TABLE 1-1. 24-HOUR STORM TYPE II DISTRIBUTION -- 2 TO 13 INCHES

Hours	2"	3"	4"	5"	6"	7"
0	0	0	0	0	0	0
4	.10	.15	.19	.24	.29	.34
8	.24	.37	.49	.61	.73	.85
10	.37	.55	.74	.92	1.11	1.29
11	.48	.72	.95	1.19	1.43	1.67
11.5	.57	.86	1.15	1.43	1.72	2.01
12	1.33	2.00	2.67	3.33	4.00	4.67
12.5	1.48	2.22	2.95	3.69	4.43	5.17
13	1.55	2.33	3.10	3.88	4.65	5.43
14	1.65	2.47	3.29	4.12	4.94	5.76
16	1.76	2.64	3.53	4.41	5.29	6.17
20	1.90	2.86	3.81	4.76	5.71	6.67
24	2.00	3.00	4.00	5.00	6.00	7.00

Hours	8"	9"	10"	11"	12"	13"
0	0	0	0	0	0	0
4	.39	.44	.49	.54	.58	.63
8	.97	1.10	1.22	1.34	1.46	1.58
10	1.47	1.66	1.84	2.03	2.21	2.39
11	1.91	2.15	2.38	2.62	2.86	3.10
11.5	2.29	2.58	2.87	3.15	3.44	3.73
12	5.33	6.00	6.67	7.33	8.00	8.66
12.5	5.91	6.65	7.38	8.12	8.86	9.60
13	6.21	6.98	7.76	8.53	9.31	10.08
14	6.59	7.41	8.23	9.05	9.88	10.70
16	7.05	7.93	8.82	9.70	10.58	11.46
20	7.62	8.57	9.52	10.47	11.43	12.38
24	8.00	9.00	10.00	11.00	12.00	13.00

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TABLE 1-1A

MASS RAINFALL AND RUNOFF (TYPE II DISTRIBUTION)

COUNTY HOUSTON CURVE NO. 88

DURATION HOURS	___ YEAR FREQUENCY		10 YEAR FREQUENCY		25 YEAR FREQUENCY		100 YEAR FREQUENCY	
	RAINFALL INCHES	RUNOFF INCHES	RAINFALL INCHES	RUNOFF INCHES	RAINFALL INCHES	RUNOFF INCHES	RAINFALL INCHES	RUNOFF INCHES
0			0	0	0	0	0	0
4.0			.36	0	.43	.02	.55	.04
8.0			.91	.20	1.07	.29	1.36	.48
10.0			1.38	.50	1.62	.67	2.07	1.02
11.0			1.79	.80	2.10	.96	2.67	1.58
11.5			2.15	1.08	2.52	1.40	3.21	2.00
12.0			5.00	3.66	5.87	4.49	7.46	6.03
12.5			5.44	4.08	6.50	5.10	8.27	6.82
13.0			5.74	4.36	6.83	5.42	8.69	7.23
14.0			6.17	4.78	7.25	5.83	9.22	7.75
16.0			6.61	5.20	7.75	6.31	9.88	8.41
20.0			7.14	5.72	8.38	6.93	10.66	9.18
24.0			7.50	6.07	8.80	7.34	11.20	9.71

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COOPERATOR EXAMPLE STRUCTURE NO. _____

TABLE 1-2

STORAGE-INDICATION ROUTING FOR 10 YEAR FREQUENCY FLOOD

COUNTY Houston CURVE NO. 88

1	2	3	4	5	1	2	3	4	5
Duration	Mass Runoff at Source	Storage Increments Accumulated	Accumulated Storage plus Runoff	Mass Inflow to Site	Duration	Mass Runoff at Source	Storage Increments Accumulated	Accumulated Storage plus Runoff	Mass Inflow to Site
Hours	Inches	Inches	Inches	Inches	Hours	Inches	Inches	Inches	Inches
4.00	0	0	0	0	22.00	5.91	11.29	17.20	5.73
4.75	.03	0	.03	.01	22.75	5.98	11.47	17.45	5.82
5.50	.06	.02	.08	.03	23.50	6.05	11.63	17.68	5.89
6.25	.10	.05	.15	.05	24.25	6.07	11.79	17.85	5.95
7.00	.14	.10	.24	.08	25.00	6.07	11.90	17.97	5.99
7.75	.18	.16	.34	.11	25.75	6.07	11.98	18.05	6.02
8.50	.28	.23	.51	.17					
9.25	.39	.34	.73	.24					
10.00	.50	.49	.99	.33					
10.75	.72	.66	1.38	.46					
11.50	1.08	.92	2.00	.67					
12.25	3.87	1.33	5.20	1.73					
13.00	4.36	3.47	7.83	2.61					
13.75	4.67	5.22	9.89	3.30					
14.50	4.84	6.59	11.43	3.81					
15.25	5.02	7.62	12.64	4.21					
16.00	5.20	8.43	13.63	4.54					
16.75	5.29	9.09	14.38	4.79					
17.50	5.38	9.59	14.97	4.99	Ref. Texas Engr. Tech. Note No. 210-15-TX1				
18.25	5.48	9.98	15.46	5.15	Col. 1 = Time increments (Ti)				
19.00	5.58	10.31	15.89	5.30	Col. 2 = From Fig. 1-1				
19.75	5.68	10.59	16.27	5.42	Col. 3 = Previous Col. 4 minus Col. 5				
20.50	5.78	10.85	16.63	5.54	Col. 4 = Col. 2 plus Col. 3				
21.25	5.84	11.09	16.93	5.64	Col. 5 = Col.4 x Routing Coeff. (Fig. 1-1A)				

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COOPERATOR EXAMPLE STRUCTURE NO. ____

TABLE 1-2A ~~or B~~

STORAGE-INDICATION ROUTING FOR 25 YEAR FREQUENCY FLOOD

COUNTY Houston CURVE NO. 88

1	2	3	4	5	6	7	8	9	10
Duration	Mass Runoff at Source	Storage Increments Accumulated	Storage plus Inflow	Mass Inflow to Site	Incremental Inflow to Site L_v	Storage at beginning of Time Increment S_1	$I_v + S_1$ or $S + O$	Incremental O_v	Storage at end of Increment S_2
Hours	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
4.00	0	0	0	0	0	0	0	0	0
4.75	.05	0	.05	.02	.02	.02	.020	0	.020
5.50	.10	.03	.13	.04	.02	.02	.040	0	.040
6.25	.15	.09	.24	.08	.04	.04	.080	0	.080
7.00	.20	.16	.36	.12	.04	.06	.110	.010	.100
7.75	.26	.24	.50	.17	.05	.100	.150	.020	.130
8.50	.39	.33	.72	.24	.07	.130	.200	.037	.163
9.25	.53	.48	1.01	.34	.10	.163	.263	.065	.198
10.00	.67	.67	1.34	.45	.11	.198	.309	.084	.225
10.75	.89	.89	1.78	.59	.14	.225	.365	.115	.260
11.50	1.40	1.19	2.59	.86	.27	.260	.530	.172	.358
12.25	4.79	1.73	6.52	2.77	1.31	.358	1.668	.240	1.228
13.00	5.42	4.35	9.77	3.26	1.09	1.228	2.318	.244	2.074
13.75	5.72	6.51	12.23	4.08	.82	2.074	2.894	.250	2.640
14.50	5.92	8.15	14.07	4.69	.61	2.640	3.250	.275	2.975
15.25	6.12	9.38	15.50	5.17	.48	2.975	3.455	.305	3.150
16.00	6.31	10.33	16.64	5.55	.38	3.150	3.530	.310	3.220
16.75	6.42	11.09	17.51	5.84	.29	3.220	3.510	.308	3.202

Ref: Texas Engineering Technical Note No. 210-15-TX1

Col. 1 =	Time increments (Ti)	Col. 7 =	Previous Col. 10		
Col. 2 =	From Fig. 1-1	Col. 8 =	Col. 6 + Col. 7		
Col. 3 =	Prev. Col. 4 - Col. 5	Col. 9 =	Outflow read from Fig. 1-2A		
Col. 4 =	Col. 2 + Col. 3		for the S+O values in Col. 8		
Col. 5 =	Col. 4 x Routing Coef (Fig 1-1A)	Col. 10 =	Col. 8 - Col. 9		
Col. 6 =	Difference between values in Col. 5.				

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COOPERATOR EXAMPLE STRUCTURE NO. ____

TABLE 1-2A or B

STORAGE-INDICATION ROUTING FOR 100 YEAR FREQUENCY FLOOD

COUNTY Houston CURVE NO. 88

1	2	3	4	5	6	7	8	9	10
Duration	Mass Runoff at Source	Storage Increments Accumulated	Storage plus Inflow	Mass Inflow to Site	Incremental Inflow to Site L_v	Storage at beginning of Time Increment S_1	$I_v + S_1$ or $S + O$	Incremental O_v	Storage at end of Increment S_2
Hours	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
4.00	.04	0	.04	.01	.01	0	.01	0	.010
4.75	.12	.03	.15	.05	.04	.010	.05	0	.050
5.50	.20	.10	.30	.10	.05	.050	.10	.010	.090
6.25	.28	.20	.48	.16	.06	.090	.15	.020	.130
7.00	.36	.32	.68	.23	.07	.130	.200	.037	.163
7.75	.45	.45	.90	.30	.07	.163	.233	.050	.183
8.50	.63	.60	1.23	.41	.11	.183	.273	.068	.205
9.25	.82	.82	1.64	.55	.14	.205	.345	.102	.243
10.00	1.02	1.09	2.11	.70	.15	.243	.293	.124	.269
10.75	1.51	1.41	2.92	.97	.27	.269	.539	.174	.365
11.50	2.00	1.95	3.95	1.32	.35	.365	.715	.213	.502
12.25	4.61	2.63	7.24	2.41	1.09	.502	1.592	.238	1.354
13.00	7.23	4.83	12.06	4.02	1.61	1.354	2.964	.255	2.709
13.75	7.62	8.04	15.66	5.22	1.20	2.709	3.909	.375	3.534
14.50	7.91	10.44	18.35	6.12	.90	3.534	4.434	.460	3.974
15.25	8.16	12.23	20.39	6.80	.68	3.974	4.654	.500	4.154
16.00	8.41	13.59	22.00	7.33	.53	4.154	4.684	.505	4.179
16.75	8.55	14.67	23.22	7.74	.41	4.179	4.589	.490	4.099

Ref. Texas Engineering Technical Note No. 210-15-TX1

Col. 1 =	Time increments (Ti)	Col 7 =	Previous Col. 10		
Col. 2 =	From Fig. 1-1	Col. 8 =	Col. 6 + Col. 7		
Col. 3 =	Prev. Col. 4 - Col. 5	Col. 9 =	Outflow read from Fig. 1-2A		
Col. 4 =	Col. 2 + Col. 3		for the S+O values in Col. 8		
Col. 5 =	Col 4xRouting Coef (Fig 1-1A)	Col. 10 =	Col. 8 - Col. 9		
Col. 6 =	Difference between values in Col. 5.				

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COOPERATOR EXAMPLE STRUCTURE NO.

TABLE 1-2C

STORAGE-INDICATION ROUTING CURVE TABULATION

COUNTY HOUSTON CURVE NO. 88

		1	2	3	4	5	6	7
		Stage Feet	Detention Storage S Inches	Discharge Principal Spillway CFS	Discharge Emergency Spillway CFS	Total Discharge CFS	Total Discharge O In/.75 Hr.	S + O
		98.30	0	0	0	0	0	0
		99.00	.20	34	0	34	.066	.266
		100.00	.58	118	0	118	.228	.808
		101.00	1.01	121	0	121	.234	1.244
		102.00	1.51	123	0	123	.238	1.748
		103.00	2.16	126	0	126	.244	2.404
		103.50	2.53	128	0	128	.248	2.778
		103.75	2.76	129	3	132	.256	3.016
		104.00	2.99	130	13	143	.277	3.267
		104.25	3.24	131	34	165	.320	3.560
		104.50	3.50	132	58	190	.368	3.868
		104.75	3.79	133	85	218	.422	4.212
		105.00	4.08	134	117	251	.486	4.566
		105.50	4.70	135	186	321	.622	5.322
		106.00	5.34	136	276	412	.798	6.138

Ref. Texas Engineering Technical Note No. 210-15-TX1

Col. 1	= From Stage-Capacity Curve			Fig. 1-2		Derivation of
Col. 2	= From Stage-Capacity Curve			Fig. 1-2		0.03719
Col. 3,4 & 5	= From Stage-Capacity Curve			Fig. 1-2	1 cfs	=1.983 Ac.Ft./24Hrs.
Col. 6	= Col. 5	x K. K =	(0.03719)(Ti)			=23.8 Ac.In./24Hrs.
			(Dr.A. Sq.Mi.)(24	Hrs.)	23.8	= 0.03719
Col. 7	= Col. 2	+ Col. 6			640	In./SM/24 Hrs.

Table 1-3. Example of computations for head-discharge relationship

Pipe Flow 36" Barrel $Q_p = A\sqrt{\frac{2g\ H}{K}}$			54" Riser				60" Riser			
			Weir Flow $Q_w = 3.5LH_w^{\frac{3}{2}}$		Orifice Flow $Q_o = 0.6A\sqrt{2gH_o}$		Weir Flow		Orifice Flow	
Elev.	H_p	Q_p	H_w	Q_w	H_o	Q_o	H_w	Q_w	H_o	Q_o
82.4	0	0								
90.0	7.6	77.3								
95.0	12.6	99.5								
98.3	15.9	112.0	0	0	0	0	0	0	0	0
98.8	16.4	113.0	0.5	17.5	0.5	54.3	0.5	19.4	0.5	67.0
99.3	16.9	115.0	1.0	49.5	1.0	76.9	1.0	55.0	1.0	94.8
99.5	17.1	116.0	1.2	65.2	1.2	84.2	1.2	72.3	1.2	104.0
99.7	17.3	116.5	1.4	82.0	1.4	91.0	1.4	91.0	1.4	113.2
99.9	17.5	117.0	1.6	100.2	1.6	97.0	1.6	111.2	1.6	120.0
100.1	17.7	118.0	1.8	119.3	1.8	103.2	1.8	132.2	1.8	127.6
100.5	18.1	119.2	2.2	162.0	2.2	114.0	2.2	178.9	2.2	140.9
100.9	18.5	121.0	2.6	208.0	2.6	124.0	2.6	229.8	2.6	153.1
102.0	19.6	123.0								
103.0	20.6	127.0								
104.0	21.6	131.0								
105.0	22.6	134.0								

Table 1-4. Weighted average estimated gross erosion rates

Resource Area	Cultivated Land	Grassland - Woods
	Ac.ft./Ac./yr.	Ac.ft./Ac./yr.
Cross Timbers, East & West	0.006179	0.000828
East Texas Timberlands	0.00850	0.00067
Blackland Prairies	0.00925	0.00042
Coast Prairie	0.00142	0.00017
Coast Marsh	0.00008	0.00008
Rio Grande Plain	0.00467	0.00025
Rolling Plains	0.00417	0.00033
North Central Prairie	0.00567	0.00033
Grand Prairie	0.00517	0.00025
Edwards Plateau	0.00325	0.00025
Central Basin	0.00525	0.00017
Trans-Pecos	0.00058	0.00017
High Plains	0.00018	0.00018

TABLE 1-5. TABLES FOR COMPUTING CULVERT DISCHARGE $Q = C A\sqrt{2gh}$ AND MINIMUM SURCHARGE h_1

Table "A" Values of $A\sqrt{2gh}$

H	12"	15"	18"	21"	24"	30"	36"	42"	48"	60"
0.1	2.0	3.11	4.48	6.11	7.96	12.44	17.91	24.38	31.84	49.75
0.2	2.8	4.40	6.33	8.63	11.26	17.60	25.34	34.49	45.05	70.39
0.3	3.4	5.39	7.77	10.56	13.81	21.58	31.07	42.28	55.23	86.30
0.4	4.0	6.22	8.96	12.19	15.93	24.88	35.83	48.77	63.70	99.53
0.5	4.4	6.96	10.00	13.64	17.82	27.83	40.08	54.55	71.25	111.33
0.6	4.9	7.62	10.98	14.93	19.53	30.51	43.94	59.80	78.11	122.05
0.7	5.3	8.24	11.86	16.14	21.09	32.95	47.45	64.59	84.36	131.81
0.8	5.6	8.81	12.67	17.24	22.53	35.20	50.61	68.98	90.10	140.78
0.9	6.0	9.34	13.45	18.30	22.91	37.36	53.80	73.23	95.64	149.44
1.0	6.3	9.84	14.17	19.29	25.20	39.37	56.69	77.16	100.78	157.47
1.5	7.7	12.05	17.36	23.62	30.87	48.23	69.45	94.53	123.46	192.91
2.0	8.9	13.91	20.04	27.27	35.63	53.67	80.16	109.10	142.50	222.66
2.5	10.0	15.56	22.41	30.50	39.84	62.24	89.63	121.99	159.34	248.97
3.0	10.9	17.04	24.55	33.40	43.65	68.19	98.20	133.65	174.55	272.75
3.5	11.8	18.40	26.51	36.07	47.15	73.66	106.07	144.36	188.55	294.62
4.0	12.6	19.68	28.34	38.58	50.40	78.74	113.39	154.32	201.56	314.95
4.5	13.4	20.86	30.06	40.91	53.45	83.50	120.24	163.65	213.75	333.99
5.0	14.1	22.00	31.69	43.12	56.35	88.03	126.77	172.53	225.35	352.11

"C" - Coefficient of Discharge "C" From King's Handbook of Hydraulics (Tables "B"; "C-1" and "C-2")

Table "B" Corrugated Metal Pipe

	Length in Feet				
Diam.	20'	30'	40'	60'	100'
12"	0.55	0.48	0.43	0.36	0.29
15"	0.60	0.53	0.48	0.41	0.33
18"	0.63	0.56	0.51	0.44	0.36
21"	0.66	0.60	0.55	0.48	0.39
24"	0.68	0.62	0.57	0.50	0.41
30"	0.71	0.65	0.61	0.54	0.46
36"	0.73	0.68	0.64	0.58	0.49
42"	0.74	0.70	0.66	0.60	0.52
48"	0.75	0.71	0.68	0.62	0.54
60"	0.76	0.73	0.70	0.66	0.58

Table "C-1" Concrete Pipe-Beveled Lip

	Length in Feet				
Diam.	20'	30'	40'	60'	100'
12"	0.79	0.73	0.68	0.61	0.52
15"	0.82	0.77	0.73	0.66	0.57
18"	0.84	0.80	0.76	0.70	0.61
21"	0.86	0.82	0.78	0.73	0.65
24"	0.87	0.83	0.80	0.75	0.67
30"	0.89	0.86	0.83	0.79	0.71
36"	0.90	0.87	0.85	0.81	0.74
42"	0.91	0.89	0.87	0.83	0.77
48"	0.91	0.89	0.88	0.85	0.79
60"	0.92	0.90	0.89	0.87	0.82

Table "C-2"
Concrete Pipe, Sq. Cornered Entrance

Diam.	20'	30'	40'	60'	100'
12"	0.74	0.69	0.65	0.59	0.51
15"	0.76	0.72	0.68	0.63	0.55
18"	0.77	0.73	0.70	0.65	0.58
21"	0.77	0.74	0.72	0.67	0.60
24"	0.78	0.75	0.73	0.69	0.62
30"	0.78	0.76	0.74	0.71	0.65
36"	0.77	0.76	0.74	0.72	0.67
42"	0.77	0.76	0.74	0.72	0.68
48"	0.76	0.75	0.74	0.72	0.69
60"	0.75	0.74	0.74	0.72	0.70

Table "D"

"D"	"A"
Diam. (Inches)	Area (Sq.Ft.)
6"	0.196
8"	0.349
12"	0.785
15"	1.227
18"	1.767
21"	2.405
24"	3.142
30"	4.909
36"	7.069
42"	9.621
48"	12.566
60"	19.635

$V = \frac{Q}{A}$; where "V" is velocity of flow in feet per second; "Q" is cubic feet per second, and "A" is sq. ft. of pipe section.

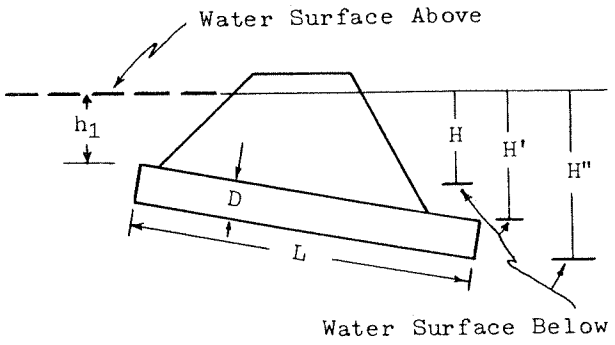
Table I-5 Continued. Minimum surcharge h_1 required for velocities shown (Tables "E" and "F")

Feet $h_1 = 0.022\ V^2$

Table "E" Corrugated Metal Pipe										
h_1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	-	2.13	3.01	3.69	4.27	4.76	5.22	5.64	6.03	6.40
1.0	6.74	7.07	7.39	7.69	7.98	8.26	8.59	8.79	9.04	9.29
2.0	9.53	9.77	10.00	10.22	10.44	10.65	10.87	11.08	11.28	11.48
3.0	11.67	11.87	12.06	12.25	12.43	12.61	12.79	12.96	13.14	13.31
4.0	13.48	13.65								

Feet $h_1 = 0.017\ V^2$

Table "F" Concrete Pipe										
h_1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	-	2.42	3.41	4.18	4.85	5.42	5.94	6.34	6.86	7.27
1.0	7.67	8.04	8.40	8.76	9.08	9.39	9.70	10.00	10.29	10.57
2.0	10.87	11.11	11.38	11.63	11.88	12.12	12.37	12.58	12.84	13.06
3.0	13.28	13.50	13.72	13.94	14.14	14.34	14.55	14.75	14.95	15.15
4.0	15.34	15.53	15.72	15.88	16.09	16.26	16.45	16.63		



h_1 = Surcharge at culvert entrance.

$h_1 > 0.022\ V^2$ for C.M.P.

$h_1 > 0.017\ V^2$ for concrete pipe.

For free outlet, use H' for H; H' may be approximated as H" less an Assumed Vertical Diameter.

Example: It is required to carry 44 cfs through a CMP culvert 60 ft. long with submerged outlet where the difference H in water surface above and below is 2.0 feet.
Try 36" diam. Enter Table A with 2.0' Head and 36" diam. Find A $\sqrt{2gh}$ = 80.16. Enter Table B CMP with 36" diam. and 60' length L. find C = 0.58. 80.16 x 0.58 = 46.5 cfs.
The 36" will do. Enter Table D, find area of 36" = 7.069 sq. ft. 44 ÷ 7.069 = 6.22 fps velocity. Enter Table E with velocity 6.22 fps. find minimum surcharge h_1 of 0.85'. The top of the 36" CMP must be set 0.85' below the water surface or hydraulic gradient above the culvert.

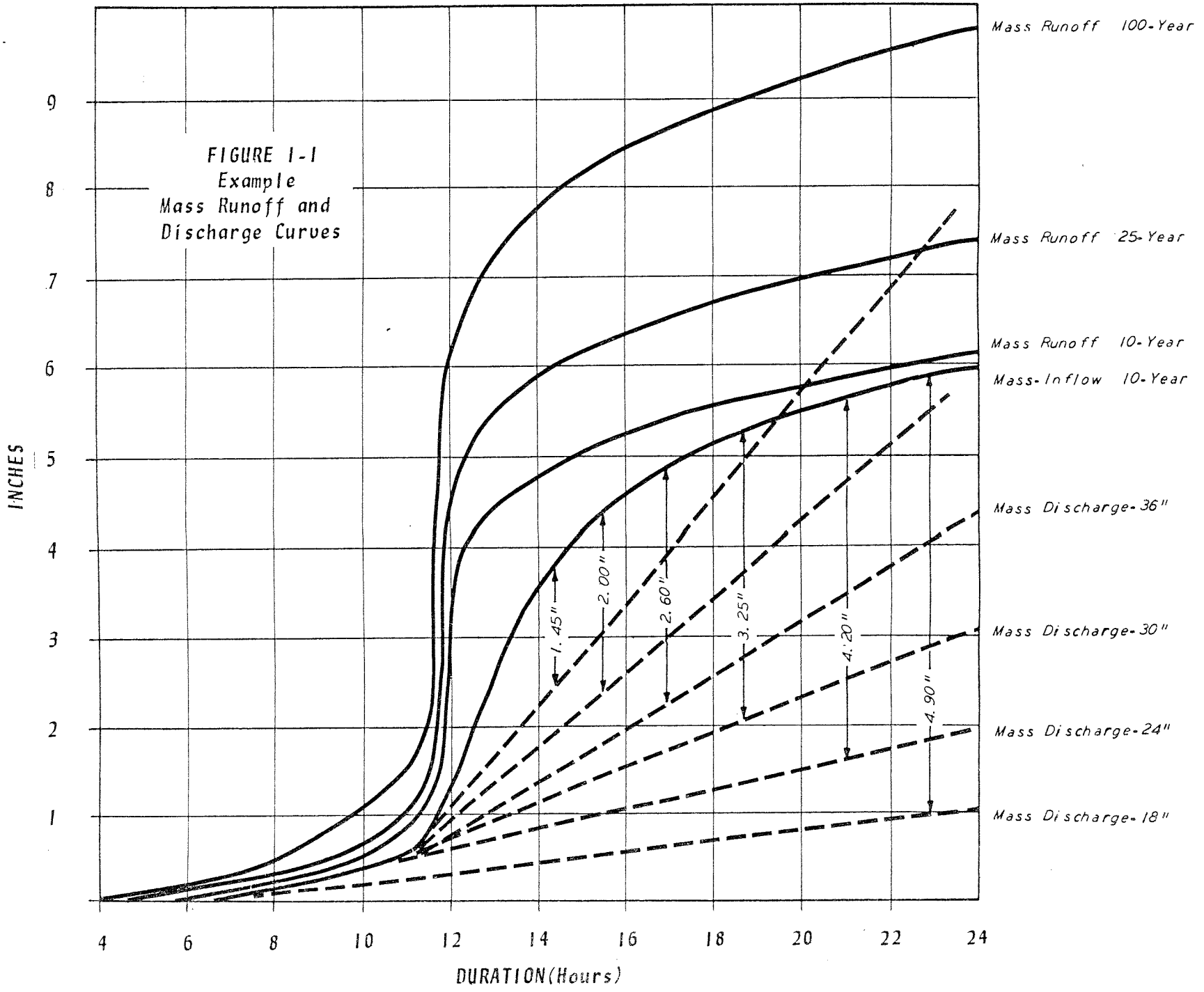


FIGURE 1-1
Example
Mass Runoff and
Discharge Curves
Mass Runoff 100-Year
Mass Runoff 25-Year
Mass Runoff 10-Year
Mass-Inflow 10-Year
Mass Discharge-36"
Mass Discharge-30"
Mass Discharge-24"
Mass Discharge-18"
1.45"
2.00"
2.60"
3.25"
4.20"
4.90"
INCHES
DURATION(Hours)
1
2
3
4
5
6
7
8
9
4
6
8
10
12
14
16
18
20
22
24

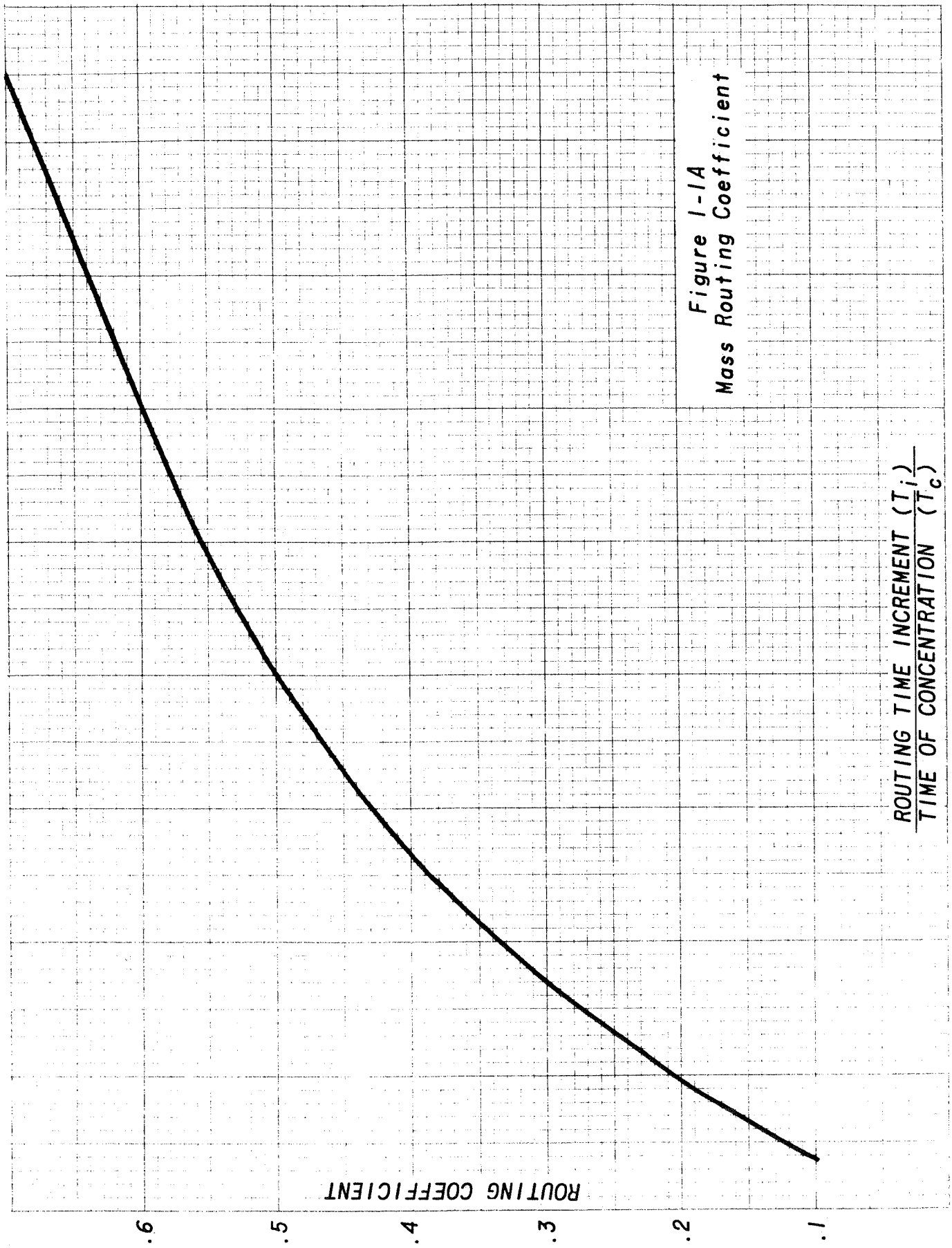


Figure 1-1A
Mass Routing Coefficient
ROUTING COEFFICIENT
.1
.2
.3
.4
.5
.6
.25
.50
1.00
1.50
2.00
ROUTING TIME INCREMENT (T_i) / TIME OF CONCENTRATION (T_c)

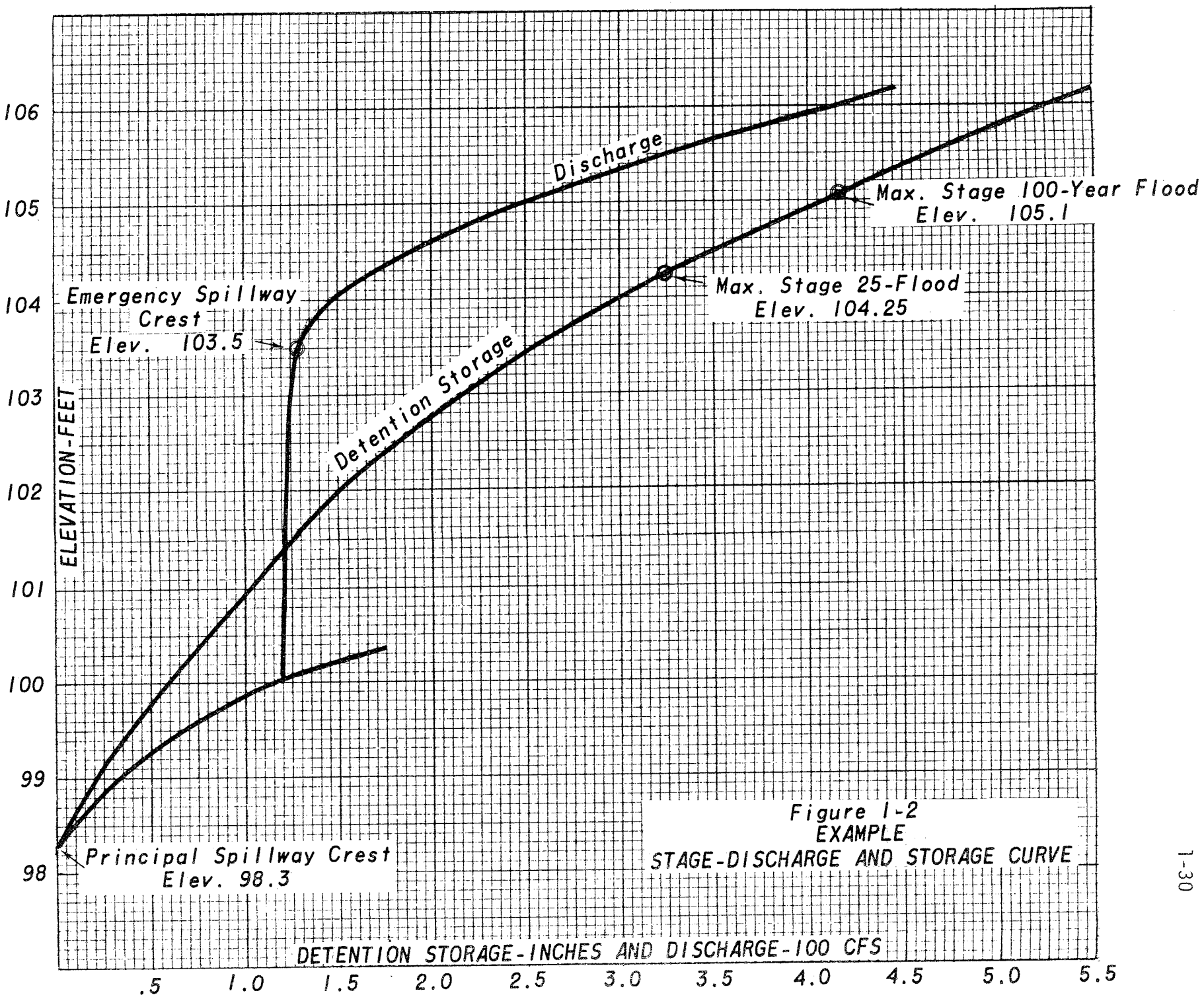


Figure 1-2
EXAMPLE
STAGE-DISCHARGE AND STORAGE CURVE

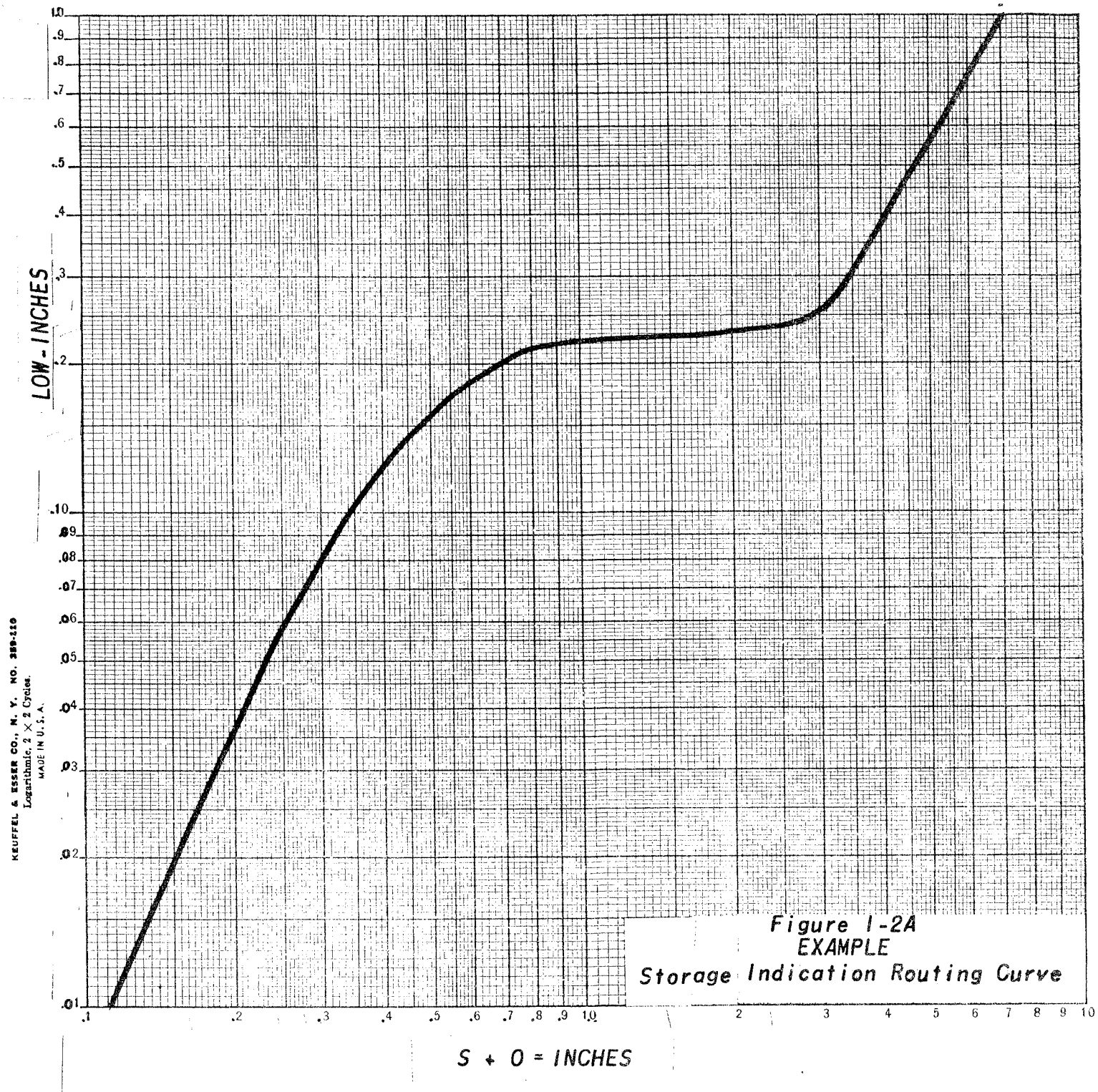


Figure 1-2A
EXAMPLE
Storage Indication Routing Curve

Figure 1-3 HEAD-DISCHARGE RELATIONSHIPS

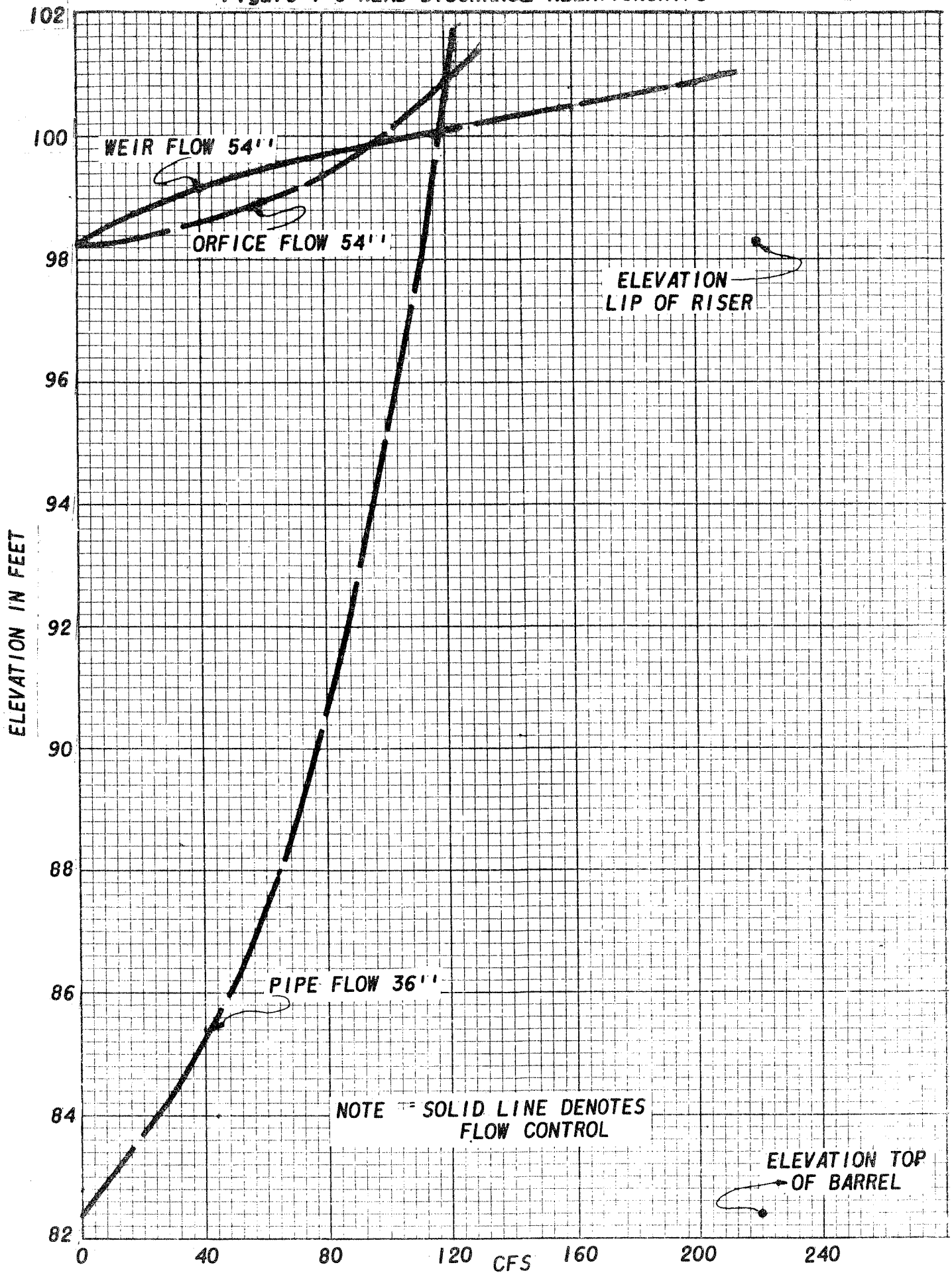
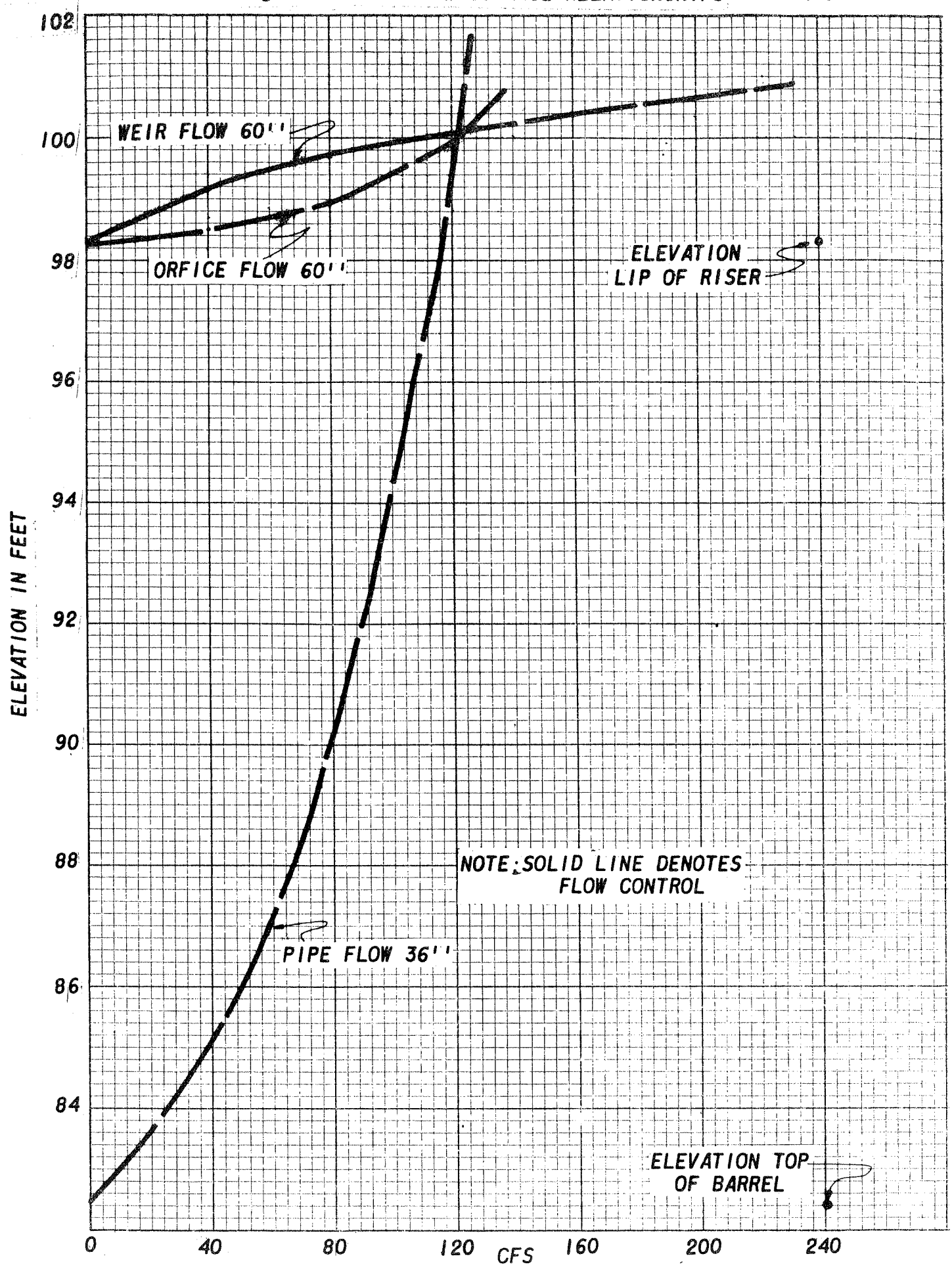



Figure 1-4 HEAD-DISCHARGE RELATIONSHIPS