use 12 inch concrete or CMP for Culvert "A"

AREA 2 C = 0.4 A = 4.3 AC

Pt. "B" to Road Ditch 300 feet V = 1.0 ft/sec.

Road Ditch to C.B. #1 350 feet V = 2.0 ft/sec.

$$\text{Time} = \frac{300}{(60)(1)} + \frac{300}{(60)(2)} + \frac{350}{(60)(2)} + 10 = 5+3+10 = 18 \text{ min.}$$

I = 1.15

Q = (.4)(4.3)(1.15) = 2.0 CFS

Use 12 foot concrete or CMP (See Area 1)

CB #1 to CB #2 Slope = 1.0%

12 inch concrete @ 1.0% = 3.8 CFS > 2.0 CFS OK

Use 12 inch concrete @ 1.0%

RUNOFF CALCULATIONS (Continued)

AREA 3 C = 0.4 A = 1.8 AC

Length = Culvert "A" to CB #2 = 260'

Time = 18 min. + $\frac{260}{(60)(2)}$ = 18 + 2 = 20 min.

I = 1.05

$$Q = \underbrace{(.4)(1.8)(1.05)}_{\text{Area 3}} + \underbrace{(.4)(5.0)(1.05)}_{\text{Area 1}} = (.4)(6.8)(1.05) = 2.9 \text{ cfs}$$

From Hydraulic Charts for the selection of Highway Culverts by Bureau of Public Roads:

12" Conc. for Q = 2.9 cfs 12" CMP for Q = 2.9 cfs

$\frac{HW}{D} = 1.1 < 2.0$ OK $\frac{HW}{D} = 1.3 < 2.0$ OK

Use 12" Conc. or CMP for entrance pipe @ CB #2

CB #2 to CB #4 Slope = 1.5%

$$Q = \underbrace{(.4)(6.8)(1.05)}_{\text{Area 1 \& 3}} + \underbrace{(.4)(4.3)(1.05)}_{\text{Area 2}} = (.4)(11.1)(1.05) = 4.7 \text{ cfs}$$

12" conc. @ 1.5% = 4.8 cfs > 4.7 cfs OK

12" CMP @ 1.5% = 2.6 cfs < 4.7 cfs Try 15" CMP

15" CMP @ 1.5% = 4.9 cfs > 4.7 cfs OK

Use 12" conc. or 15" CMP @ 1.5%

RUNOFF CALCULATIONS (Continued)

AREA 4 C = 0.4 A = 1.0 AC

Pt. "C" to Road Ditch or Gutter 240' V = 1.0 ft/sec.

Road Ditch or Gutter to Inlet 3A 180' V = 2.0 ft/sec.

$$\text{Time} = \frac{240}{(60)(1)} + \frac{180}{(60)(2)} + 10 = 4+2+10 = 16 \text{ min.}$$

I = 1.25

Q = (.4)(1.0)(1.25) = 0.5 cfs

Inlet 3A to CB #3 Slope = 1.0%

8" conc. @ 1.0% = 1.2 cfs > 0.5 cfs OK

Use 8" conc. @ 1.0%

AREA 5 C = 0.4 A = 1.1 AC

Time = 16 min. (Same as Area 4)

Q = (.4)(2.1)(1.25) = 1.1 cfs

CB #3 to CB #4 Slope = 1.0%

12" conc. @ 1.0% = 4.0 cfs > 1.1 cfs OK

12" CMP @ 1.0% = 2.3 cfs > 1.1 cfs OK

Use 12" conc. or CMP @ 1.0%

RUNOFF CALCULATIONS (Continued)

AREA 6 C = 0.4 A = 0.5 AC

Inlet 4A to CB #4
By inspection, use 8" conc. or CMP

CB #4 to CB #5 C = 0.4 A = 13.7 AC

Time = 20 min. (See Area 3)

Q = (.4)(13.7)(1.05) = 5.8 cfs

12" conc. @ 1.0% = 4.0 cfs $<$ 5.8 cfs Try 15" conc.

15" conc. @ 1.0% = 7.0 cfs $>$ 5.8 cfs OK

15" CMP @ 1.0% = 4.2 cfs $<$ 5.8 cfs Try 18" CMP

18" CMP @ 1.0% = 6.6 cfs $>$ 5.8 cfs OK

Use 15" conc. or 18" CMP @ 1%

AREA 7 C = 0.4 A = 0.8 AC

Inlet 5A to CB #5
By inspection, use 8" conc. or CMP

AREA 8 C = 0.4 A = 1.3 AC

Length = 300' V = 5.5 ft/sec.

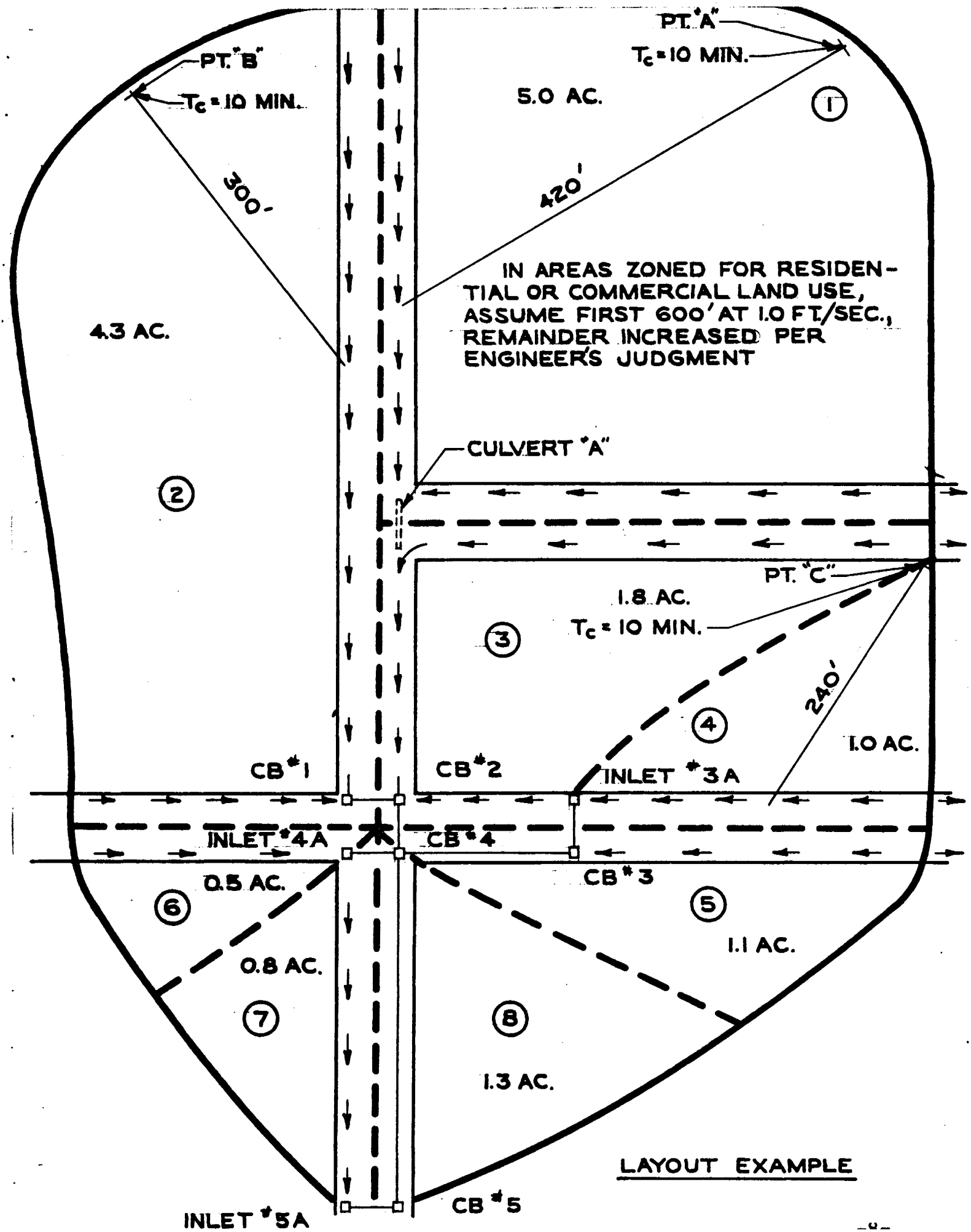
Time = 20 min. + $\frac{300}{(60)(5.5)}$ = 20 + 1 = 21 min.

I = 1.01

Q = (0.4)(15.8)(1.01) = 6.4 cfs

CB #5 to outfall Slope = 1.0%

Use 15" conc. or 18" CMP @ 1.0% (See Area 6)


PT. "A"
T_c = 10 MIN.
5.0 AC.
1
PT. "B"
T_c = 10 MIN.
300'
420'
IN AREAS ZONED FOR RESIDENTIAL OR COMMERCIAL LAND USE, ASSUME FIRST 600' AT 1.0 FT./SEC., REMAINDER INCREASED PER ENGINEER'S JUDGMENT
4.3 AC.
CULVERT "A"
2
PT. "C"
1.8 AC.
T_c = 10 MIN.
3
240'
4
1.0 AC.
CB #1
CB #2
INLET #3A
INLET #4A
CB #4
CB #3
0.5 AC.
6
5
1.1 AC.
0.8 AC.
7
8
1.3 AC.
LAYOUT EXAMPLE
INLET #5A
CB #5

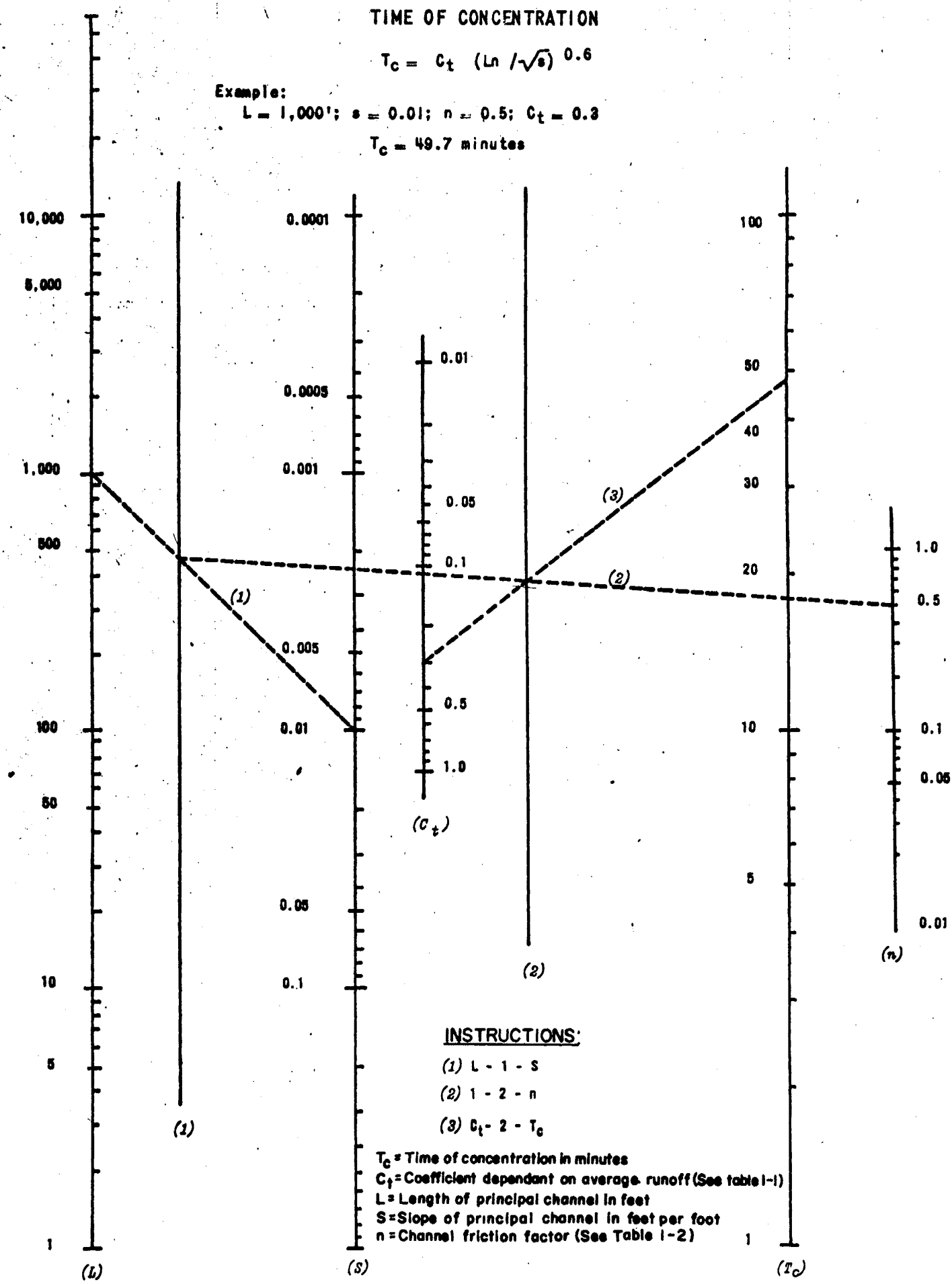


FIGURE 1-2
OVERLAND FLOW TIME

FLOOD REGIONS (C.S.W.S. Paper 1687, 88, 89 Part 12, 13, 14 and Aldridge-Bledgett Reports)	Average Annual Runoff	VALUES OF C_t (Min./Ft.) Natural Drainage Basins	Overland Flow	Sewered Areas
Regions B - C	- 0.5	1.00	0.30	0.25
	0.5 - 1.0	0.60	0.20	0.15
	1.0 - 10 +	0.40	0.15	0.10
Western Washington and Region A	10 - 30	1.00	0.30	0.25
	30 - 50	0.80	0.20	0.15
	50 - 70	0.50	0.10	0.10
	70 - 100 +	0.30	0.05	0.05

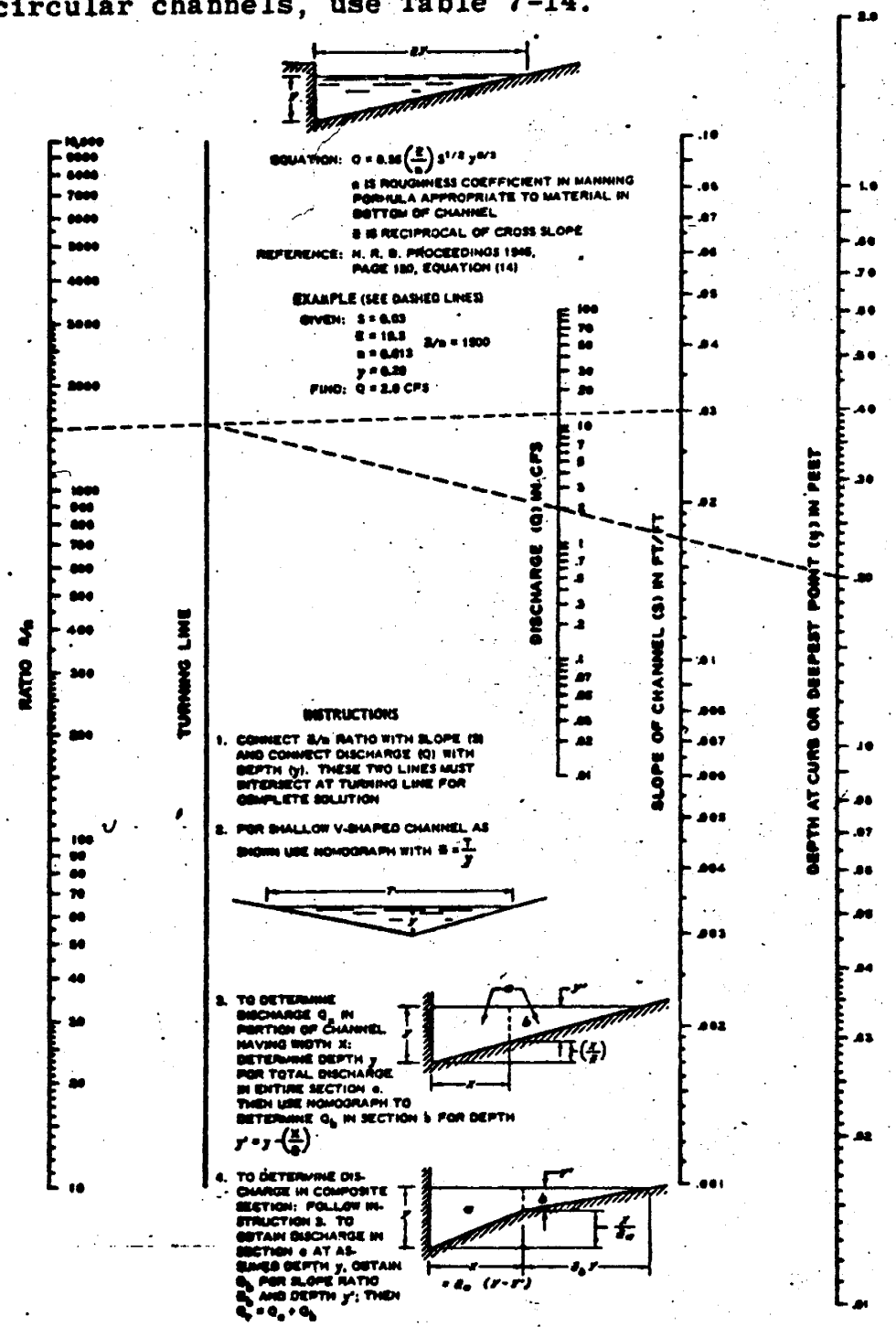
TABLE 1-1
RUNOFF COEFFICIENT

TYPE OF AREA	"n" VALUE
Average Natural Channels, overall	0.05
Paved Channels	0.014 to 0.040
Overland Flow and Improved Channels:	
Smooth paving	0.016
Bare packed soil	0.100
Poor grass cover	0.300
Average grass cover	0.400
Dense grass cover	0.500

TABLE 1-2
CHANNEL FRICTION FACTOR

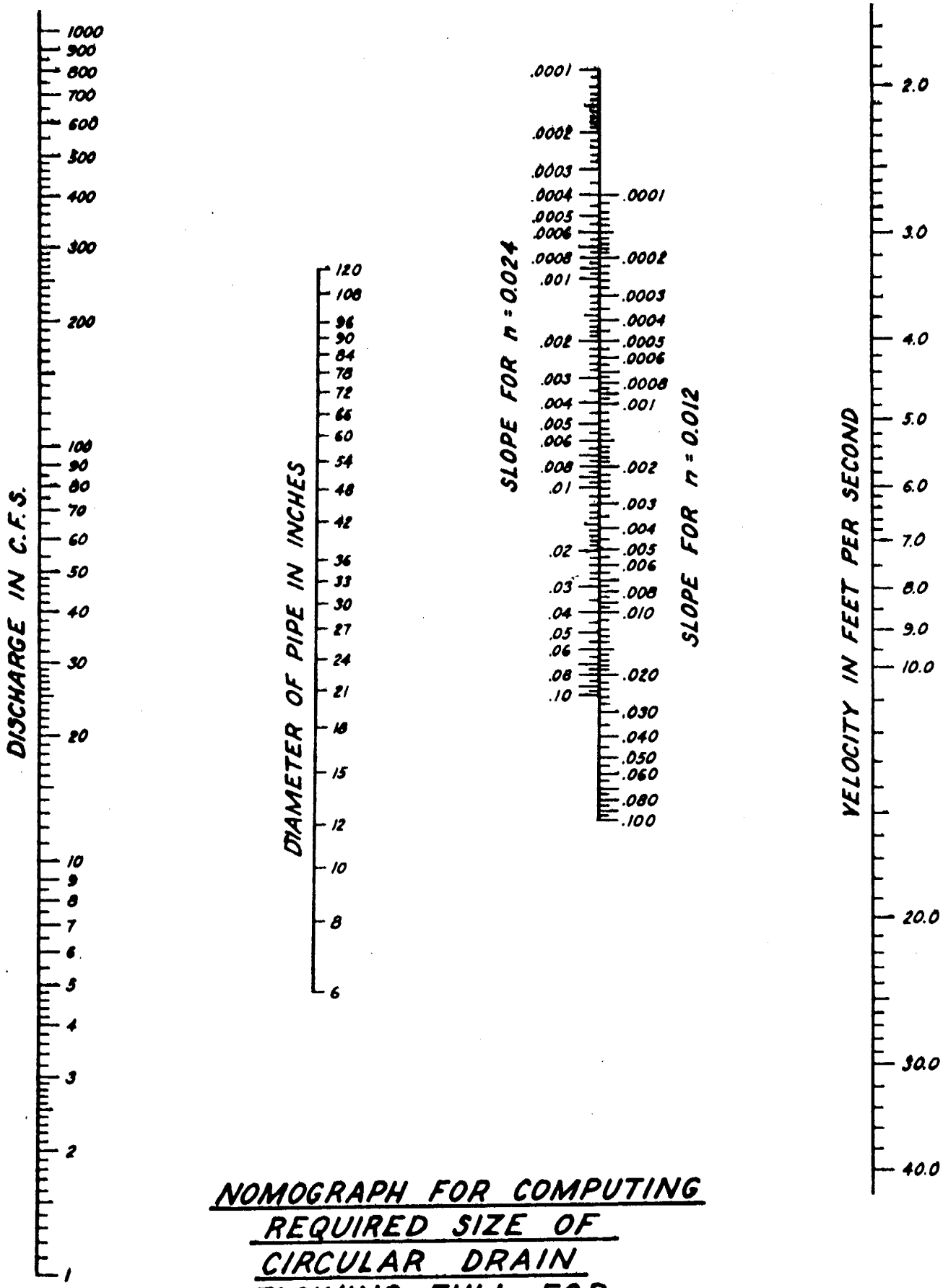
For solution of trapezoidal channels, use equation (7-39) in King's Handbook, Fifth Edition, page 7-14, and Tables 7-10 and 7-11.

For circular channels, use Table 7-14.



NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

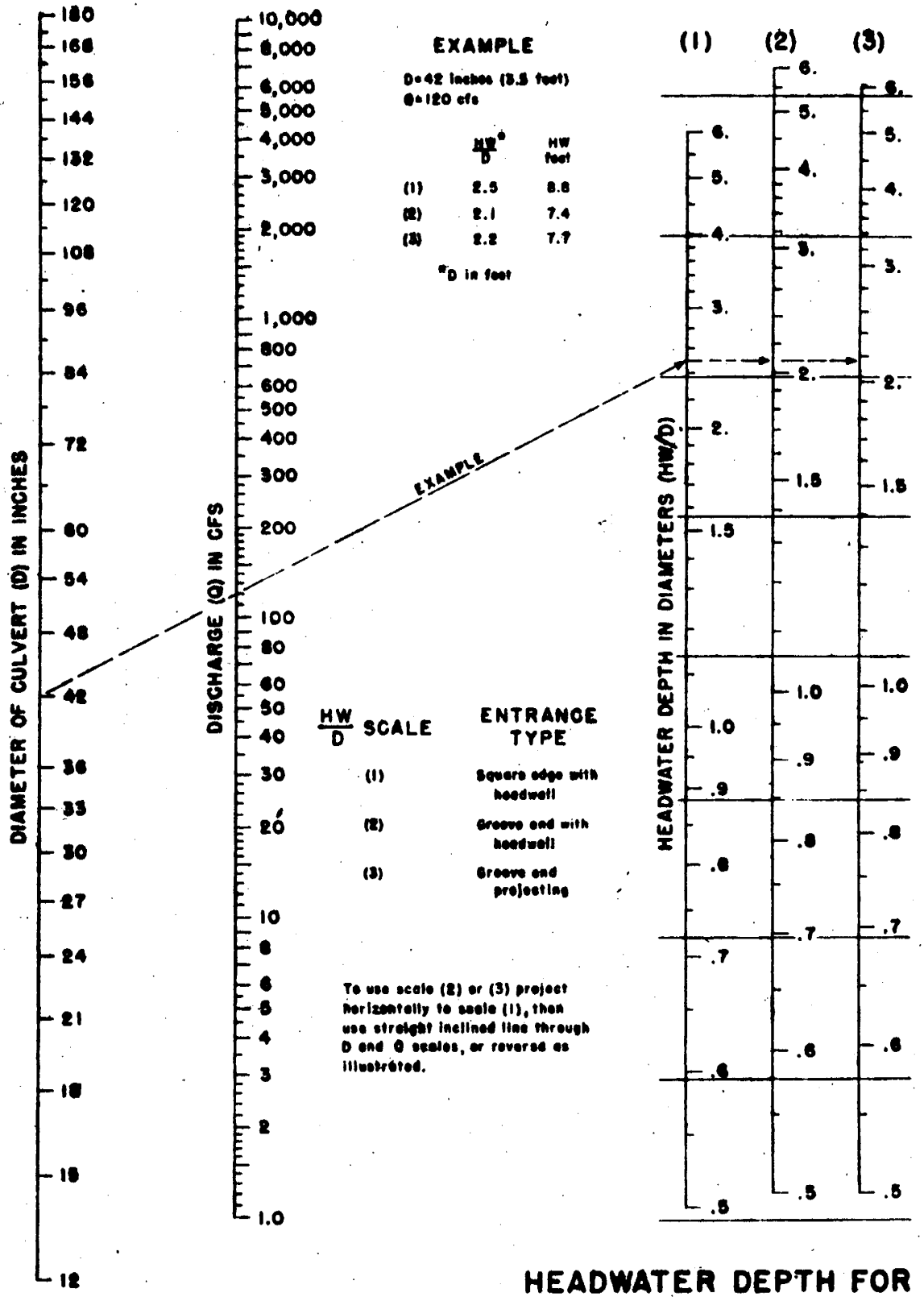
Figure 6



NOMOGRAPH FOR COMPUTING REQUIRED SIZE OF CIRCULAR DRAIN FLOWING FULL FOR n = 0.012 OR n = 0.024

Fig. 8-2

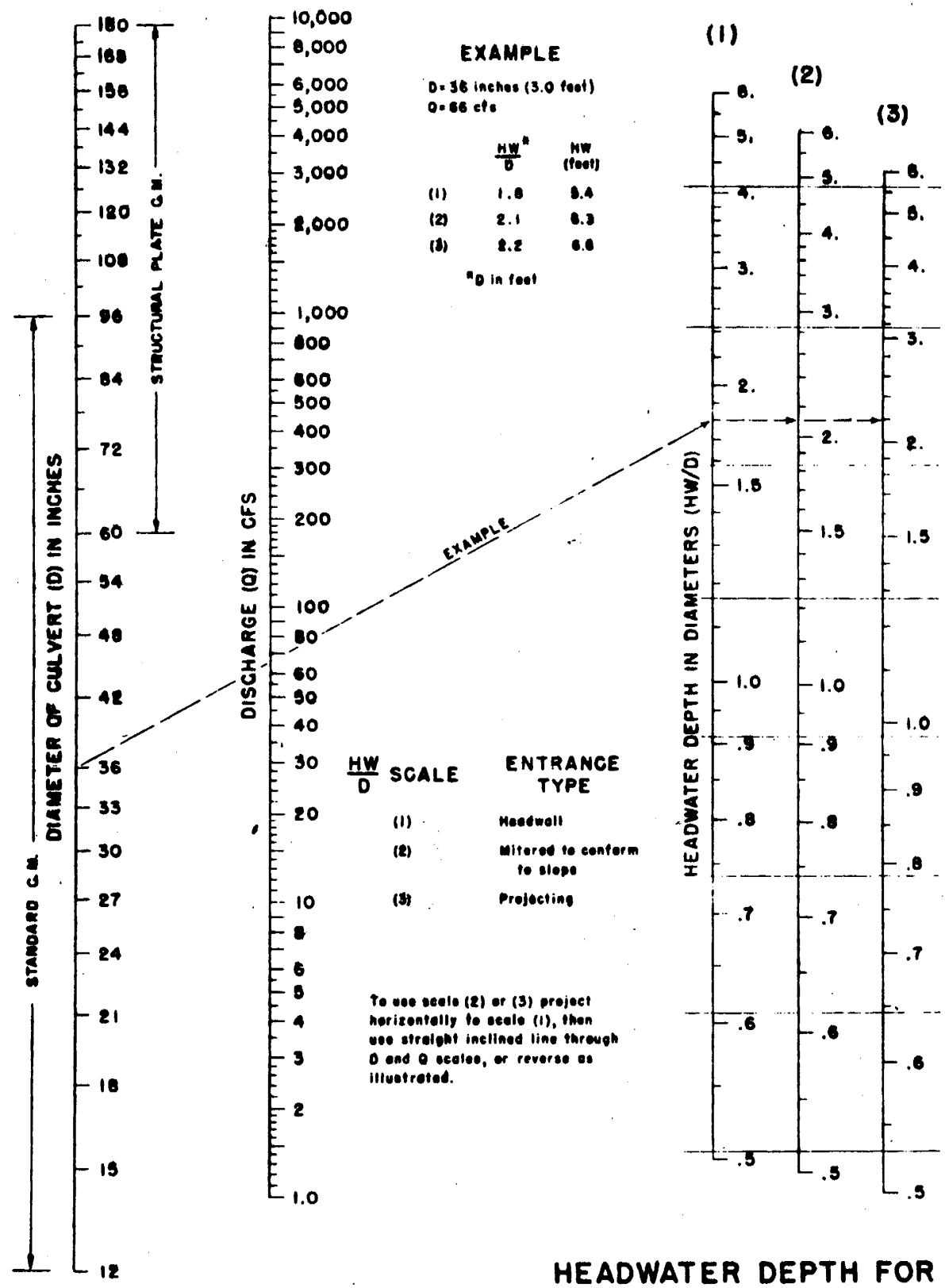
CHART I



HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

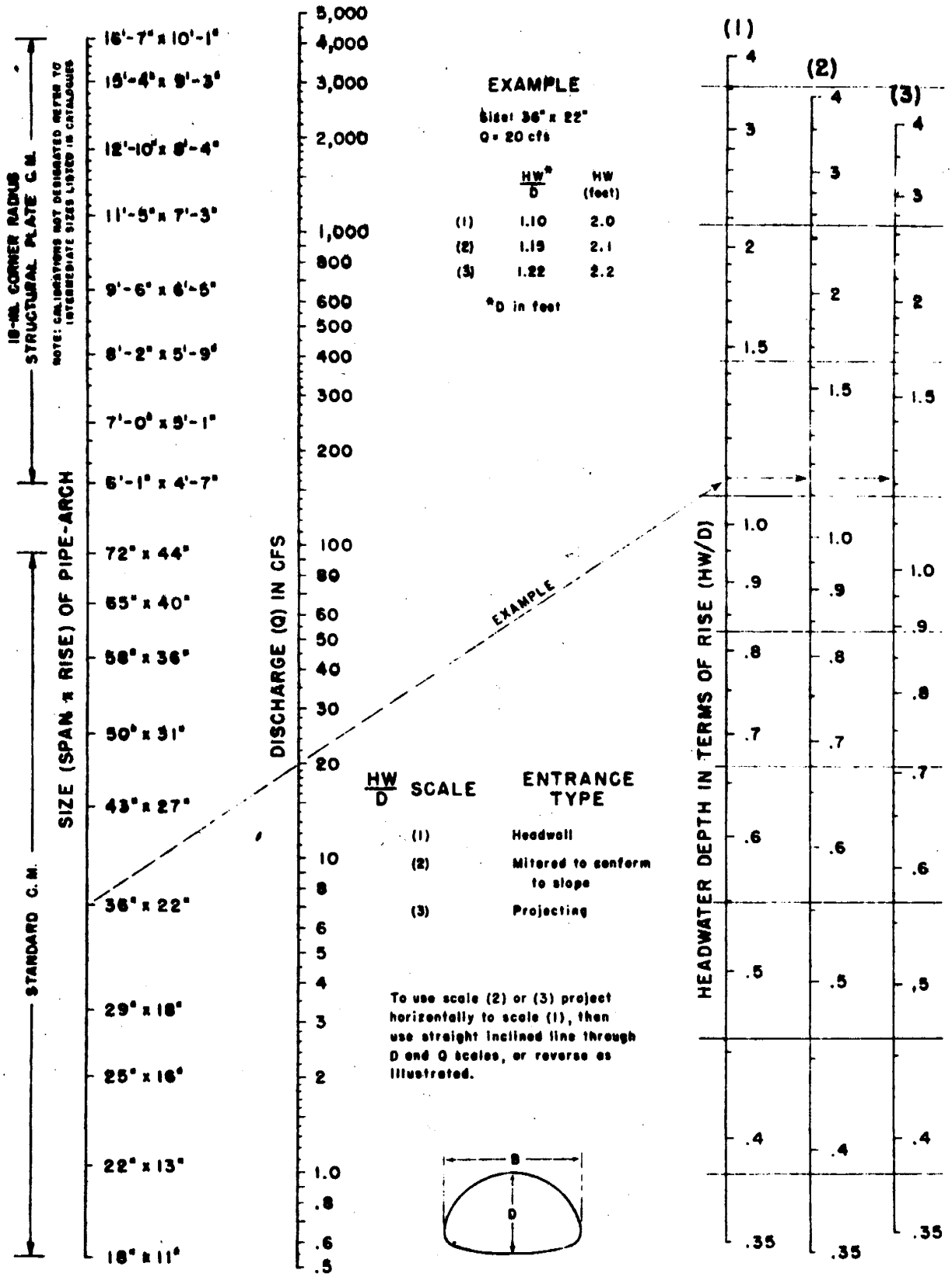
BUREAU OF PUBLIC ROADS JAN. 1963

CHART 4



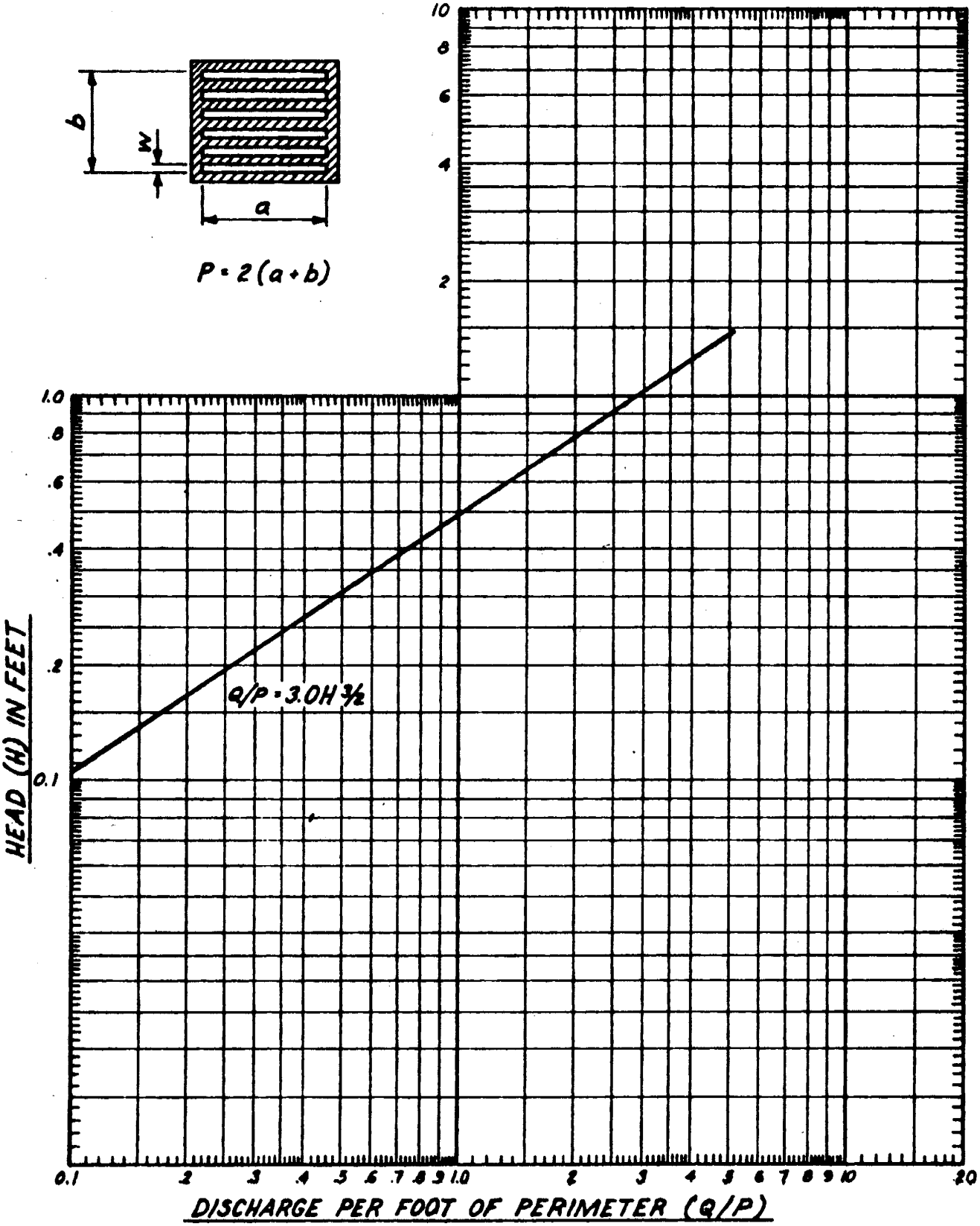
HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963



HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963



BUREAU OF PUBLIC ROADS

CAPACITY OF GRATE INLET IN SUMP

SOLUTION OF MANNING'S EQUATION—FOR CIRCULAR PIPE

Dia., in.	A Area, sq. ft.	R Hydric. Radius, ft.	$R^{2/3}$	$AR^{2/3}$	$\frac{1.486}{n} \times A \times R^{2/3}$ (for various values of n)															
					Various Values of n															
					.012	.013	.014	.015	.016	.017	.018	.019	.021	.023	.024	.027	.030	.031	.032	.033
6	.20	.125	.250	.049	6.08	5.61	5.21	4.86	4.56	4.29	4.05	3.84	3.47	3.17	3.04	2.70	2.43	2.35	2.28	2.21
8	.35	.167	.303	.106	13.09	12.08	11.22	10.47	9.82	9.24	8.73	8.27	7.48	6.83	6.55	5.82	5.24	5.07	4.91	4.76
10	.55	.208	.351	.191	23.74	21.91	20.34	18.99	17.80	16.75	15.82	14.99	13.56	12.38	11.87	10.55	9.49	9.19	8.90	8.63
12	.78	.250	.397	.312	38.60	35.63	33.08	30.88	28.95	27.24	25.73	24.38	22.06	20.14	19.30	17.15	15.44	14.94	14.47	14.04
15	1.23	.312	.461	.566	69.98	64.60	59.98	55.98	52.49	49.40	46.65	44.20	39.99	36.51	34.99	31.10	27.99	27.09	26.24	25.45
18	1.77	.375	.520	.919	113.8	105.0	97.54	91.04	85.35	80.33	75.86	71.87	65.03	59.37	56.90	50.58	45.52	44.05	42.67	41.38
21	2.41	.437	.576	1.385	171.6	158.4	147.1	137.3	128.7	121.2	114.4	108.4	98.09	89.56	85.83	76.29	68.66	66.45	64.37	62.42
24	3.14	.500	.630	1.979	245.1	226.2	210.1	196.1	183.8	173.0	163.4	154.8	140.0	127.9	122.5	108.9	98.03	94.87	91.90	89.12
30	4.91	.625	.731	3.588	444.3	410.2	380.9	355.5	333.3	313.7	296.2	280.6	254.0	231.8	222.2	197.5	177.7	172.0	166.6	161.6
36	7.07	.750	.825	5.832	722.6	667.0	619.3	578.1	541.9	510.1	481.7	456.4	412.9	377.0	361.3	321.1	289.0	279.7	271.0	262.7
42	9.62	.875	.915	8.803	1089	1006	934.2	871.9	817.4	769.4	726.6	688.4	622.8	568.7	545.0	484.4	436.0	421.9	408.7	396.3
48	12.6	1.00	1.00	12.57	1556	1436	1333	1244	1167	1098	1037	982.2	889.2	811.9	778.1	691.6	622.4	602.4	583.5	565.9
54	15.9	1.125	1.082	17.21	2130	1966	1826	1704	1597	1503	1420	1345	1217	1111	1065	946.8	852.1	824.7	798.9	774.7
60	19.6	1.25	1.16	22.78	2821	2604	2418	2257	2116	1991	1880	1781	1612	1472	1410	1253	1128	1092	1058	1025
66	23.8	1.375	1.236	29.37	3637	3358	3118	2910	2728	2567	2425	2297	2078	1898	1818	1616	1455	1408	1364	1322
72	28.3	1.50	1.310	37.04	4588	4235	3932	3670	3441	3238	3058	2897	2621	2393	2294	2039	1835	1776	1720	1668
78	33.2	1.625	1.382	45.86	5679	5242	4868	4543	4259	4009	3786	3587	3245	2963	2839	2524	2271	2198	2129	2065
84	38.5	1.75	1.452	55.88	6920	6388	5932	5536	5190	4885	4613	4370	3954	3610	3460	3075	2768	2678	2595	2516
90	44.2	1.875	1.521	67.20	8318	7678	7130	6654	6238	5871	5545	5253	4753	4340	4159	3697	3327	3220	3119	3024
96	50.3	2.00	1.587	79.77	9880	9120	8469	7904	7410	6974	6587	6240	5646	5155	4940	4391	3952	3824	3705	3593
102	56.7	2.125	1.647	93.39	11614	10721	9955	9291	8710	8198	7743	7335	6636	6059	5807	5162	4645	4495	4355	4223
108	63.6	2.25	1.717	109.2	13526	12486	11594	10821	10145	9548	9017	8543	7729	7057	6763	6011	5410	5236	5072	4918
114	70.9	2.375	1.780	126.2	15624	14422	13392	12499	11718	11029	10416	9868	8928	8152	7812	6944	6249	6048	5859	5681
120	78.5	2.50	1.842	144.7	17915	16537	15355	14332	13436	12645	11943	11314	10237	9347	8957	7962	7166	6934	6718	6514
126	86.6	2.625	1.902	164.7	20404	18834	17489	16323	15303	14403	13602	12887	11659	10645	10202	9068	8161	7898	7651	7419
132	95.0	2.750	1.963	186.5	23099	21322	19799	18479	17324	16305	15399	14589	13199	12051	11549	10266	9239	8941	8662	8399
138	103.9	2.875	2.022	210.1	26006	24005	22291	20805	19504	18357	17337	16425	14860	13568	13003	11558	10402	10067	9752	9456
144	113.1	3.00	2.080	235.2	29132	26891	24970	23305	21849	20563	19421	18399	16646	15199	14566	12947	11652	11276	10924	10593
150	122.7	3.125	2.137	262.2	32482	29983	27841	25985	24361	22928	21654	20515	18561	16947	16241	14436	12992	12573	12180	11811
156	132.7	3.250	2.194	291.1	36063	33289	30911	28850	27047	25456	24042	22777	20607	18815	18031	16028	14425	13960	13523	13114
162	143.1	3.375	2.250	322.0	39882	36814	34184	31905	29911	28152	26588	25188	22789	20808	19941	17725	15952	15438	14995	14502
168	153.9	3.50	2.305	354.7	43943	40563	37665	35154	32957	31018	29295	27753	25110	22927	21971	19530	17577	17010	16478	15979
174	165.1	3.625	2.360	389.6	48254	44542	41360	38603	36190	34061	32169	30476	27573	25176	24127	21446	19301	18679	18095	17546
180	176.7	3.750	2.414	426.6	52819	48756	45274	42255	39614	37284	35213	33359	30182	27558	26409	23475	21127	20446	19807	19207

Note: To obtain flow, Q, multiply values given in table by slope, $S^{1/2}$.

SOLUTION OF MANNING'S EQUATION—FOR PIPE ARCH

Size, in.		A	R			$\frac{1.486}{n} \times A \times R^{2/3}$ (for various values of n)															
						Various Values of n															
Span	Rise	Area, sq. ft.	Hydric.	$R^{2/3}$	$AR^{2/3}$	.012	.013	.014	.015	.016	.017	.018	.019	.021	.023	.024	.027	.030	.031	.032	.033
18	11	1.1	.280	.428	.471	58.33	53.84	49.99	46.66	43.74	41.17	38.88	36.84	33.33	30.43	29.16	25.92	23.33	22.58	21.87	21.21
22	13	1.6	.340	.478	.779	96.47	89.05	82.69	77.17	72.35	68.09	64.31	60.93	55.12	50.33	48.23	42.87	38.59	37.34	36.17	35.08
25	16	2.2	.400	.543	1.195	148.0	136.6	126.8	118.4	111.0	104.5	98.65	93.46	84.56	77.21	73.99	65.77	59.19	57.28	55.49	53.81
29	18	2.8	.447	.567	1.644	203.6	187.9	174.5	162.9	152.7	143.7	135.7	128.6	116.3	106.2	101.8	90.48	81.43	78.81	76.34	74.03
36	22	4.4	.560	.679	2.988	370.0	341.5	317.1	296.0	277.5	261.2	246.7	233.7	211.4	193.0	185.0	164.4	148.0	143.2	138.8	134.5
43	27	6.4	.678	.773	4.947	612.6	565.5	525.1	490.1	459.4	432.4	408.4	386.9	350.1	319.6	306.3	272.3	245.0	237.1	229.7	222.8
50	31	8.7	.790	.855	7.439	921.2	850.3	789.6	737.0	690.9	650.3	614.1	581.8	526.4	480.6	460.6	409.4	368.5	356.6	345.4	335.0
58	36	11.4	.905	.935	10.66	1320	1218	1131	1056	990.0	931.8	880.0	833.7	754.3	688.7	660.0	586.7	528.0	511.0	495.0	480.0
65	40	14.3	1.02	1.007	14.40	1783	1646	1528	1426	1337	1258	1188	1126	1018	930.4	891.6	792.5	713.3	690.3	668.7	648.4
72	44	17.6	1.12	1.078	18.97	2349	2168	2013	1879	1761	1658	1566	1483	1342	1225	1774	1044	939.6	909.3	880.9	854.2
84	55	25.3	1.34	1.215	30.74	3806	3513	3262	3045	2854	2687	2537	2404	2175	1986	1903	1691	1522	1473	1427	1384
71	64	25	1.38	1.239	31.0	3838	3543	3290	3071	2879	2709	2559	2424	2193	2002	1919	1706	1535	1486	1439	1395
76	66	27	1.43	1.269	34.3	4247	3920	3640	3397	3185	2998	2831	2682	2427	2216	2123	1887	1698	1644	1592	1544
80	67	29	1.48	1.299	37.6	4656	4297	3990	3724	3492	3286	3104	2940	2660	2429	2328	2069	1862	1802	1746	1693
83	69	32	1.57	1.351	43.2	5349	4938	4585	4279	4012	3776	3566	3378	3056	2791	2674	2377	2139	2070	2006	1945
88	71	34	1.61	1.374	46.6	5770	5326	4946	4616	4327	4073	3847	3644	3297	3010	2885	2564	2308	2233	2163	2098
92	73	37	1.69	1.413	52.2	6464	5966	5540	5171	4848	4562	4309	4082	3693	3372	3232	2872	2585	2502	2424	2350
96	74	39	1.71	1.430	57.8	7157	6606	6135	5726	5368	5052	4771	4520	4090	3734	3578	3181	2863	2770	2684	2602
100	76	42	1.78	1.469	61.7	7640	7052	6549	6112	5730	5393	5093	4825	4366	3986	3820	3395	3056	2957	2865	2778
103	78	45	1.85	1.507	68.0	8420	7772	7217	6736	6315	5944	5613	5318	4811	4393	4210	3742	3368	3259	3157	3062
108	80	48	1.91	1.539	73.9	9151	8447	7843	7321	6863	6459	6100	5779	5229	4774	4575	4067	3660	3542	3431	3327
112	82	50	1.92	1.545	77.5	9597	8858	8226	7677	7197	6774	6398	6061	5484	5007	4798	4265	3838	3715	3598	3489
117	83	53	1.99	1.582	83.7	10364	9567	8884	8291	7773	7316	6909	6546	5922	5407	5182	4606	4145	4012	3886	3769
120	85	56	2.04	1.608	90.2	11169	10310	9574	8935	8377	7884	7446	7054	6382	5827	5584	4964	4467	4323	4188	4061
125	87	60	2.13	1.655	99.6	12333	11385	10571	9867	9250	8706	8222	7789	7047	6435	6166	5481	4933	4774	4625	4485
129	89	63	2.17	1.676	105	13002	12002	11145	10402	9751	9178	8668	8212	7430	6783	6501	5778	5201	5033	4875	4728
135	90	66	2.20	1.691	112	13869	12802	11888	11095	10402	9790	9246	8759	7925	7236	6934	6164	5547	5368	5201	5043
137	92	69	2.25	1.717	119	14736	13602	12631	11788	11052	10402	9824	9307	8420	7688	7368	6549	5894	5704	5526	5358
140	94	73	2.32	1.752	128	15850	14631	13586	12680	11888	11188	10567	10010	9057	8269	7925	7044	6340	6135	5944	5763
146	96	76	2.36	1.772	134	16593	15317	14223	13274	12445	11713	11062	10480	9482	8657	8296	7374	6637	6423	6222	6034
149	98	80	2.42	1.802	144	17832	16460	15284	14265	13374	12587	11888	11262	10189	9303	8916	7925	7132	6902	6687	6484
154	99	83	2.45	1.817	151	18698	17260	16027	14959	14024	13199	12465	11809	10685	9755	9349	8310	7479	7238	7012	6799
157	101	87	2.51	1.847	161	19937	18403	17089	15949	14952	14073	13291	12591	11392	10402	9968	8860	7974	7717	7476	7249
163	103	91	2.56	1.871	170	21051	19432	18044	16841	15788	14860	14034	13295	12029	10983	10525	9356	8420	8149	7894	7655
166	105	95	2.63	1.905	181	22413	20689	19211	17931	16810	15821	14942	14156	12807	11694	11206	9961	8965	8676	8405	8150
171	106	98	2.65	1.915	188	23280	21489	19954	18624	17460	16433	15520	14703	13303	12146	11640	10346	9312	9011	8730	8465
174	108	102	2.70	1.939	198	24519	22632	21016	19615	18389	17307	16346	15485	14010	12792	12259	10897	9807	9491	9194	8916
177	110	107	2.78	1.977	212	26252	24233	22502	21002	19689	18531	17501	16580	15001	13697	13126	11667	10501	10162	9844	9546
183	112	111	2.82	1.996	222	27491	25376	23563	21992	20618	19405	18327	17362	15709	14343	13745	12218	10996	10641	10309	9996
186	114	115	2.86	2.015	232	28729	26519	24625	22983	21547	20279	19152	18144	16416	14989	14364	12768	11491	11121	10773	10447
192	115	119	2.90	2.034	242	29967	27662	25686	23974	22475	21153	19978	18926	17124	15635	14983	13318	11987	11600	11237	10897
194	117	123	2.95	2.057	253	31329	28919	26854	25063	23497	22115	20886	19787	17902	16346	15664	13924	12531	12127	11748	11392
200	119	128	3.01	2.085	268	33187	30634	28446	26549	24890	23426	22124	20960	18964	17315	16593	14749	13274	12846	12445	12068
203	121	132	3.05	2.103	277	34301	31663	29401	27441	25726	24213	22867	21664	19601	17896	17150	15245	13720	13278	12863	12473

Note: To obtain flow, Q, multiply values given in table by slope, $S^{1/2}$.

PIPE DIAMETER (INCHES)	MAXIMUM COVER (FEET) BY INSTALLATION DESIGN														
	PLAIN			CLASS II			CLASS III			CLASS IV			CLASS V		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
12	19	52	57	13	33	37	17	45	50	26	69	78	33	87	100
18	29	77	86	13	29	37	17	38	50	26	58	78	33	73	100
24				13	25	37	17	33	50	26	50	78	33	62	100
30				13	21	37	17	29	50	26	44	78	33	54	100
36				13	19	37	17	26	50	26	39	78	33	48	100
48				13	17	37	17	23	50	26	35	78	33	43	100
60				13	16	32	17	21	43	26	32	65	33	41	82
72				13	16	31	17	20	43	26	31	65	33	40	82
84				13	15	29	17	20	40	26	30	60	33	38	74
96				13	15	26	17	19	34	26	30	51	33	38	64
108				13	15	23	17	18	31	26	29	46	33	37	58

NOTE: 2' Min. Cover for Concrete Pipe for primaries and arterials.
1' Min. Cover for Concrete Pipe for residential roads.

CONCRETE PIPE

SCHEDULE	*HEIGHT OF COVER (FEET)
A	1 - 15
B	15 - 25
C	25 - 40
D	40 - 60

* The heights of cover shown on this table are to be used as a guide in designing only. See standard plan B-35 for alternate pipes.

SCHEDULE GUIDE FOR 12" THRU 30" DIAMETER CULVERT PIPE

TABLE I

PIPE DIAMETER (INCHES)	MINIMUM COVER (FEET)	MAXIMUM COVER (FEET) (PLATE THICKNESS)									
		5/16" rivets or helical				3/8" rivets or helical					
		.064"		.079"		.109"		.138"		.168"	
		*C	E	C	E	C	E	C	E	C	E
36	1	82		38	44	47	69	57	72	66	76
42	1	27		30	37	36	59	42	62	48	65
48	1	24		26	33	30	52	34	54	38	57
54	1	21		23	29	26	46	28	48	31	50
60	1	19		21	26	23	41	25	43	27	45
66	1	17		20	24	22	37	23	39	25	41
72	1	16		19	22	20	34	22	36	23	38
78	1	14		19	20	20	32	21	33	21	35
84	1			18		19	29	20	31	21	32
90	1			17		19	27	19	29	20	30
96	1					18	26	19	27	19	28
102	2					18	24	18	25	19	26
108	2					18	23	18	24	18	25
114	2							18	22	18	24
120	2							18	21	18	22
		Spot welded or bolted (1/2" A 325 bolts)									
		or 3/8" rivets				or 7/16" rivets					
36	1	84	43	38	57	47	88	57	101	66	106
42	1	27	36	30	49	36	72	42	84	48	91
48	1	24	32	26	42	30	60	34	68	38	76
54	1	22	28	23	38	26	52	28	56	31	62
60	1	20	25	21	34	23	46	25	50	27	54
66	1	19	23	20	31	22	44	23	46	25	50
72	1	19	21	19	28	20	40	22	44	23	46
78	1	19	19	19	26	20	40	21	42	21	42
84	1			18	24	19	37	20	40	21	42
90	1			18	22	19	35	19	38	20	40
96	1					18	33	19	38	19	38
102	2					18	31	18	35	19	37
108	2					18	29	18	33	18	35
114	2							18	32	18	33
120	2							18	29	18	32

* C= Circular, E= Elongated

CORRUGATED STEEL PIPE
3"x1" Corrugations

PIPE DIAMETER (INCHES)	MINIMUM COVER (FEET)	MAXIMUM COVER (FEET) (PLATE THICKNESS)									
		.064"		.079"		.109"		.138"		.168"	
		*C	E	C	E	C	E	C	E	C	E
12	1	83		91							
15	1	67		72		93					
18	1	47	55	55	60	71	78				
24	1	29	41	33	45	40	58	47	61		
30	1	23	33	25	36	28	46	32	49	36	51
36	1	20	27	21	30	23	39	26	40	28	42
42	1	19	30	20	40	21	42	22	44	24	48
48	1	18	26	19	37	19	38	20	40	21	42
54	1			18	33	19	38	19	38	20	40
60	1					18	36	19	38	19	38
66	1					18	29	18	36	18	36
72	1							18	28	18	36
78	1									18	28
84	1									17	23

* C= Circular, E= Elongated.

CORRUGATED STEEL PIPE
2 2/3"x 1/2" Corrugations

PIPE DIMENSIONS SPAN-RISE (INCHES)	CORNER RADIUS (INCHES)	MINIMUM COVER (2T/ft²) (FEET)	MINIMUM THICKNESS (INCHES)	MAXIMUM COVER (FEET) for corner pressures in tons per sq. ft.	
				2 TONS	3 TONS
18 X 11	3 1/2	1.5	.064"	12	19
22 X 13	4	1.5	.064"	12	18
25 X 16	4	1.5	.064"	10	16
29 X 18	4 1/2	1.5	.064"	10	15
36 X 22	5	1.5	.064"	9	13
43 X 27	5 1/2	1.5	.064"	8	12
50 X 31	6	1.5	.079"	7	11
58 X 36	7	1.5	.109"	8	12
65 X 40	8	1.5	.109"	8	12
72 X 44	9	1.5	.138"	8	12
79 X 49	10	1.5	.168"	8	12
85 X 54	11	1.5	.168"	8	12

CORRUGATED STEEL PIPE ARCH
2 2/3"x 1/2" Corrugations

PIPE DIMENSIONS SPAN-RISE (INCHES)	CORNER RADIUS (INCHES)	MINIMUM COVER (FEET)	MINIMUM THICKNESS (INCHES)	MAXIMUM COVER (FEET) for corner pressures in tons per sq. ft.	
				2 TONS	3 TONS
43 X 27	7 1/4	1.5	.064	12	18
50 X 31	9	1.5	.064	11	17
58 X 36	10 1/2	1.5	.064	12	18
65 X 40	12	1.5	.064	12	18
72 X 44	13 1/4	1.5	.064	12	18
73 X 55	18	1.5	.064	16	19
81 X 59	18	1.5	.079	14	19
87 X 63	18	1.5	.079	13	18
95 X 67	18	1.5	.109	12	18
103 X 71	18	2	.109	11	17
112 X 75	18	2	.109	10	16
117 X 79	18	2	.109	10	15
128 X 83	18	2	.138	9	14

CORRUGATED STEEL PIPE ARCH
3"x1" Corrugations

TABLE II

PIPE DIAMETER (INCHES)	MINIMUM COVER (FEET)	MAXIMUM COVER (FEET)													
		12 GAGE		10 GAGE		8 GAGE		7 GAGE		5 GAGE		3 GAGE		1 GAGE	
		* C	E	C	E	C	E	C	E	C	E	C	E	C	E
60	2	42		50	62	58	81	63	93	71	112	79	132	88	144
72	2	32	35	36	51	40	67	43	77	48	93	53	106	58	116
84	2	26	30	29	44	32	57	33	66	36	72	39	78	43	86
96	2	23	26	25	38	27	50	28	56	30	60	32	64	34	68
108	2	21	23	22	34	24	45	25	50	26	52	27	54	29	58
120	2	20	21	21	31	22	40	22	44	23	46	24	48	25	50
132	2	19		20	28	21	36	21	42	22	44	23	46	24	48
144	2	17		19	25	20	33	20	38	21	42	21	42	22	44
156	2	16		18	23	19	31	19	35	20	40	20	40	21	42
168	2	15		18	22	18	28	19	33	19	38	19	38	20	40
180	2	14		18	20	18	27	18	31	19	37	19	38	19	38
192	2			18	19	18	25	18	29	18	35	18	36	19	38
204	3			17	18	18	23	18	27	18	32	18	36	18	36
216	3					17	22	18	25	18	31	18	36	18	36
228	3					17	21	17	23	18	27	18	31	18	35
240	3							17	20	17	23	18	26	18	30
252	3									17	20	17	23	18	26

* C = Circular, E = Elongated.

CORRUGATED STEEL STRUCTURAL PLATE PIPE

6" x 2" Corrugations

PIPE DIMENSIONS SPAN - RISE (FEET & INCHES)	CORNER RADIUS (INCHES)	MINIMUM COVER 2T/ft.² (FEET)	MINIMUM GAGE REQUIRED	MAXIMUM COVER (FEET) for corner pressures in tons per sq. ft.		
				2 TONS	3 TONS	4 TONS
6-1 X 4-7	18	1.5	12	16	24	32
7-0 X 5-1	18	1.5	12	14	21	28
7-11 X 5-7	18	1.5	12	12	18	25
8-10 X 6-1	18	2	12	11	16	22
9-9 X 6-7	18	2	12	10	15	20
10-11 X 7-1	18	2	12	9	13	18
11-10 X 7-7	18	2	12	8	12	16
12-10 X 8-4	18	2	12	7	11	15
14-1 X 8-9	18	2	12	7	10	14
15-4 X 9-3	18	2	10	6	9	13
15-10 X 9-10	18	2	10	6	9	12
16-7 X 10-1	18	3	10	6	9	12
13-3 X 9-4	31	2	12	12	19	19
14-2 X 9-10	31	2	12	12	18	18
15-4 X 10-4	31	2	10	11	16	18
16-3 X 10-10	31	3	10	10	15	18
17-2 X 11-4	31	3	10	10	15	18
18-1 X 11-10	31	3	8	9	14	18
19-3 X 12-4	31	3	8	8	13	17
19-11 X 12-10	31	3	8	8	12	17
20-7 X 13-2	31	3	7	8	12	16

CORRUGATED STEEL STRUCTURAL PLATE PIPE ARCH

6" x 2" Corrugations

TABLE III

PIPE DIAMETER (INCHES)	MINIMUM COVER (FEET)	MAXIMUM COVER (FEET) (PLATE THICKNESS)															
		0.09"		0.10"		0.125"		0.15"		0.175"		0.20"		0.225"		0.25"	
		C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E
72	1	18		20		27	29	28	37	30	44	32	50	35	55	36	60
78	1	17		20		24	26	26	34	28	40	29	46	31	50	32	55
84	1	15		18		23	24	24	31	25	37	27	42	28	47	29	51
90	1	14		17		22	23	23	29	24	35	25	40	26	44	27	48
96	1	13		16		21		22	27	22	33	23	37	24	41	25	45
102	1	13		15		20		21	26	21	31	22	35	23	38	24	42
108	2	12		14		19		20	24	21	29	21	33	22	36	22	40
114	2	11		13		18		20	23	20	27	21	31	21	34	22	37
120	2			13		17		19	22	20	26	20	30	20	33	21	36
126	2			12		16		19	21	19	25	20	28	20	31	20	34
132	2			12		15		19	20	19	24	19	27	19	30	20	32
138	2					15		18	19	19	22	19	26	19	28	19	31
144	2					14		18		18	22	19	25	19	27	19	30
150	2					13		17		18	21	18	24	19	26	19	28
156	2					13		17		18	20	18	23	18	25	19	27
162	2							16		18	19	18	22	18	24	18	26
168	2							15		18		18	21	18	23	18	25
174	2									18		18	20	18	22	18	24
180	2									17		18	20	18	22	18	24

C = Circular, E = Elongated

CORRUGATED ALUMINUM STRUCTURAL PLATE PIPE

9" x 2½" Corrugations

PIPE DIAMETER (INCHES)	MINIMUM COVER (FEET)	MAXIMUM COVER (FEET) (PLATE THICKNESS)									
		.060"		.075"		.105"		.135"		.164"	
		C	E	C	E	C	E	C	E	C	E
12	1	45		45		78					
18	1	27	30	30		36	52	42	54	56	
24	1	21	22	22		25	39	27	40	37	42
30	1			18		21	31	22	32	24	33
36	1			15		19	26	20	27	21	28
42	1			18	25	18	36	19	38	19	38
48	1					18	28	18	36	18	36
54	1					17	20	18	26	18	31
60	1							17	18	17	23
66	1							14		17	
72	1									13	

NOTE: Pipes below heavy line exceed the flexibility factor limit of 7.6×10^{-2}.
C = Circular, E = Elongated.

CORRUGATED ALUMINUM PIPE

2 2/3" x ½" Corrugations

PIPE DIMENSIONS SPAN-RISE (FEET & INCHES)	MINIMUM COVER 2T/ft² (FEET)	MINIMUM THICKNESS (INCHES)	MAXIMUM COVER (FEET) for corner pressure in tons per sq. ft.	
			2 TONS	3 TONS
5-11 X 5-4	1	.125	26	27
6-11 X 5-9	1	.125	22	23
8-0 X 6-2	2	.125	19	20
9-0 X 6-8	2	.125	17	19
10-0 X 7-1	2	.15	15	19
11-2 X 7-6	2	.15	13	18
12-2 X 8-0	2	.15	12	18
13-1 X 8-5	2	.175	11	17
14-3 X 8-10	2	.175	10	16
15-3 X 9-4	2	.20	10	15
16-2 X 9-9	2	.225	9	14
16-11 X 10-1	2	.25	9	13

CORRUGATED ALUMINUM STRUCTURAL PLATE PIPE ARC

9" x 2½" Corrugations

PIPE DIMENSIONS SPAN-RISE (INCHES)	CORNER RADIUS (INCHES)	MINIMUM COVER (2T/ft.²) (FEET)	MINIMUM THICKNESS (INCHES)	MAXIMUM COVER (FEET) for corner pressure in Tons per sq. ft.	
				2 TONS	3 TONS
18 X 11	4 3/4	1.5	.060	17	26
22 X 13	4 3/4	1.5	.060	14	21
25 X 16	4 7/8	1.5	.060	12	18
29 X 18	4 1/2	1.5	.060	10	15
36 X 22	5	1.5	.060	9	13
43 X 27	5 1/2	1.5	.075	8	12
50 X 31	6	1.5	.105	7	11
58 X 36	7	1.5	.135	8	12
65 X 40	8	1.5	.135	8	12
72 X 44	9	1.5	.164	8	12

NOTE: Pipe-arches below heavy line exceed the flexibility factor of 7.6×10^{-2}.

CORRUGATED ALUMINUM PIPE ARCH

2 2/3" x ½" Corrugations

TABLE IV

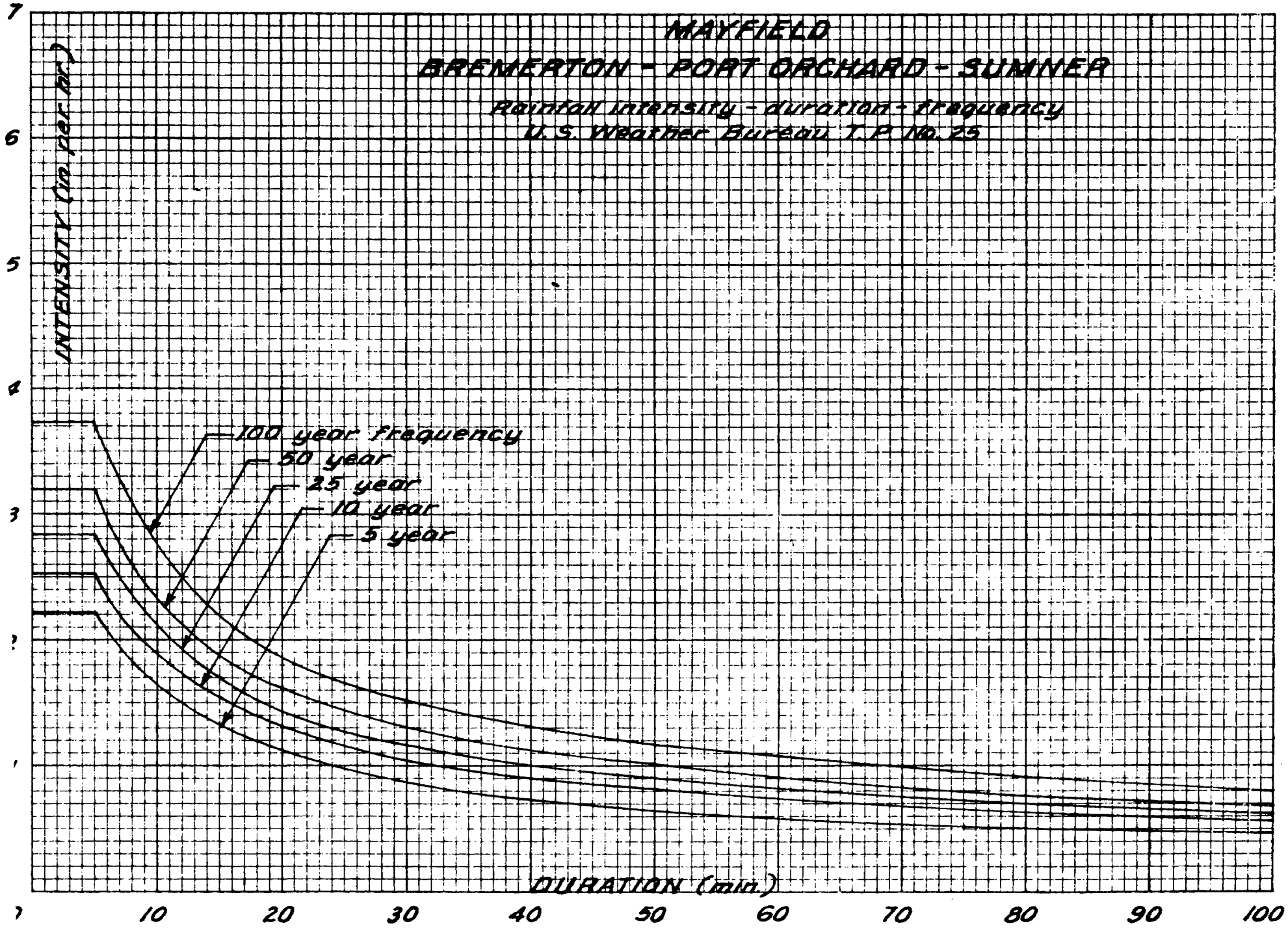

MAYFIELD
BREMERTON - PORT ORCHARD - SUMNER
Rainfall intensity - duration - frequency
U.S. Weather Bureau T.P. No. 25
INTENSITY (in. per hr.)
DURATION (min.)
100 year frequency
50 year
25 year
10 year
5 year
7
6
5
4
3
2
1
10
20
30
40
50
60
70
80
90
100

Chart 6

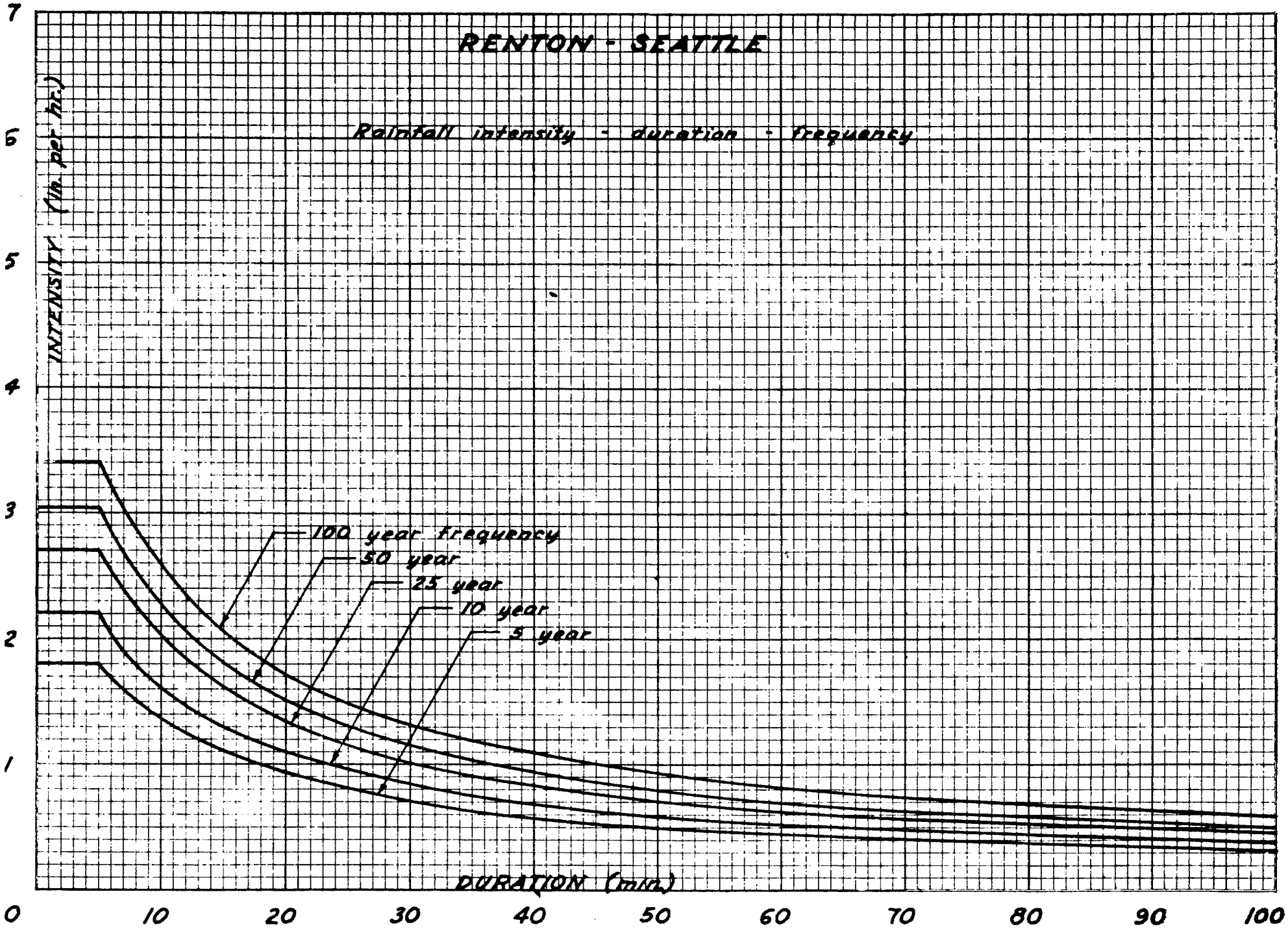

RENTON - SEATTLE
Rainfall intensity - duration - frequency
INTENSITY (in. per hr.)
DURATION (min.)
100 year frequency
50 year
25 year
10 year
5 year
0
1
2
3
4
5
6
7
10
20
30
40
50
60
70
80
90
100

Chart 10

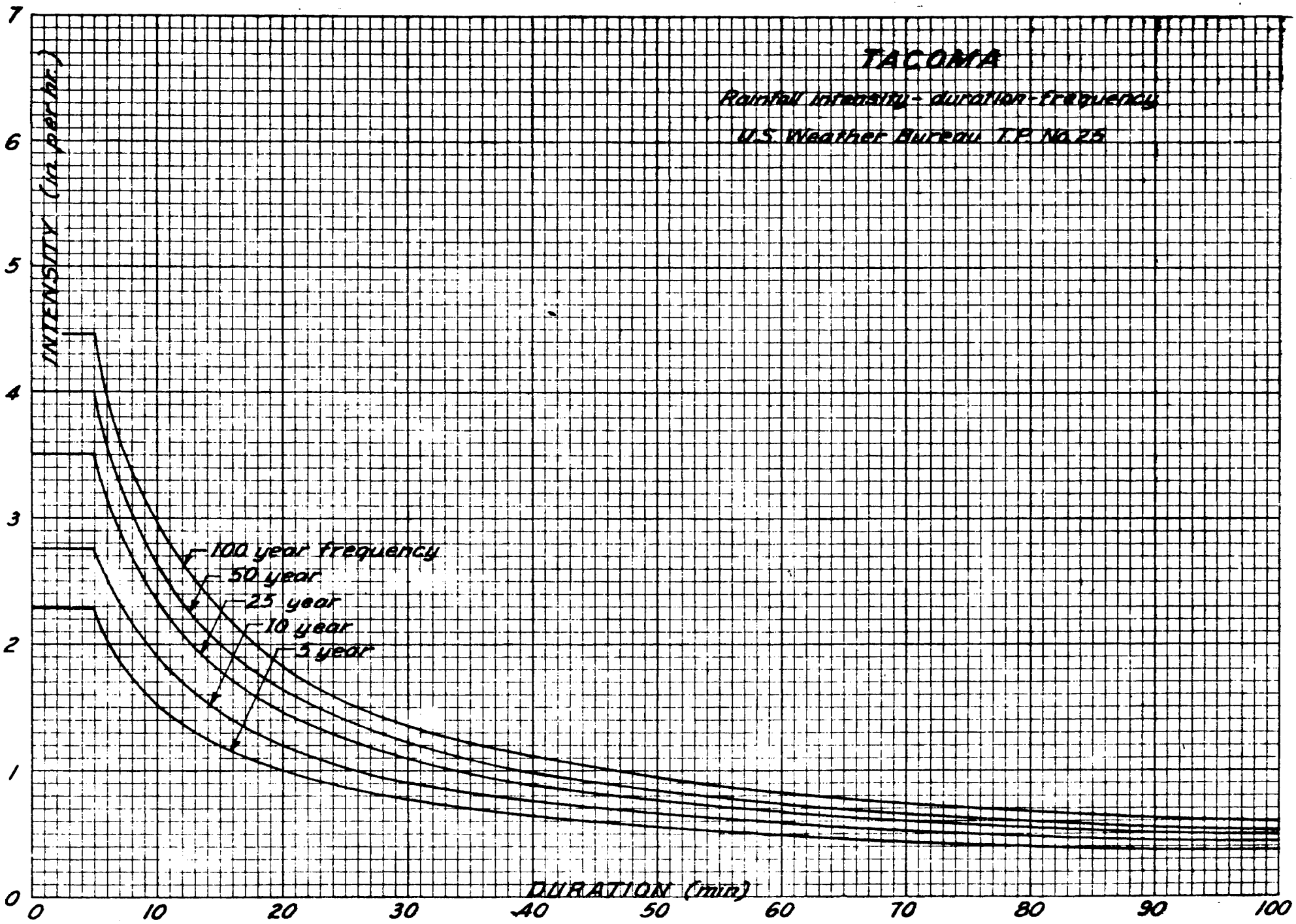

TACOMA
Rainfall intensity - duration - frequency
U.S. Weather Bureau T.P. No. 25
INTENSITY (in per hr)
DURATION (min)
100 year frequency
50 year
25 year
10 year
5 year
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
90
100

Chart 12

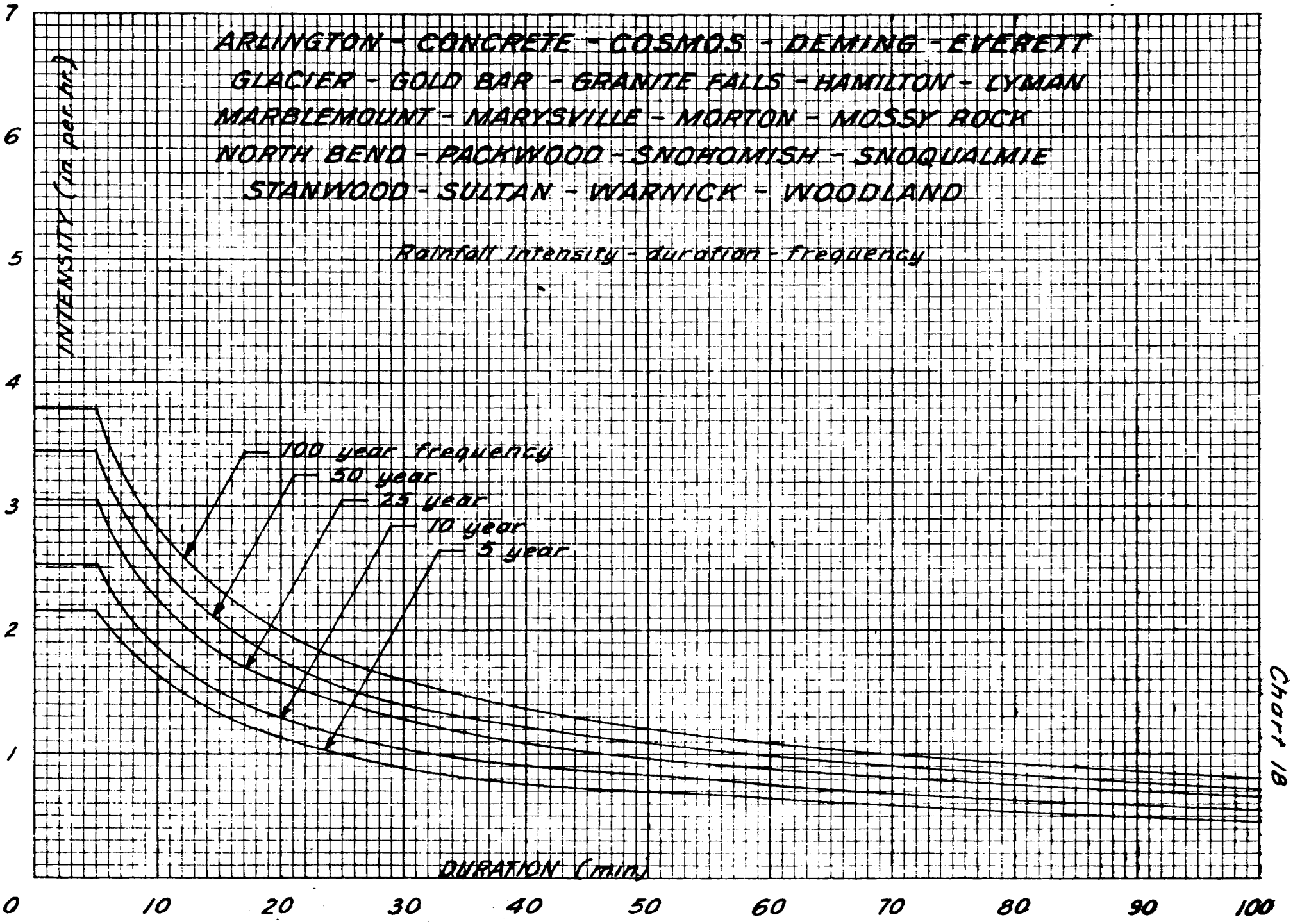

ARLINGTON - CONCRETE - COSMOS - DEMING - EVERETT
GLACIER - GOLD BAR - GRANITE FALLS - HAMILTON - LYMAN
MARBLEMOUNT - MARYSVILLE - MORTON - MOSSY ROCK
NORTH BEND - PACKWOOD - SNOHOMISH - SNOQUALMIE
STANWOOD - SULTAN - WARNICK - WOODLAND
Rainfall intensity - duration - frequency
INTENSITY (in per hr)
100 year frequency
50 year
25 year
10 year
5 year
DURATION (min)
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7

Chart 18

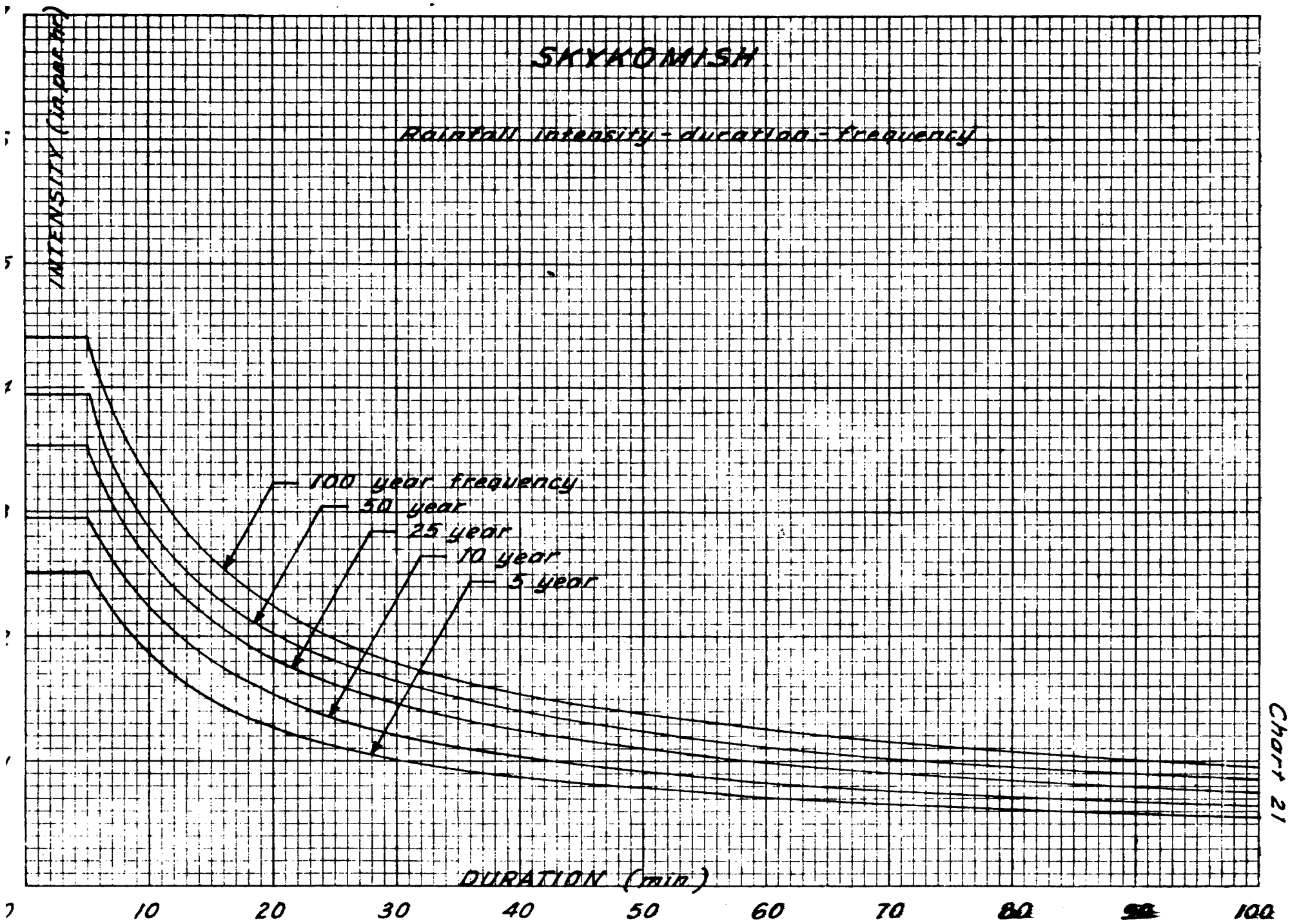

SKYKOMISH
Rainfall intensity - duration - frequency
INTENSITY (in per hr)
100 year frequency
50 year
25 year
10 year
5 year
DURATION (min)
10
20
30
40
50
60
70
80
90
100

Chart 21

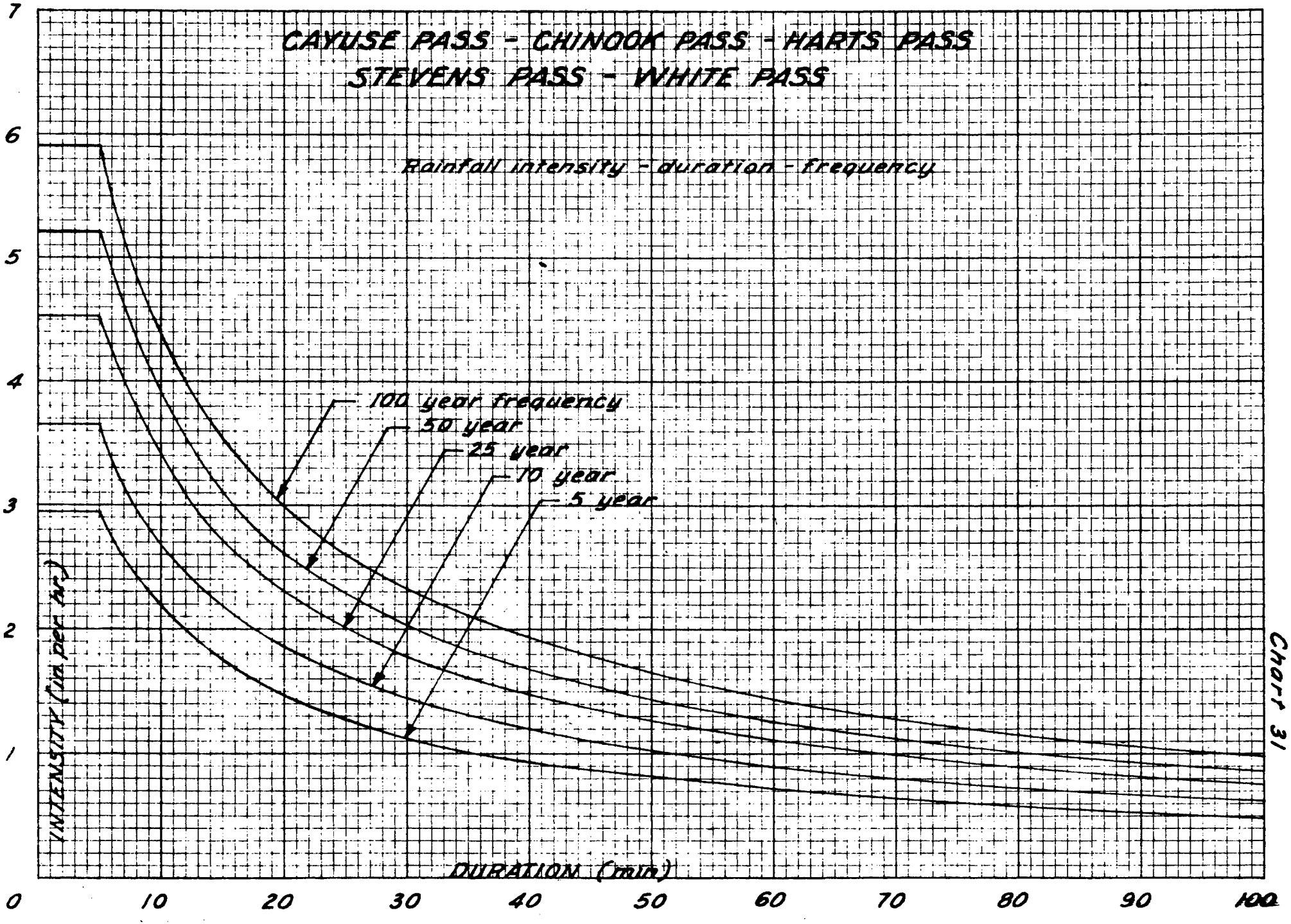

CAYUSE PASS - CHINOOK PASS - HARTS PASS
STEVENS PASS - WHITE PASS
Rainfall intensity - duration - frequency
100 year frequency
50 year
25 year
10 year
5 year
INTENSITY (in per hr)
DURATION (min)
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7

Chart 31

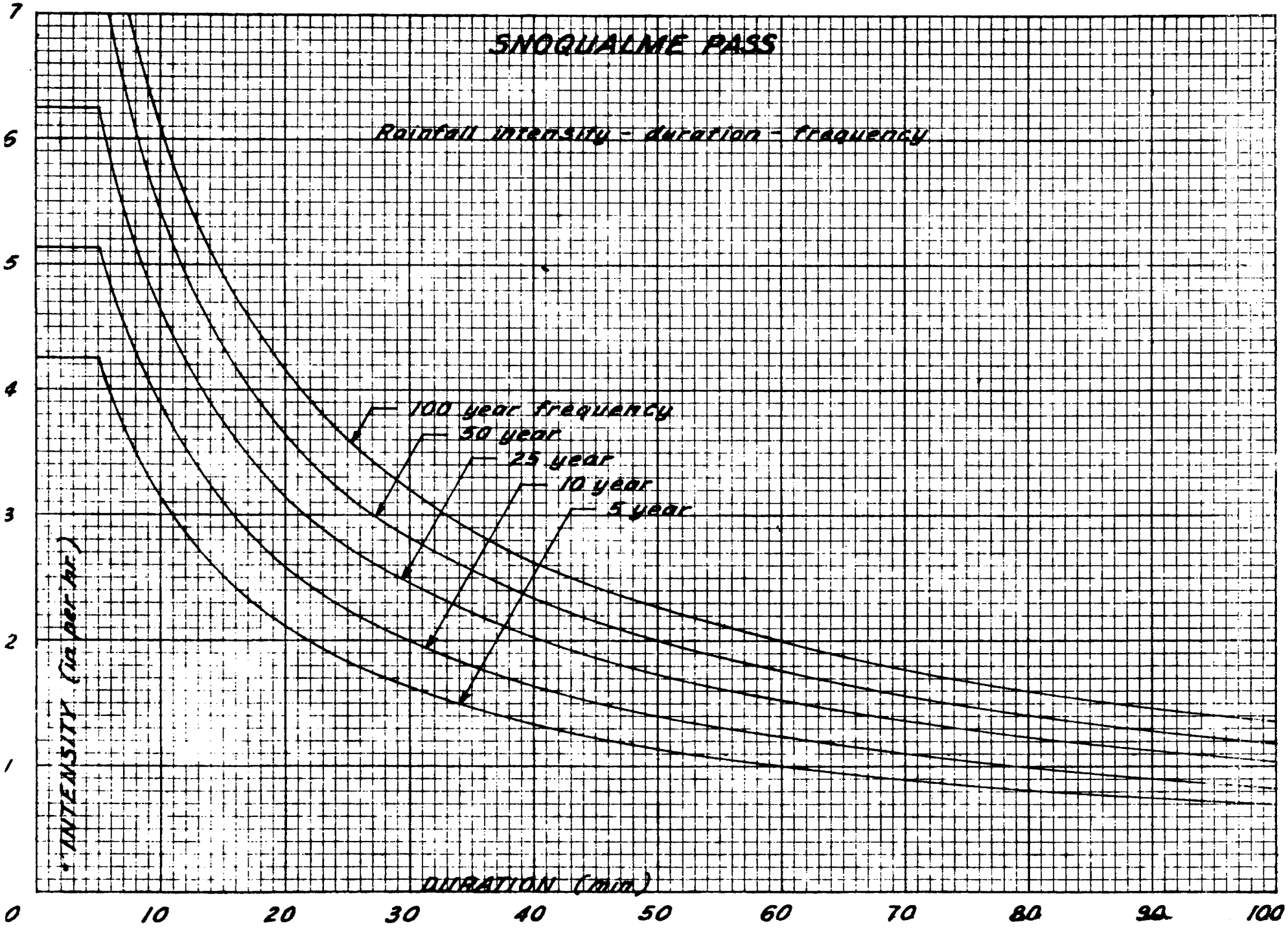

SNOQUALMIE PASS
Rainfall intensity - duration - frequency
100 year frequency
50 year
25 year
10 year
5 year
INTENSITY (in per hr)
DURATION (min)
0
1
2
3
4
5
6
7
10
20
30
40
50
60
70
80
90
100

Chart 33

RUNOFF COMPUTATION

SYSTEM NO. SHEET OF DESIGN STORM

LOCATION

AREA		LENGTH	FEET/SEC. FLOW	FLOW TIME (min.)	CONC. TIME (min.)	TOTAL TIME (min.)	ACRES/AREA	AREA PER RUNOFF COEFF. C ACRES			ACRES x C	ACRES x C	ACRES x C	TOTAL ACRES x C	RAINFALL INTENSITY INCH/HR.	RUNOFF CFS (15)x(16)	PIPE SIZE
TO	FROM							C=	C=	C=							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)

EXAMPLE

3-25-68

FC 40:00

Calculated by _____ Date _____
Checked by _____ Date _____

STORM SEWER DESIGN CALCULATIONS

S.M. No. 1 Project Westside Storm Sewer
Sheet No. 1 of 1 Sheets

LOCATION			DISCHARGE												SEWER DESIGN				SEWER PROFILE						
																					Ground Elev.		Invert Elev.		
Sewer Located on	From Station	To Station	Source of Drainage	Increment of Area A Acres	Run-off Factor I	AI	ΣAI	Time of Concentration to Sta. in Col. 2 min.	Time of Flow in Pipe Col. 2 to Col. 3 min.	Total Time to Sta. in Col. 3 min. (9+10)	Rainfall Intensity R in/hr.	Run-off ΣAIR cfs	Discharge from Laterals cfs	Total Discharge cfs (13+14)	Pipe Diameter in.	Slope of Pipe ft/ft.	Pipe Capacity cfs	Velocity Flowing Full ft/sec.	Length ft.	Fall of Sewer ft.	At Sta. in Col. 2	At Sta. in Col. 3	At Sta. in Col. 2	At Sta. in Col. 3	REMARKS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
LAT-A	0+00L	0+00R	Pvm't	0.58	0.90	0.52	0.52	5.0	0	5.0	2.20	1.14	-	1.14	12	0.0400	7.70	9.70	50	2.00	1019.50	1019.45	1037.00	1035.00	
	0+00R	2+70R	Pvm't	0.20	0.90	0.18																			
			Grass	0.35	0.35	0.12	0.82	5.0	0.6	5.6	2.20	1.81	-	1.81	12	0.0250	6.10	7.70	270	6.75	1019.45	1034.15	1035.00	1028.25	
	2+70L	2+70R	Pvm't	0.20	0.90	0.18	0.18	5.0	0	5.0	2.20	0.40	-	0.40	12	0.0400	7.70	9.70	50	2.00	1034.30	1034.15	1030.25	1028.25	
	2+70R	100+00	Pvm't	0.20	0.90	0.18																			
			Grass	0.25	0.35	0.09	1.27	5.6	0.8	6.4	2.10	2.66	-	2.66	12	0.0250	6.10	7.60	300	7.50	1034.15	1026.05	1028.25	1027.75	
	5+40 L	100+00	Pvm't	0.20	0.90	0.18	0.18	5.0	0	5.0	2.20	0.40	-	0.40	12	0.0450	8.20	10.40	65	2.93	1027.10	1026.05	1023.67	1020.75	
	100-00	104+00	Pvm't	0.65	0.90	0.59																			
			P. Grass	2.15	0.20	0.43	2.47	6.4	1.2	7.6	2.50	6.25		6.25	15	0.0095	6.80	5.50	400	3.80	1026.05	1022.50	1020.50	1016.70	
	0+00	2+00	Pvm't	0.10	0.90	0.09																			
			Grass	0.95	0.40	0.38	0.47	9.0	0.5	9.5	[illegible]	[illegible]	-	0.80	12	0.0180	5.20	6.50	200	3.60	1030.00	1027.00	1026.85	1023.25	
	2+00	104+00	Pvm't	0.30	0.90	0.27																			
			Grass	0.20	0.50	0.10																			
			P. Grass	1.48	0.25	0.37	1.21	[illegible]	0.9	10.4	1.60	1.94		1.94	12	0.0180	5.20	6.50	350	6.30	1027.00	1022.50	1023.25	1016.94	
	104+00	105+50	Pvm't	0.35	0.90	0.[illegible]																			
			G. Grass	0.85	0.6[illegible]	0.55	[illegible]	10.4	0.4	10.8	1.95	8.90	-	8.90	18	0.0095	11.0	6.40	150	1.42	1022.50	1020.25	1016.45	1015.03	
	105+50	107+50	Pvm't	0.15	0.90	0.14	4.69	10.8	0.5	11.3	1.90	8.90		8.90	18	0.0100	11.50	6.40	200	2.00	1020.25	1015.60	1005.80	1003.80	Drop MH
	107+50	110+50	P. Grass	20.5	0.20	4.10	8.79	24.0	0.8	24.8	1.20	10.50		10.50	18	0.0100	11.50	6.40	300	3.00	1015.60	1008.30	1003.80	1000.80	Long T.
	110+50	Outfall	-	-	-	-	8.79	24.8	-	-	1.15	10.10	-	10.10	21	0.0060	13.20	5.40	300	1.80	1008.30	1001.50	1000.55	998.75	

EXAMPLE