Table 3-1-3 Water Level at Tha Khai

Tha Khai (MSL)

	Max (in River side) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean	Max	Min
1978	1.22	1.17	1.15	1.10	1.14	1.20	1.30	1.38	1.42	1.56	1.26	1.17	1.26	1.56	1.10
1979	1.17	1.20	1.08	1.10	1.05	1.13	1.28	1.06	1.05	1.37	1.22	1.15	1.16	1.37	1.05
1980	1.18	1.19	1.06	1.20	1.08	1.20	1.40	1.35	1.42	1.43	1.29	1.25	1.25	1.43	1.06
1981	1.23	1.16	1.14	1.13	1.26	1.20	1.35	1.40	1.40	1.43	1.31	1.24	1.27	1.43	1.13
1982	1.17	1.12	1.14	1.18	1.21	1.08	1.18	1.25	1.45	1.48	1.30	1.38	1.25	1.48	1.08
1983	1.26	1.20	1.15	1.10	1.20	1.40	1.02	1.50	1.59	1.67	1.58	1.31	1.33	1.67	1.02
1984	1.28	1.28	1.18	1.05	1.13	1.14	1.30	1.35	1.23	1.34	1.29	1.21	1.23	1.35	1.05
1985	1.18	1.25	1.27	1.18	1.15	1.15	1.25	1.21	1.37	1.30	1.42	1.20	1.24	1.42	1.15
1986	1.19	1.35	1.20	1.13	1.28	1.25	1.38	1.50	1.43	1.46	1.33	1.23	1.31	1.50	1.13
1987	1.26	1.18	1.17	1.17	1.15	1.16	1.10	1.10	1.35	1.30	1.32	1.25	1.21	1.35	1.10
1988	1.30	1.25	1.16	1.27	1.26	1.42	1.40	1.43	1.41	1.55	1.43	1.21	1.34	1.55	1.16
1989	1.23	1.24	1.17	1.05	1.10	1.10	1.10	1.38	1.25	1.37	1.23	1.19	1.20	1.38	1.05
1990	1.20	1.29	1.14	1.15	1.20	1.10	1.00	1.05	1.15	1.65	1.67	1.55	1.26	1.67	1.00
1991	1.18	1.16	1.25	1.06	1.05	1.16	1.10	1.36	1.40	1.53	1.30	1.22	1.23	1.53	1.05
Mean	1.22	1.22	1.16	1.13	1.16	1.19	1.23	1.31	1.35	1.46	1.35	1.25	1.25	1.48	1.06
Max	1.30	1.35	1.27	1.27	1.28	1.42	1.40	1.50	1.59	1.67	1.67	1.55	1.34	1.67	1.16
Min	1.17	1.12	1.06	1.05	1.05	1.08	1.00	1.05	1.05	1.30	1.22	1.15	1.16	1.35	1.00

	Min (in River side) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean	Max	Min
1978	-1.18	-1.10	-1.17	-1.12	-1.15	-1.25	-0.95	-0.74	-0.80	-0.50	-1.10	-1.20	-1.02	-0.50	-1.25
1979	-1.22	-1.22	-1.20	-1.15	-1.37	-1.22	-1.20	-1.04	-1.10	-0.96	-1.10	-1.20	-1.17	-0.96	-1.37
1980	-1.21	-1.08	-1.10	-1.05	-1.32	-1.25	-1.30	-1.05	-0.35	-0.50	-0.95	-1.10	-1.02	-0.35	-1.32
1981	-1.10	-1.15	-1.01	-1.08	-1.07	-1.30	-1.22	-0.82	-0.90	-0.57	-0.75	-1.21	-1.02	-0.57	-1.30
1982	-1.20	-1.10	-0.10	-1.10	-1.25	0.41	-1.14	-1.10	-0.58	-0.88	-0.94	-1.15	-0.84	0.41	-1.25
1983	-1.30	-1.18	-1.10	-1.20	-1.20	-1.43	-1.42	-0.90	0.70	0.15	-0.50	-1.02	-0.87	0.70	-1.43
1984	-1.27	-1.20	-1.18	-1.25	-1.35	-1.35	-1.35	-1.23	-1.00	-0.87	-1.03	-1.20	-1.19	-0.87	-1.35
1985	-1.35	-1.30	-1.18	-1.35	-1.25	-1.38	-1.30	-1.20	-0.70	-1.03	-1.01	-1.44	-1.21	-0.70	-1.44
1986	-1.31	-1.20	-1.15	-1.20	-1.16	-1.36	-1.38	-1.17	-0.50	-0.33	-0.92	-1.20	-1.07	-0.33	-1.38
1987	-1.24	-1.27	-1.28	-1.11	-1.34	-1.40	-1.42	-1.36	-1.34	-0.98	-0.98	-1.24	-1.25	-0.98	-1.42
1988	-1.35	-1.19	-1.12	-1.18	-1.25	-1.32	-1.30	-0.85	-0.96	-0.48	-0.95	-1.32	-1.11	-0.48	-1.35
1989	-1.26	-1.25	-1.10	-0.25	-1.39	-1.42	-1.39	-1.28	-0.75	-0.96	-1.10	-1.25	-1.12	-0.25	-1.42
1990	-1.15	-1.18	-1.10	-1.32	-1.32	-1.45	-1.43	-1.34	-1.25	-0.94	-0.47	-1.32	-1.19	-0.47	-1.45
1991	-1.26	-1.28	-1.02	-1.20	-0.85	-1.43	-1.37	-1.12	-1.40	-1.36	-1.04	-1.30	-1.22	-0.85	-1.43
Mean	-1.24	-1.19	-1.06	-1.11	-1.23	-1.23	-1.30	-1.09	-0.78	-0.73	-0.92	-1.23	-1.09	-0.44	-1.37
Max	-1.10	-1.08	-0.10	-0.25	-0.85	0.41	-0.95	-0.74	0.70	0.15	-0.47	-1.02	-0.84	0.70	-1.25
Min	-1.35	-1.30	-1.28	-1.35	-1.39	-1.45	-1.43	-1.36	-1.40	-1.36	-1.10	-1.44	-1.25	-0.98	-1.45

Figure 3-1-6 Monthly Mean of Water Level at Tha Khai

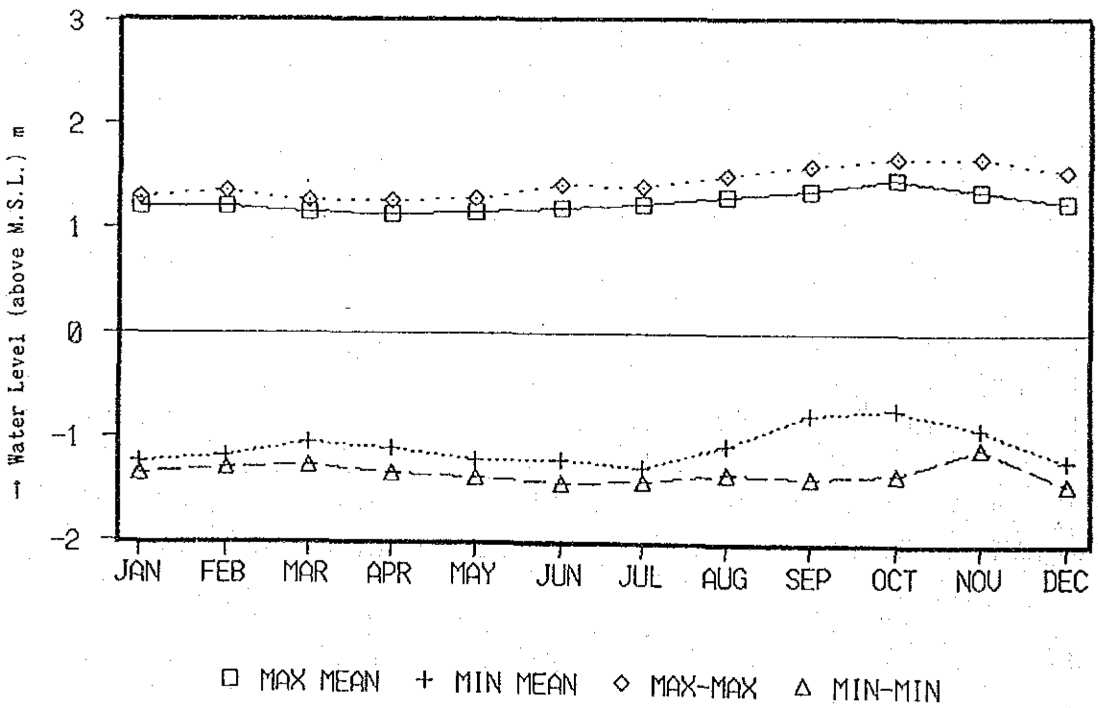


Table 3-1-4 Summary of Actual Tide Level at Bang Pakong

unit;m(M.S.L)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Mean
H'est H.W.	1.75	1.75	2.02	1.78	1.83	1.79	1.78	1.66	1.86	1.78	2.02
M.H.H.W.	1.23	1.25	1.27	1.25	1.23	1.21	1.25	1.20	1.23	1.21	1.23
M.L.H.W.	0.77	0.78	0.88	0.74	0.81	0.71	0.82	0.75	0.73	0.74	0.77
M.H.W.S.	1.15	1.26	1.29	1.32	1.34	1.25	1.29	1.26	1.28	1.29	1.27
M.H.W.	0.94	1.11	1.16	1.12	1.17	1.09	1.15	1.09	1.09	1.13	1.11
M.H.W.N.	0.94	1.00	1.08	1.01	1.01	0.98	1.05	1.00	0.92	0.98	1.00
M.T.L.	0.16	0.12	0.18	0.13	0.09	0.08	0.13	0.14	0.09	0.12	0.12
M.S.L.	0.18	0.20	0.18	0.17	0.15	0.12	—	0.14	0.15	0.17	0.16
M.L.W.N.	-0.62	-0.73	-0.82	-0.78	-0.91	-0.86	-0.83	-0.84	-0.88	-0.90	-0.82
M.L.W.	-0.63	-0.71	-0.81	-0.85	-0.98	-0.92	-0.88	-0.86	-0.91	-0.91	-0.85
M.L.W.S.	-0.67	-0.73	-0.91	-1.02	-1.12	-1.03	-0.97	-0.95	-1.03	-1.06	-0.95
M.H.L.W.	-0.04	-0.13	-0.10	-0.20	-0.31	-0.24	-0.21	-0.16	-0.15	-0.34	-0.19
M.L.L.W.	-1.02	-1.03	-1.08	-1.09	-1.31	-1.17	-1.13	-1.12	-1.02	-1.11	-1.09
L'est L.W.	-1.56	-1.51	-1.56	-1.61	-1.64	-1.65	-1.60	-1.58	-1.61	-1.67	-1.67
Mean	-0.83	-0.53	-0.53	-0.54	-0.36	-0.49	-0.47	-0.55	-0.50	-0.46	-0.53

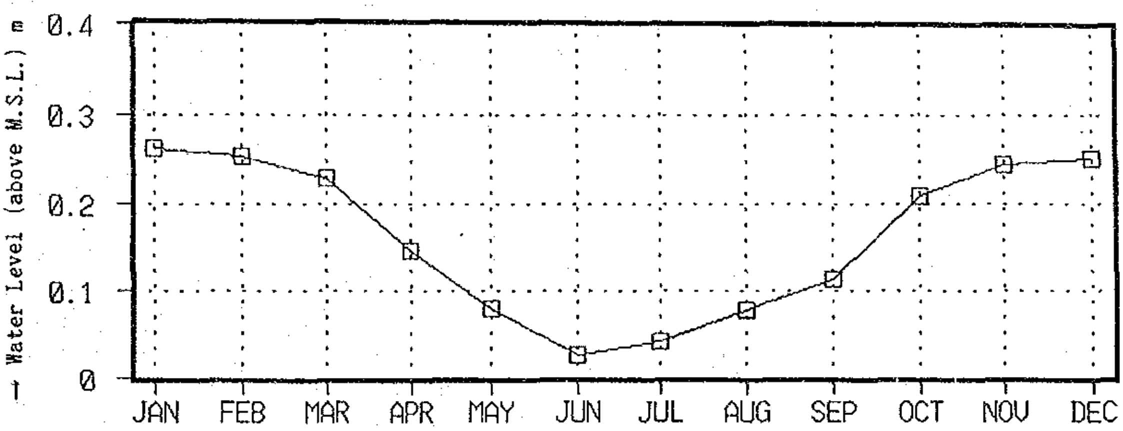
LOCATION;Lat.13°30'03"N , Long.101°59'16"E

Table 3-1-5 Monthly Mean of Tide Level

unit;m(M.S.L)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1982	0.250	0.260	0.210	0.210	0.100	0.060	0.090	0.090	0.130	0.190	0.250	0.260
1983	0.260	0.190	0.230	0.160	0.110	0.050	0.130	0.220	0.160	0.270	0.340	0.300
1984	0.300	0.320	0.240	0.130	0.120	0.040	0.070	0.080	0.140	0.180	0.290	0.290
1985	0.240	0.260	0.350	0.140	0.120	0.040	0.060	0.100	0.140	0.200	0.170	0.250
1986	0.260	0.250	0.240	0.130	0.080	0.030	0.000	0.030	0.110	0.180	0.240	0.220
1987	0.230	0.180	0.110	0.120	0.050	0.030	-0.040	0.020	0.040	0.170	0.200	0.270
1988	0.210	0.250	0.250	0.170	0.030	0.020	0.070	0.120	—	—	—	—
1989	0.310	0.300	0.240	0.100	0.030	-0.010	0.070	0.050	0.090	0.180	0.130	0.180
1990	0.280	0.290	0.220	0.150	0.090	0.000	-0.030	-0.010	0.050	0.230	0.260	0.240
1991	0.280	0.230	0.190	0.150	0.070	0.010	0.000	0.080	0.150	0.270	0.320	0.250
Mean	0.262	0.253	0.228	0.146	0.080	0.027	0.042	0.078	0.112	0.208	0.244	0.251

Figure 3-1-7 Monthly Mean of Tide Level



Note;Bang-Pakong (1982-1991)

Figure 3-1-8 Discharge and Saltwater Intrusion

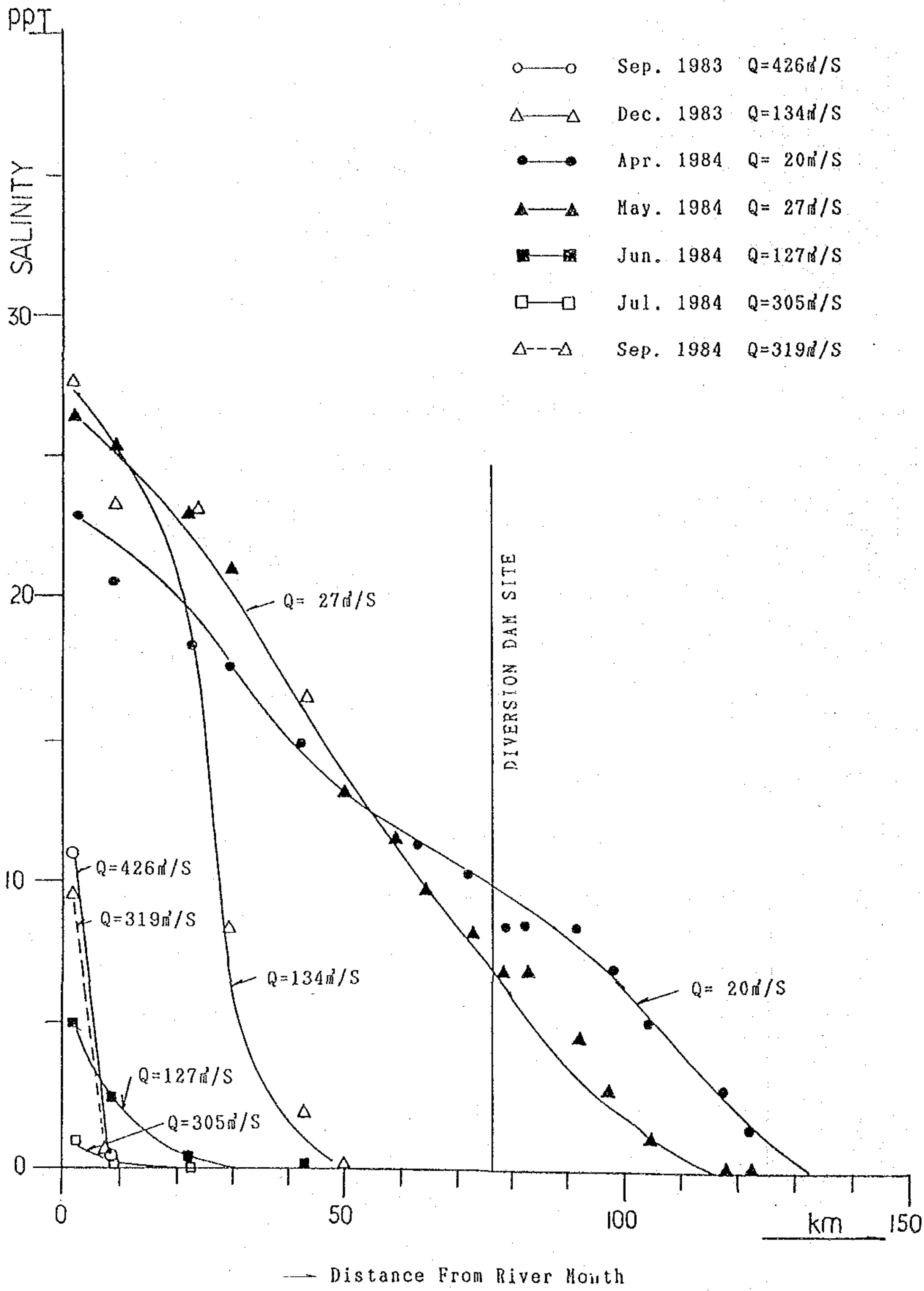


Figure 3-2-1 Bang Pakong River System

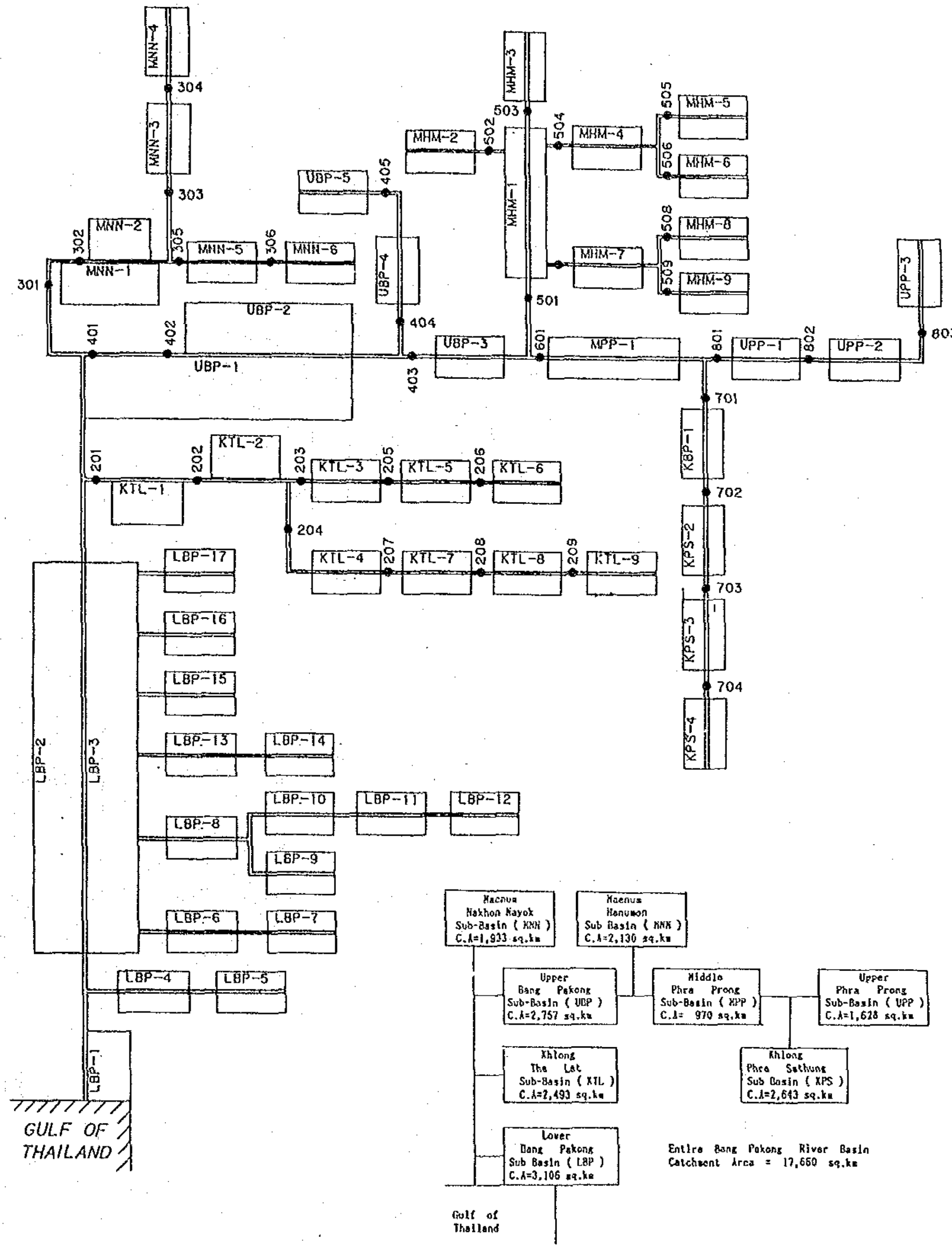


Figure 3-2-2 Diagram for Flood Simulation Study

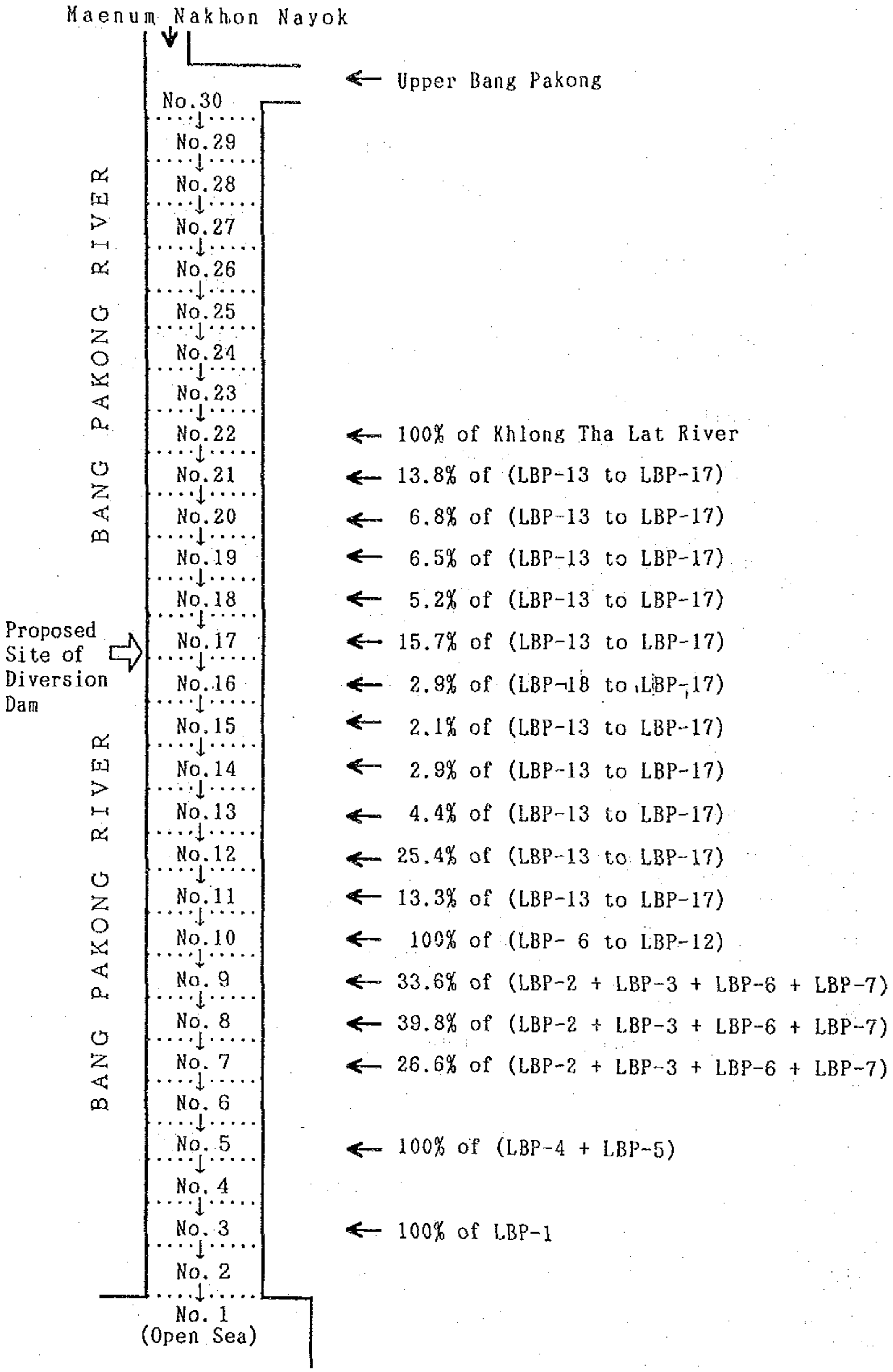


FIGURE 3-2-3 RESULT OF HYDRAULIC ANALYSIS (HYDRAULIC PROFILE)

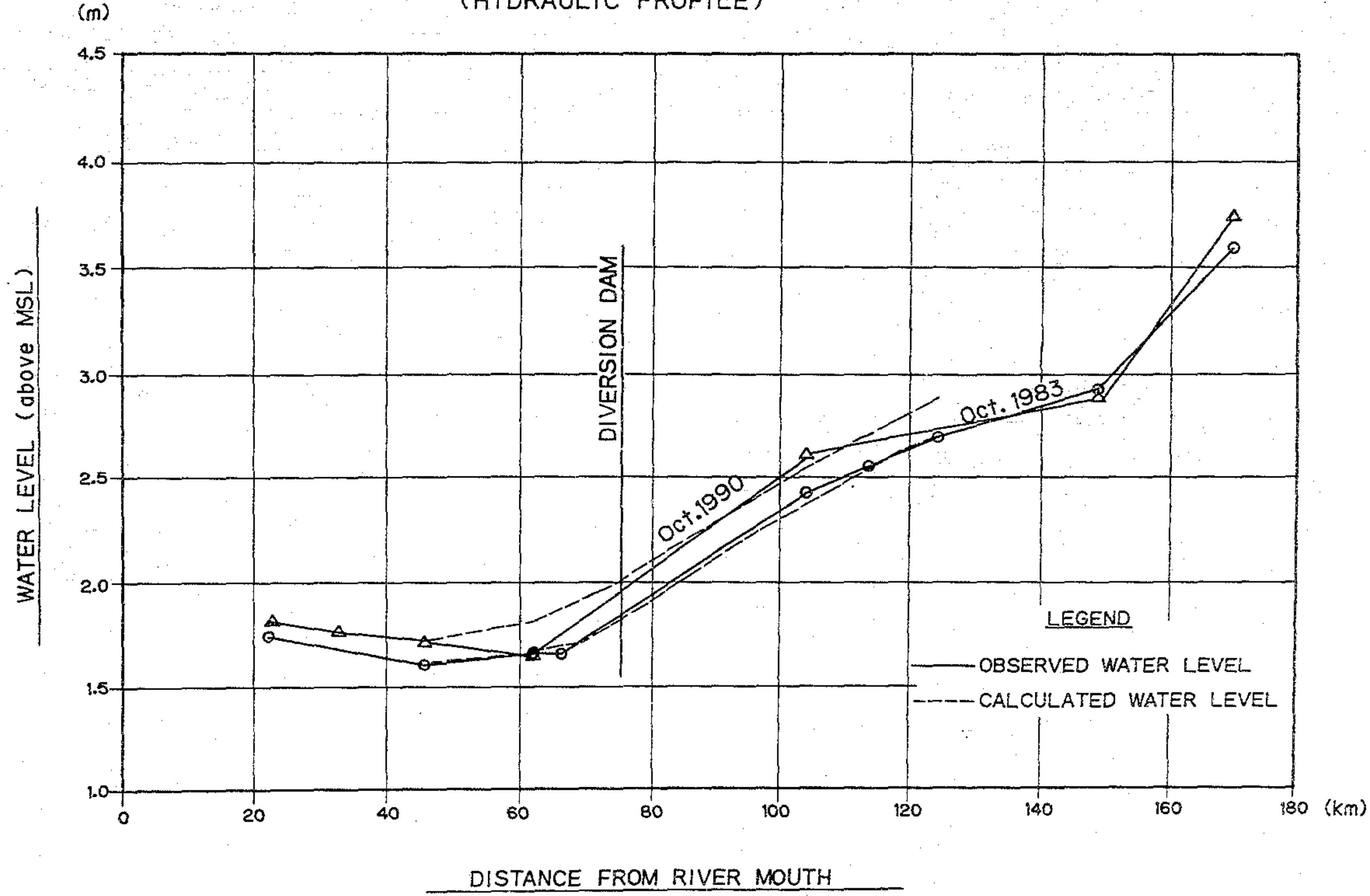
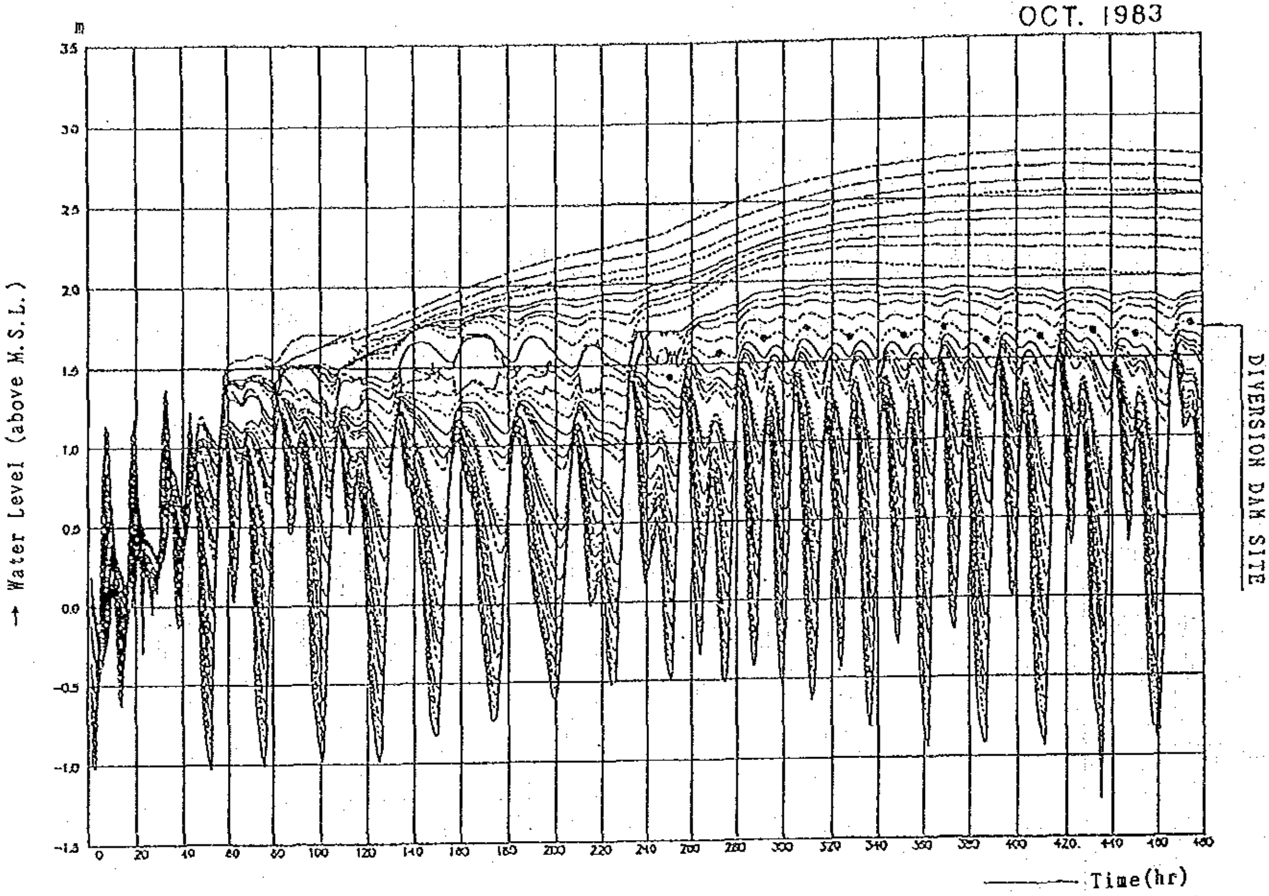


Figure 3-2-4 Result of Hydraulic Analysis



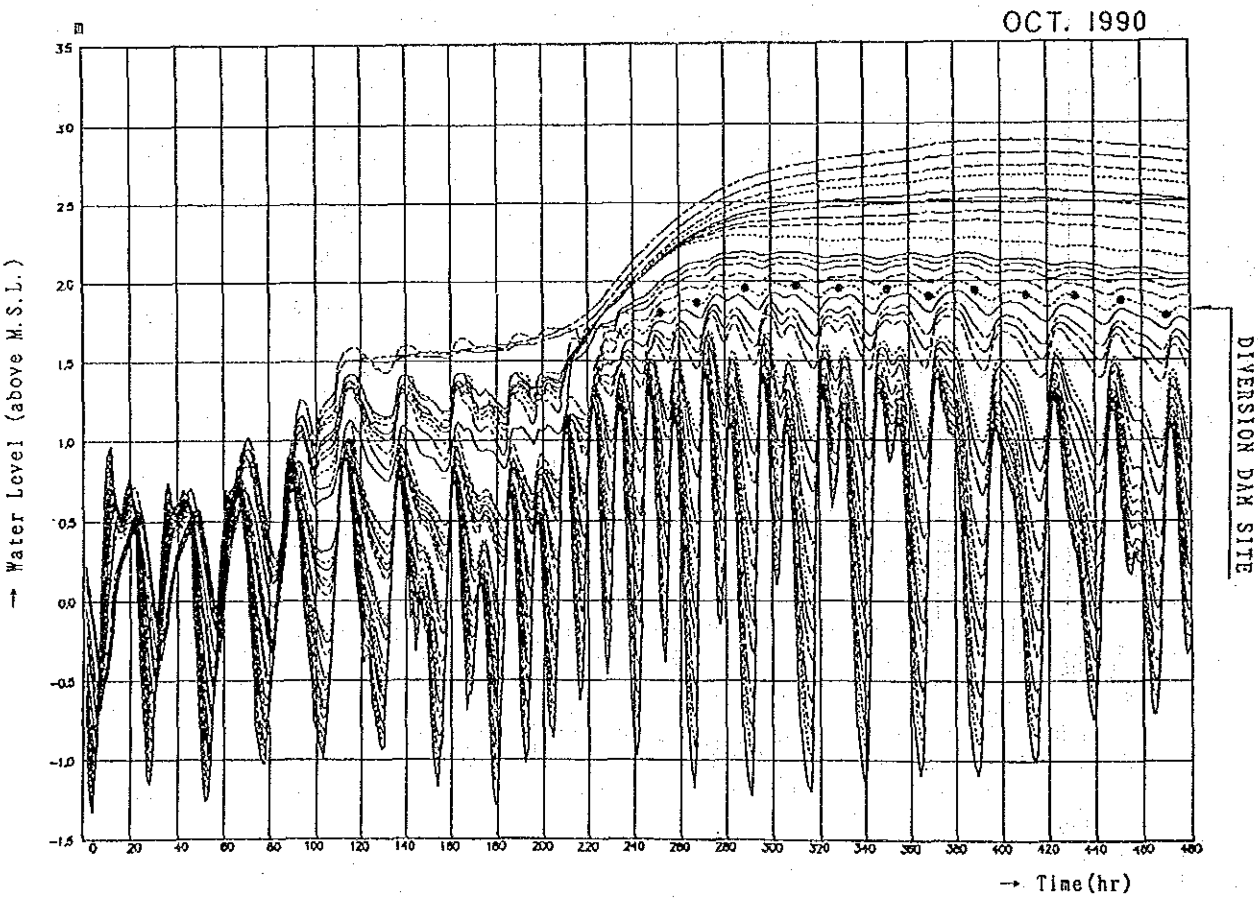


Figure 3-2-5 Proposed Flood (W=1/50 Years)

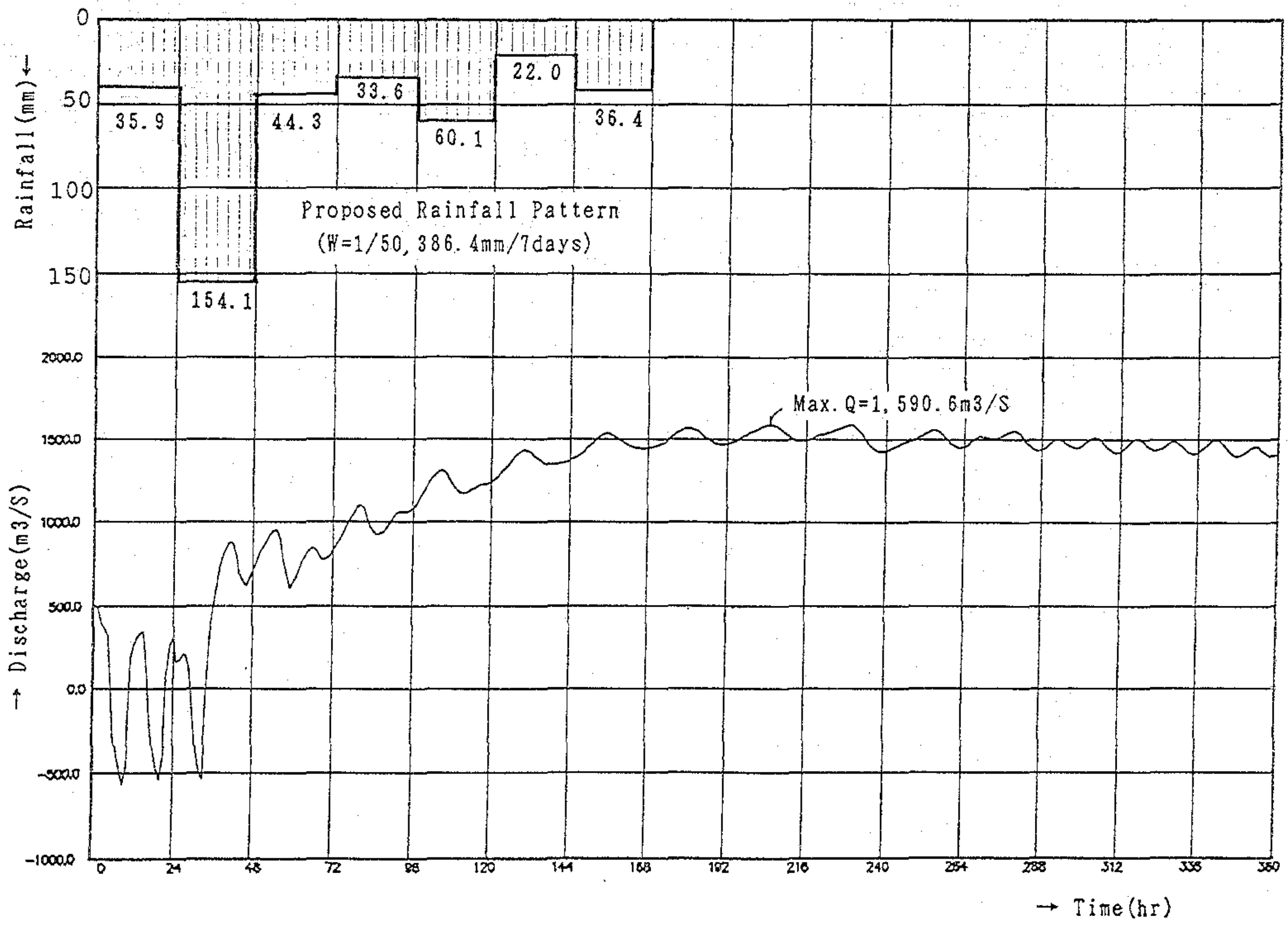
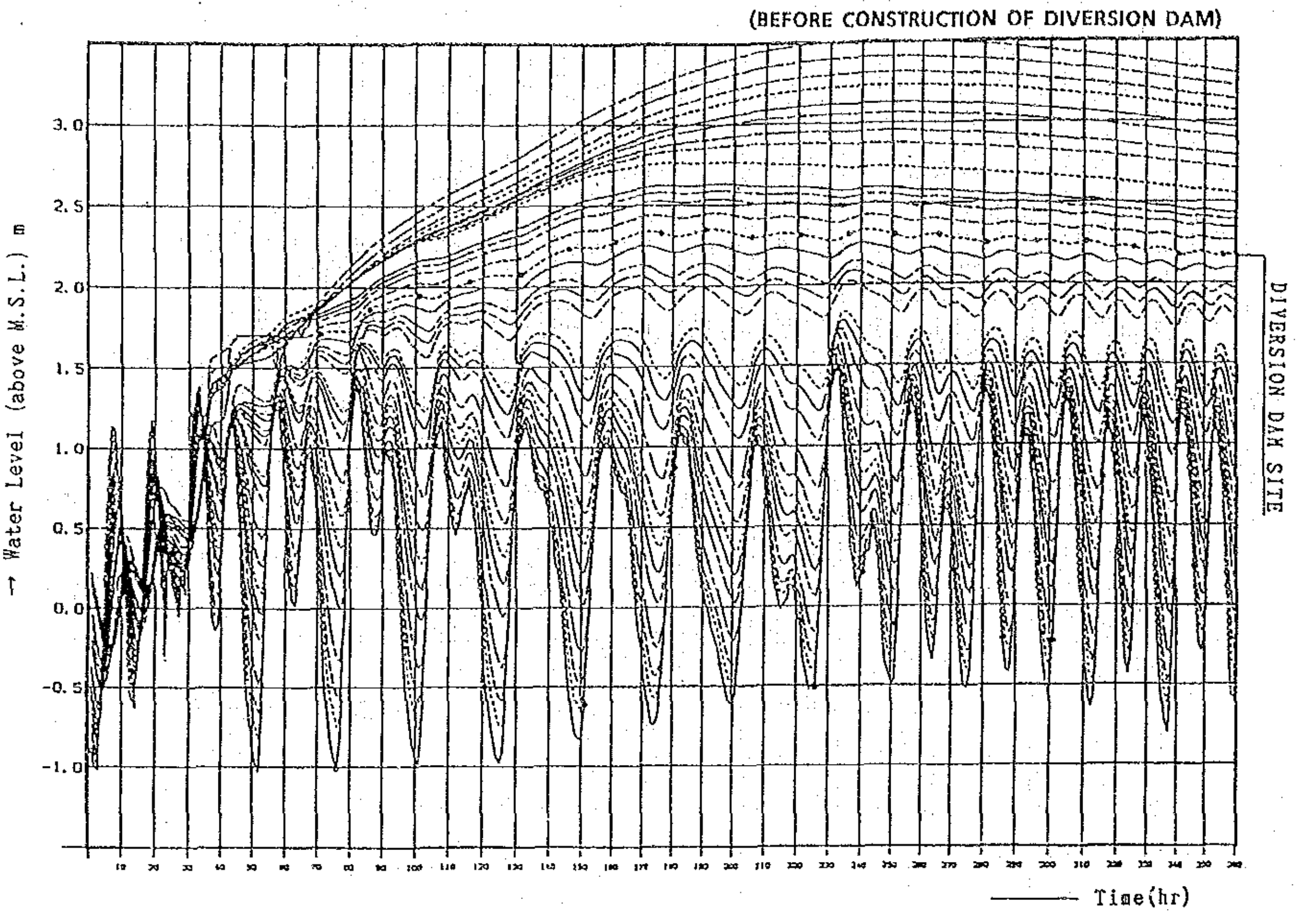


Figure 3-2-6 Flood Water Level of 50 Years Probability



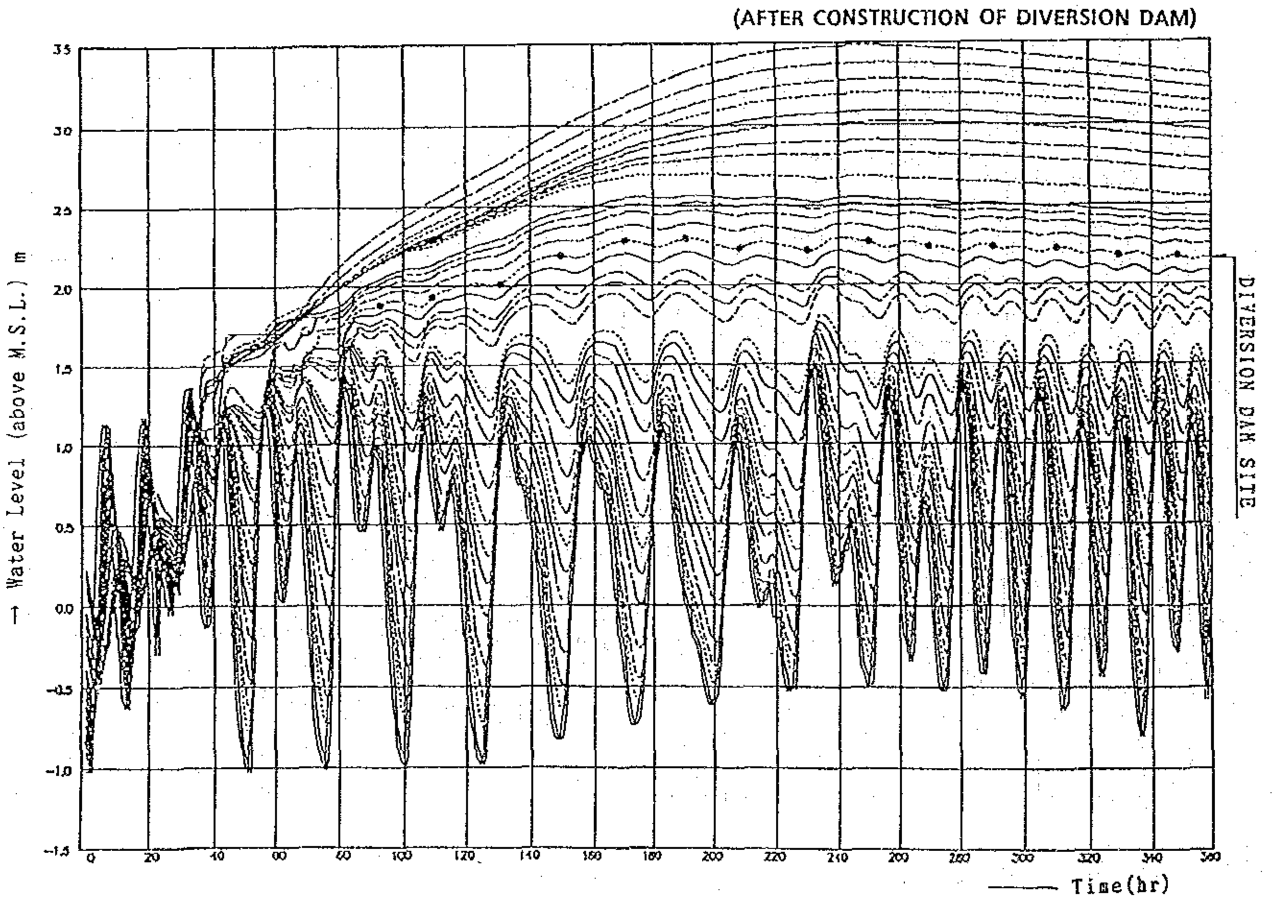


Table 3-2-1 Daily Maximum Discharge in Dry Season

(m³/s)

	Kgt. 3 7,502 km²	Kgt. 10 2,523km²	Kgt. 12 1,540km²	Kgt. 13 5,347km²	Kgt. 14 366km²	Kgt. 15A 530km²	Kgt. 18 951km²	Kgt. 19 535km²	Kgt. 25 243km²	Ny. 1, 1B 520km²	Ny. 3 203km²
1967	77 May 29	9 May 26	48 Nov 14	45 Nov 15	25.0 May 28	—	—	3.7 May 4	—	30.0 May 28	—
1968	88 〃 14	74 〃 12	10 May 13	40 May 14	1.0 〃 9	2.5 May 12	—	6.4 〃 12	—	32.0 〃 5	—
1969	82 Nov 5	17 Nov 6	14 Nov 1	—	9.3 〃 31	9.0 Nov 1	5.8 Nov 5	3.8 Nov 5	—	34.0 Nov 2	—
1970	108 〃 1	17 Dec 8	29 〃 1	—	2.2 Nov 1	7.7 〃 1	2.0 Dec 7	2.6 Apr 15	—	23.0 〃 5	—
1971	243 〃 2	207 Nov 2	61 〃 3	174 Nov 2	4.2 May 20	5.8 〃 1	71.0 Nov 1	22.0 Nov 1	—	19.0 〃 1	—
1972	192 〃 24	97 〃 23	62 〃 12	135 〃 24	23.0 Nov 16	41.0 〃 6	7.3 〃 10	5.6 〃 10	—	22.0 〃 21	—
1973	250 〃 21	240 〃 18	76 〃 20	169 〃 21	1.2 〃 15	4.0 May 26	64.0 〃 15	4.4 May 7	—	15.0 〃 10	—
1974	190 〃 3	104 〃 2	36 〃 2	116 May 28	12.0 〃 6	15.0 Nov 12	90.0 〃 6	44.0 Nov 12	—	39.0 〃 5	—
1975	94 〃 1	68 May 28	19 〃 1	61 Nov 1	3.9 〃 16	8.8 〃 10	7.2 May 28	12.0 〃 9	—	25.0 〃 15	—
1976	444 〃 2	281 Nov 4	134 〃 6	364 〃 1	14.0 〃 2	46.0 〃 1	64.0 Nov 2	46.0 〃 3	—	36.0 〃 1	—
1977	174 〃 1	14 〃 1	65 〃 1	112 〃 1	3.1 〃 29	9.5 〃 1	1.4 〃 1	4.0 May 26	—	26.0 May 30	7.7 Nov 1
1978	114 May 30	70 May 16	35 May 30	58 May 30	10.6 May 27	8.9 May 28	14.7 May 25	34.4 〃 20	2.0 May 16	21.3 〃 27	7.4 May 27
1979	48 〃 27	22 〃 25	13 〃 24	20 〃 27	2.3 〃 21	3.6 Nov 5	0.4 〃 14	13.6 〃 5	0.7 〃 8	17.8 〃 31	2.7 〃 22
1980	255 Nov 1	34 Nov 9	45 Nov 1	143 Nov 1	12.8 Nov 7	71.0 〃 7	9.0 Nov 1	6.5 Nov 10	2.3 Nov 1	22.8 Nov 7	10.2 Nov 9
1981	198 〃 2	183 〃 1	47 〃 1	155 〃 2	8.6 〃 7	10.6 〃 27	31.6 May 19	11.3 〃 9	15.2 May 26	—	—
1982	126 〃 1	49 〃 19	30 〃 1	67 〃 1	3.9 Dec 2	12.3 May 20	13.4 Nov 19	18.0 Apr 25	1.4 Nov 1	—	6.8 Dec 2
1983	274 〃 1	117 〃 13	45 〃 1	151 〃 1	5.7 Nov 1	11.8 Nov 1	13.2 〃 17	11.4 Nov 18	2.6 〃 1	—	9.8 Nov 3
1984	53 〃 1	8 〃 1	10 〃 1	30 〃 1	2.7 〃 1	16.7 May 28	3.2 〃 1	2.2 May 21	7.7 May 30	—	3.8 〃 14
1985	156 〃 1	60 〃 14	56 May 17	95 May 18	—	30.1 〃 15	12.4 〃 1	9.8 〃 19	7.6 Apr 30	—	34.4 〃 1
1986	266 May 13	188 May 13	68 〃 14	208 〃 14	77.0 May 11	16.6 〃 11	84.6 May 12	43.7 〃 11	10.0 May 11	—	7.7 〃 1
1987	130 Nov 5	105 Nov 4	14 Nov 12	92 Nov 5	3.2 Nov 14	12.4 Nov 3	10.6 Nov 3	20.3 Nov 3	0.9 Nov 3	—	10.4 〃 3
1988	280 〃 1	43 May 16	29 〃 1	175 〃 1	2.6 May 16	9.3 〃 1	14.4 〃 1	20.6 May 15	2.7 〃 1	—	6.3 〃 1
1989	62 May 31	49 〃 22	17 May 30	55 May 24	17.9 〃 20	11.6 May 28	2.0 〃 7	11.2 〃 31	1.8 May 21	—	4.2 〃 8
1990	304 Nov 1	35 Nov 4	28 Nov 1	234 Nov 2	11.4 Nov 3	27.7 Nov 3	11.5 〃 1	5.4 Nov 6	—	—	11.9 〃 10

Table 3-2-2 Probability of Daily Maximum Discharge in Dry Season

	W＝1/2	W＝1/5	W＝1/10	W＝1/15	W＝1/20	W＝1/30	W＝1/50	W＝1/100	Remarks
Kgt. 3 7,502㎢	155.8 0.021	248.0 0.033	311.4 0.042	347.9 0.046	373.8 0.050	410.3 0.055	456.8 0.061	521.0 0.069	1967～1990 n＝22
Kgt. 10 2,523㎢	59.6 0.024	132.8 0.053	199.2 0.079	243.5 0.097	277.5 0.110	329.4 0.131	401.7 0.159	513.7 0.204	1967～1990 n＝22
Kgt. 12 1,540㎢	34.6 0.022	59.7 0.039	78.2 0.051	89.4 0.058	97.4 0.063	109.0 0.071	124.2 0.081	145.8 0.095	1967～1990 n＝22
Kgt. 13 5,347㎢	103.1 0.019	178.1 0.033	233.5 0.044	266.5 0.050	290.4 0.054	324.9 0.061	369.7 0.069	433.5 0.081	1967～1990 n＝20
Kgt. 14 366㎢	6.4 0.017	15.4 0.042	24.4 0.067	30.7 0.084	35.7 0.098	43.5 0.119	54.8 0.150	72.9 0.199	1967～1990 n＝22
Kgt. 15A 530㎢	11.8 0.022	23.8 0.045	34.7 0.065	41.9 0.079	47.4 0.089	55.9 0.105	67.6 0.128	85.7 0.162	1968～1990 n＝21
Kgt. 18 951㎢	11.8 0.012	35.6 0.037	62.7 0.066	83.0 0.087	99.7 0.105	126.9 0.133	167.8 0.176	237.5 0.250	1969～1990 n＝20
Kgt. 19 535㎢	10.3 0.019	22.2 0.041	33.1 0.062	40.5 0.076	46.2 0.086	54.9 0.103	67.1 0.125	86.2 0.161	1967～1990 n＝22
Kgt. 25 243㎢	2.9 0.012	6.7 0.028	10.6 0.044	13.3 0.055	15.5 0.064	18.9 0.078	23.8 0.098	31.7 0.130	1978～1989 n＝12
Ny 1,1B 520㎢	25.3 0.049	31.7 0.061	35.6 0.068	37.6 0.072	39.0 0.075	40.9 0.079	43.2 0.083	46.2 0.089	1967～1980 n＝14
Ny, 3 203㎢	7.3 0.036	13.0 0.064	18.0 0.089	21.2 0.104	23.7 0.117	27.3 0.134	32.4 0.160	40.0 0.197	1977～1990 n＝14

Note ; The lower is specific discharge ($m^3/s \cdot km^2$)

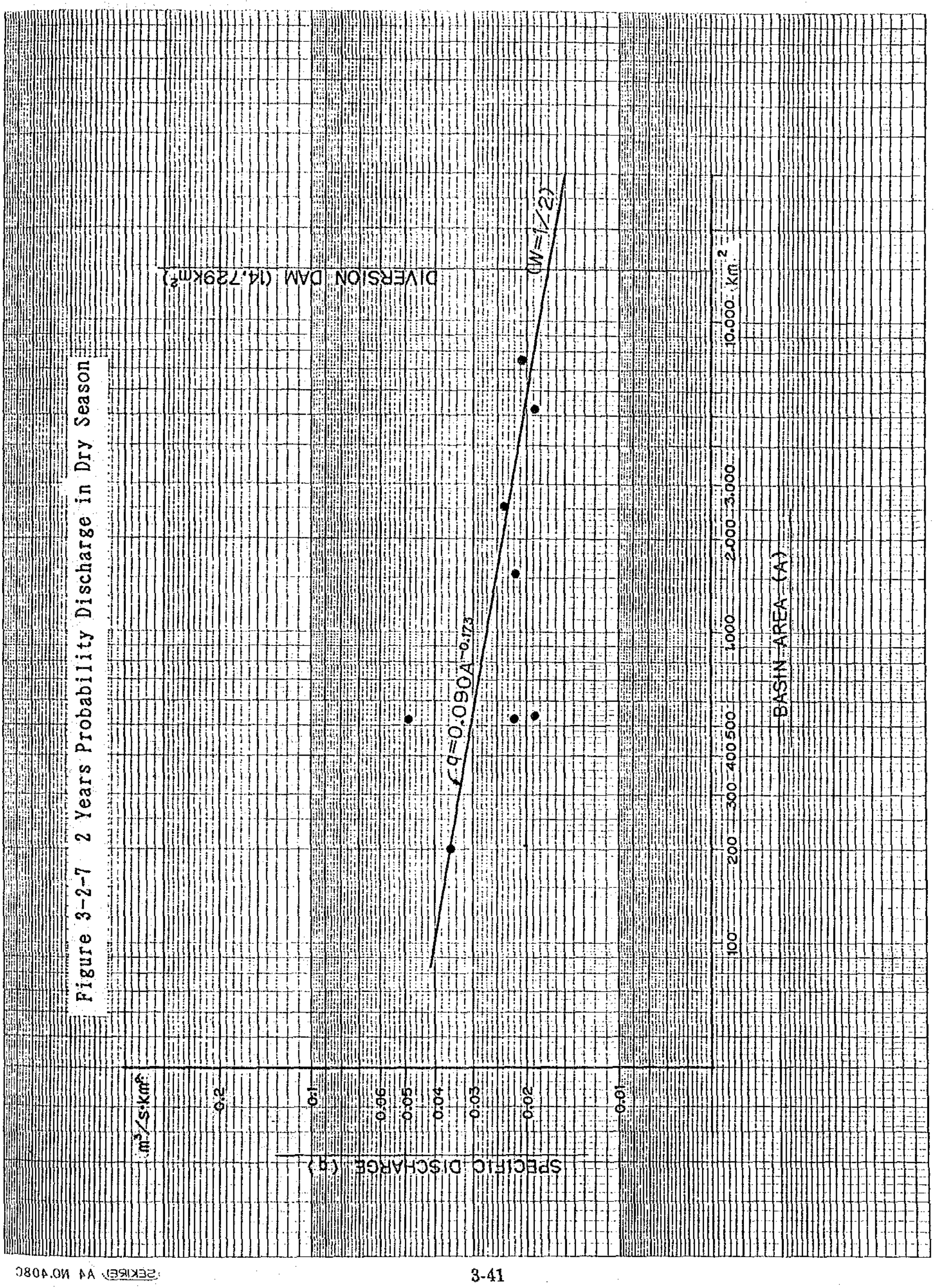


Figure 3-2-7 2 Years Probability Discharge in Dry Season

Figure 3-3-1 Fluctuation of Water Level with and without Diversion Dam in Dry Season

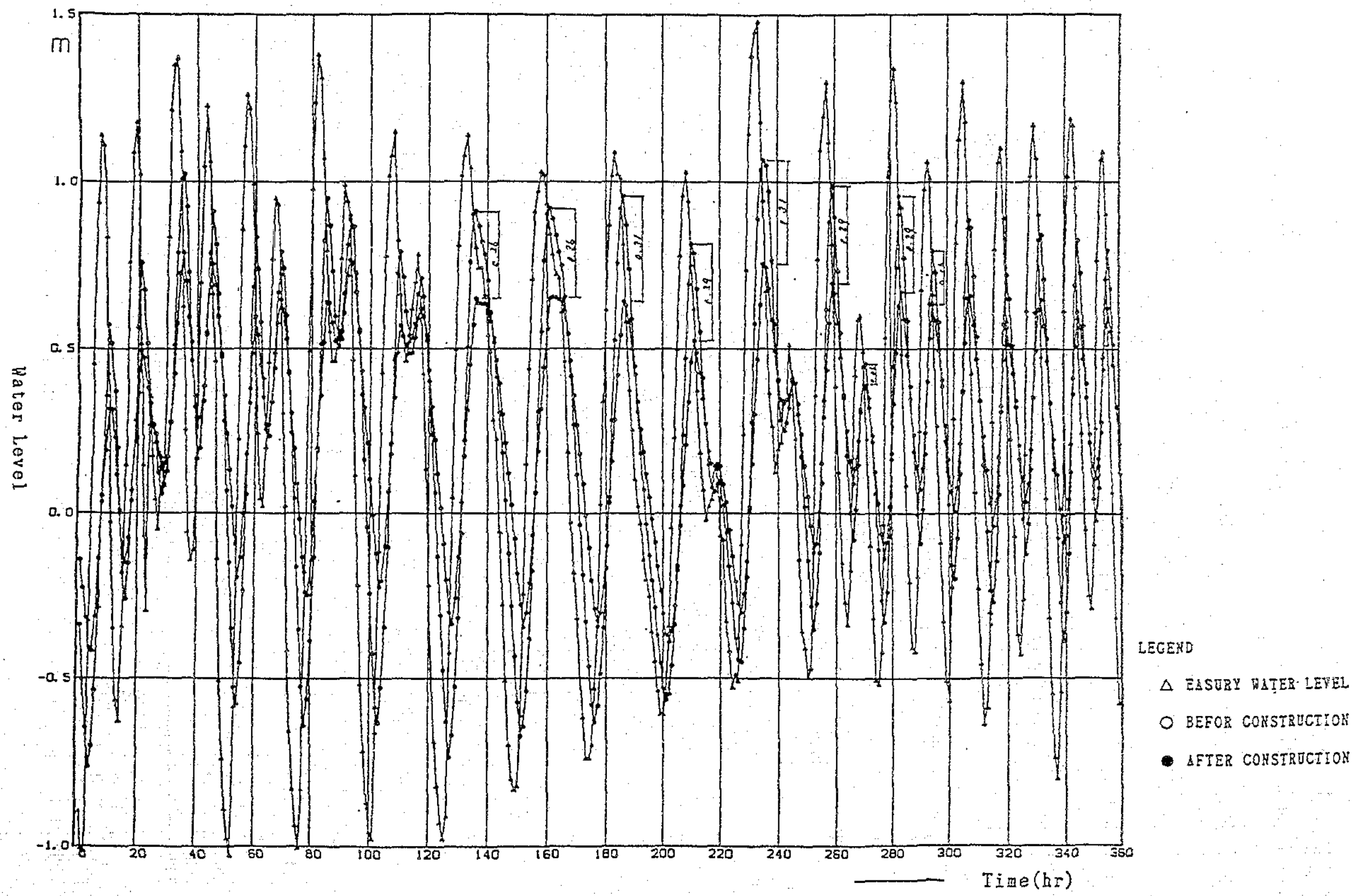
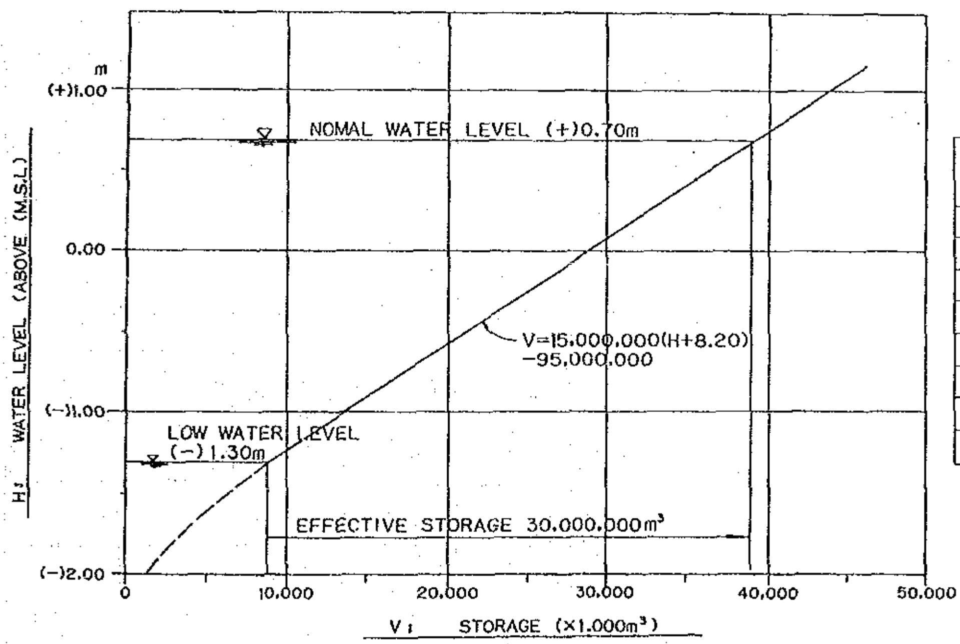


Table 3-4-1 Assumed Water Level at Diversion Dam Site

Tide	Flow m³/S	Station	High WL m (MSL)	Mean m (MSL)	Low WL m (MSL)	Range m
Spring Tide		Estuary	1.30	0.15	−1.00	2.30
	0	Dam Gate	0.81	0.23	−0.36	1.17
	30	〃	0.86	0.28	−0.31	1.17
	50	〃	0.89	0.31	−0.27	1.16
	80	〃	0.93	0.35	−0.23	1.16
	100	〃	0.96	0.38	−0.20	1.16
	200	〃	1.04	0.54	0.03	1.01
	260	〃	1.08	0.64	0.20	0.88
	300	〃	1.11	0.71	0.30	0.81
	400	〃	1.20	0.90	0.59	0.61
	500	〃	1.31	1.19	1.06	0.25
	1,000		2.21	2.20	2.19	0.02
Neap Tide		Estuary	1.00	0.10	−0.80	1.80
	0	Dam Gate	0.65	0.16	−0.34	0.99
	30	〃	0.69	0.20	−0.30	0.99
	50	〃	0.72	0.23	−0.27	0.99
	80	〃	0.76	0.27	−0.22	0.98
	100	〃	0.78	0.30	−0.19	0.97
	200	〃	0.89	0.44	−0.02	0.91
	260	〃	0.96	0.54	0.12	0.84
	300	〃	1.01	0.61	0.21	0.80
	400	〃	1.07	0.76	0.45	0.62
	500	〃	1.16	0.95	0.74	0.42
	1,000		2.14	2.13	2.11	0.03

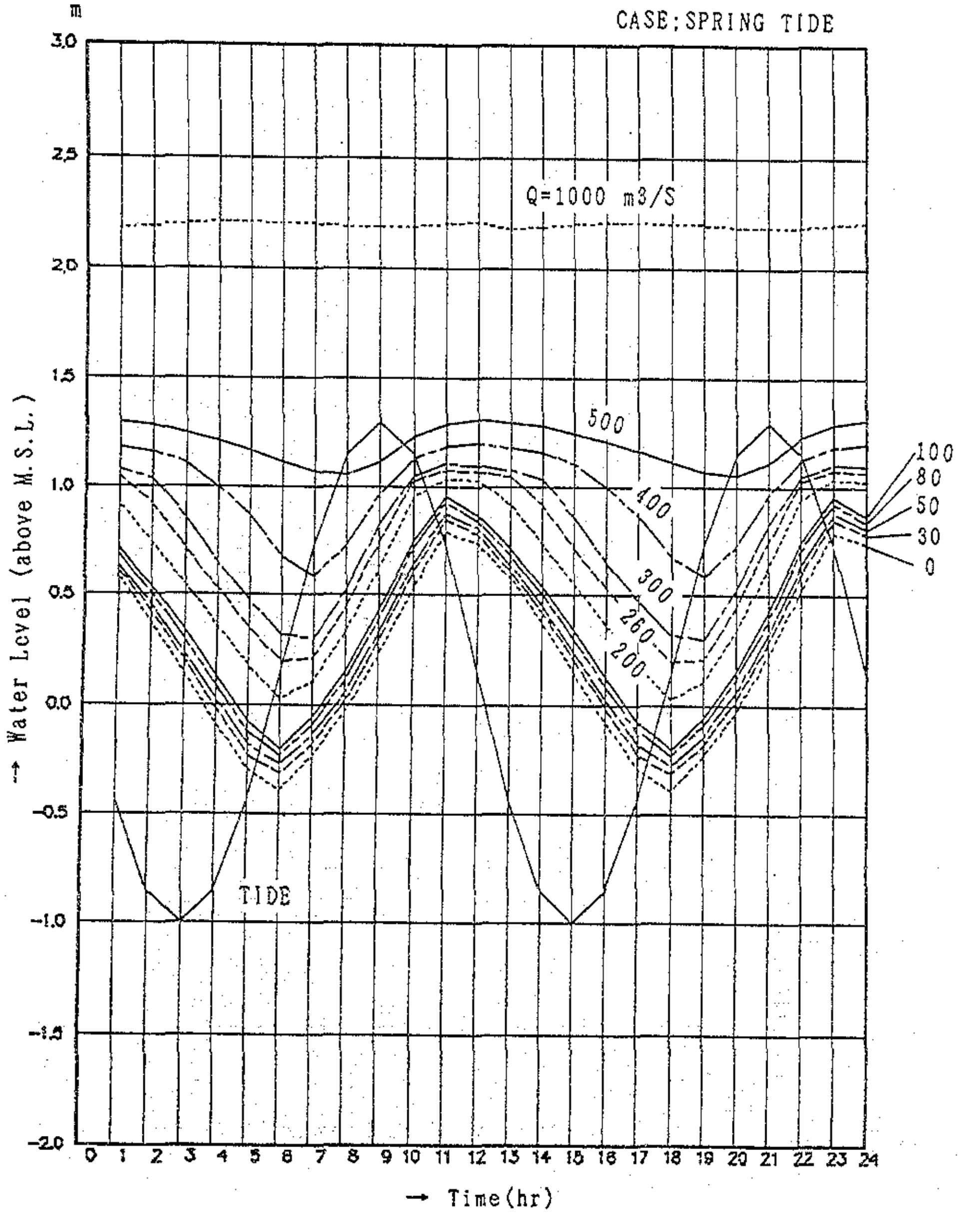
Figure 3-4-1 Water Level ~ Storage Volume Curve

(BANG PAKONG DIVERSION DAM)



WATER LEVEL (M.S.L.m)	STORAGE VOLUME (1,000m³)
(+)1.00	43,000
(+)0.70	38,500
(+)0.50	35,500
0.00	28,000
(−)0.50	20,500
(−)1.00	13,000
(−)1.30	8,500
(−)1.50	5,500

Figure 3-4-2 Tide and Water Level at Diversion Dam Site



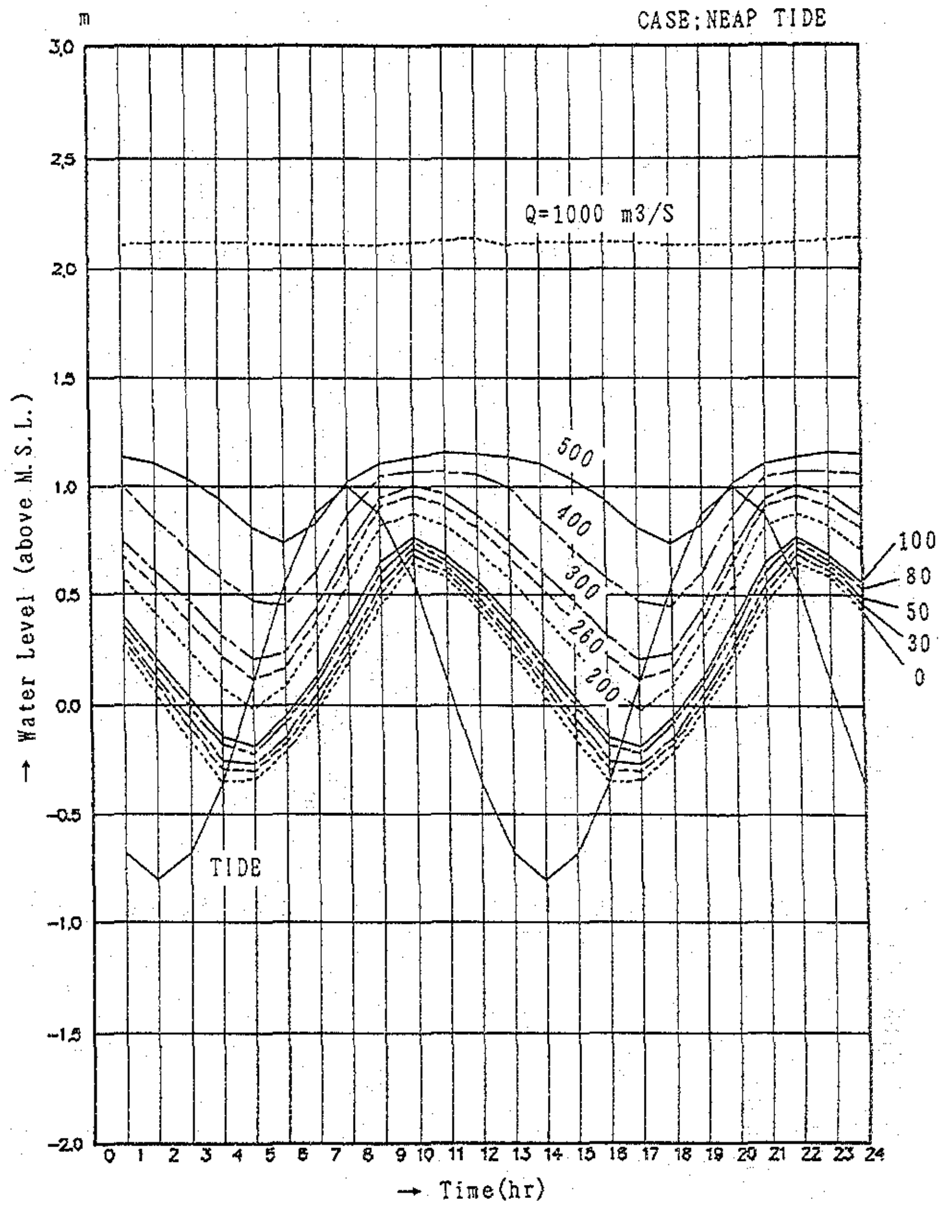


FIGURE 3-4-3 DISCHARGE COEFFICIENT (1)
(FREE FLOW UNDER THE GATE)

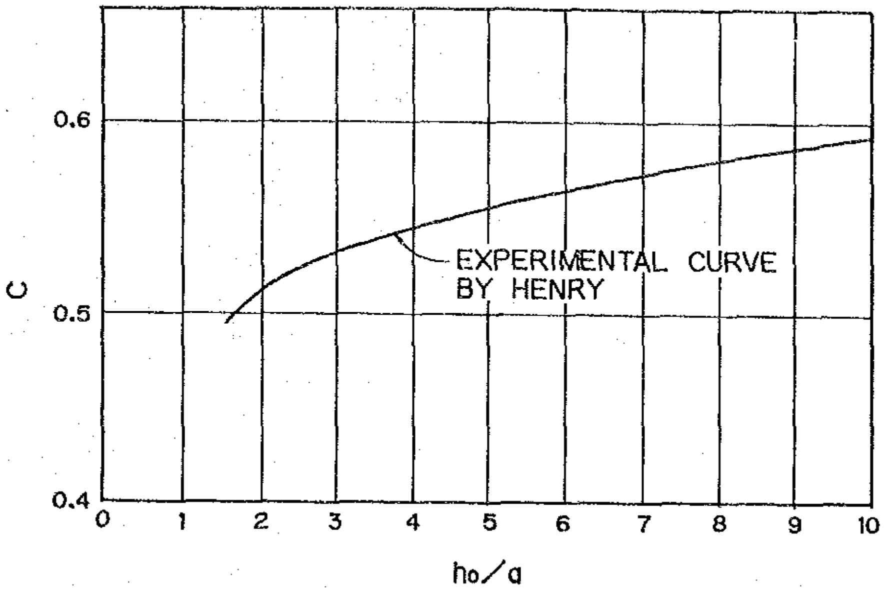


FIGURE 3-4-3 DISCHARGE COEFFICIENT (2)
(SUBMERGED FLOW UNDER THE GATE)

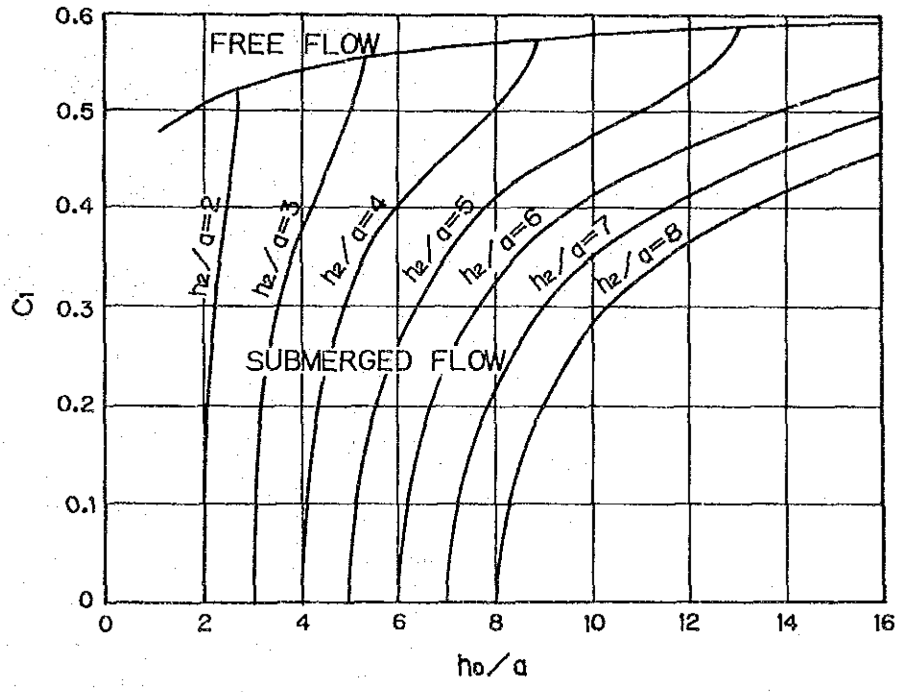


Figure 3-4-4 Gate Simulation (1)

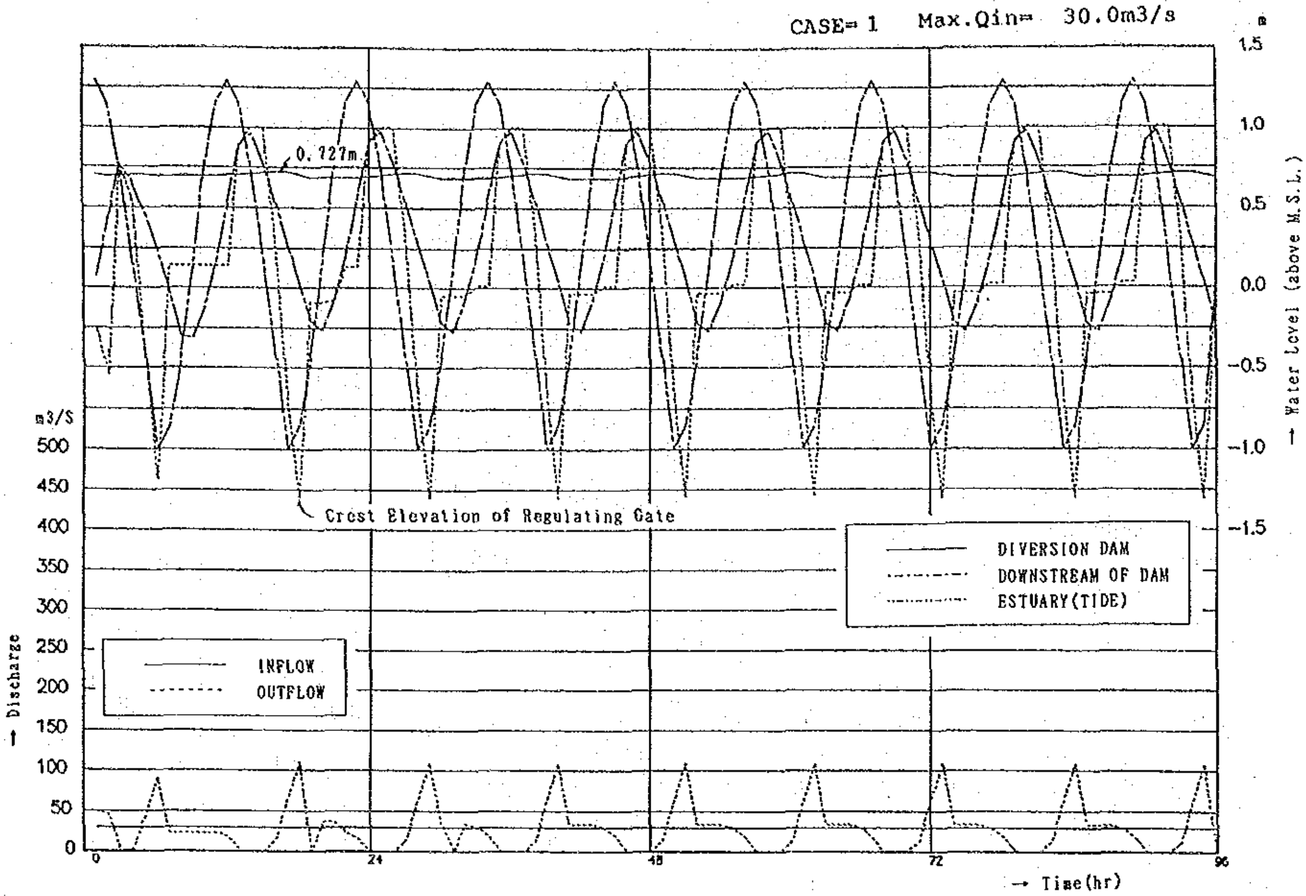


Figure 3-4-4 Gate Simulation (2)

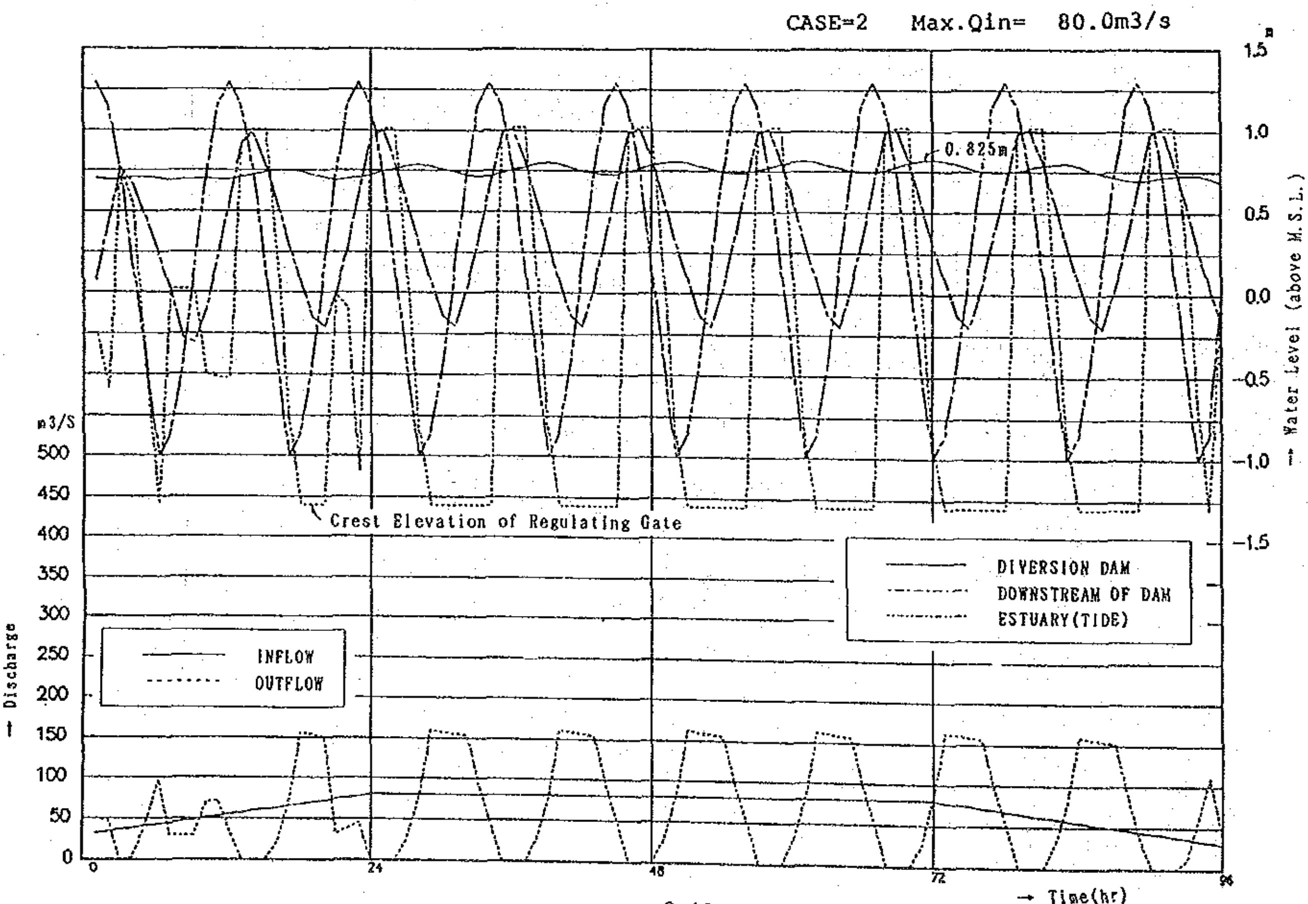


Figure 3-4-4 Gate Simulation (3)

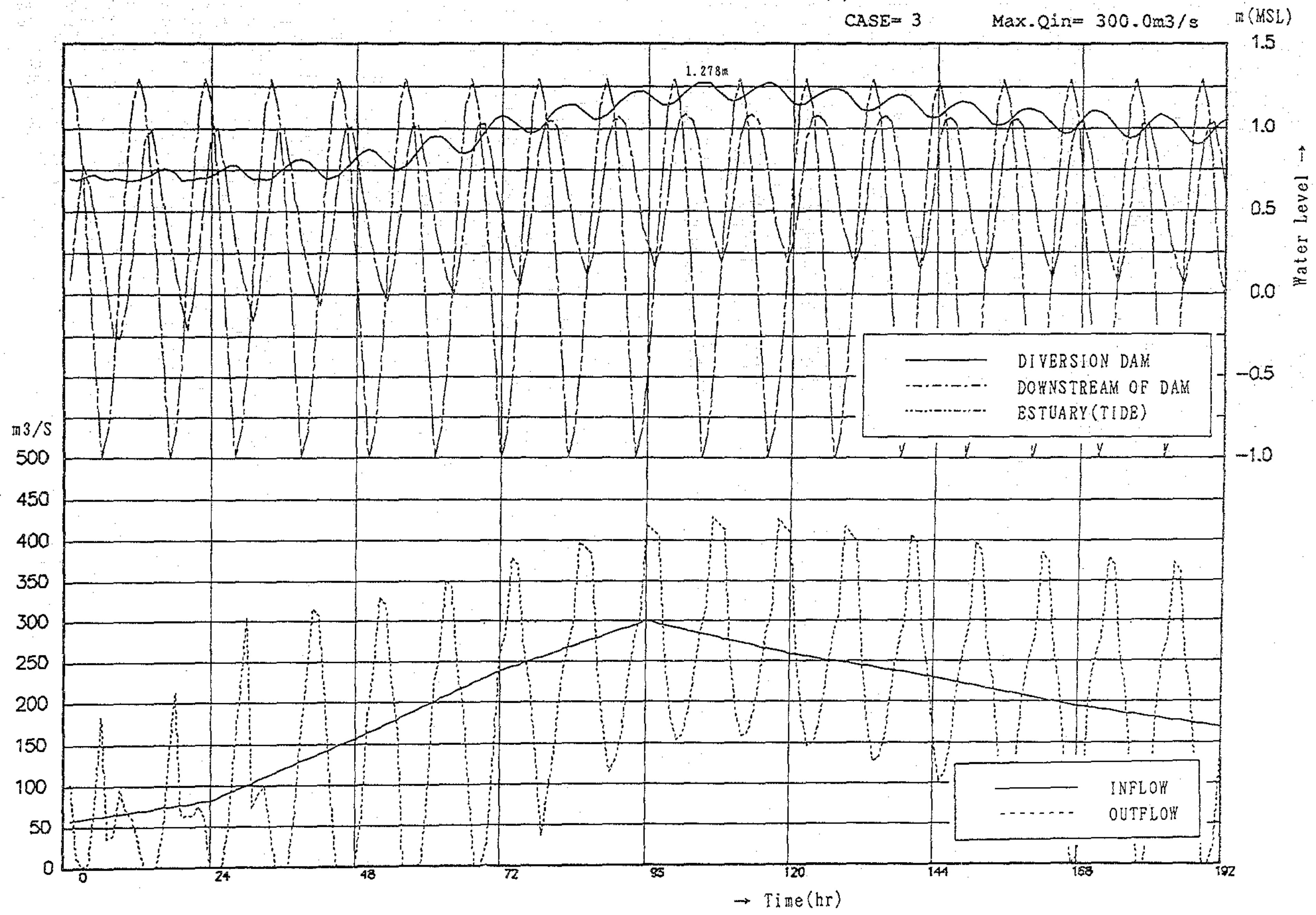


Table 3-4-2 Gate Simulation (1)

*** GATE SIMULATION ***   CASE=1   Max.Qin= 30.0m3/s

(1)

T(hr)	Qin(cms)	DIVERSION DAM(NO.17) WL(m)	Q1(cms)	Q2(cms)	QQ(cms)	U-G(m)	L-G(m)	NO.16 WL(m)	SEA WL(m)	
1	30.0	0.703	49.5	0.0	49.5	-0.24	-8.20	0.073	1.300	1
2	30.0	0.695	46.7	0.0	46.7	-0.54	-8.20	0.420	1.150	1
3	30.0	0.696	0.0	0.0	0.0	0.77	-8.20	0.767	0.731	1
4	30.0	0.704	2.1	0.0	2.1	0.55	-8.20	0.664	0.151	1
5	30.0	0.706	41.3	0.0	41.3	-0.45	-8.20	0.461	-0.429	1
6	30.0	0.697	89.8	0.0	89.8	-1.19	-8.20	0.242	-0.999	1
7	30.0	0.691	22.3	0.0	22.3	0.14	-8.20	-0.031	-0.850	1
8	30.0	0.693	22.4	0.0	22.4	0.14	-8.20	-0.302	-0.431	1
9	30.0	0.695	22.5	0.0	22.5	0.14	-8.20	-0.316	0.149	1
10	30.0	0.696	22.6	0.0	22.6	0.14	-8.20	-0.120	0.729	1
11	30.0	0.698	22.7	0.0	22.7	0.14	-8.20	0.167	1.149	1
12	30.0	0.700	16.2	0.0	16.2	0.14	-8.20	0.529	1.300	1
13	30.0	0.706	0.0	0.0	0.0	0.89	-8.20	0.892	1.150	1
14	30.0	0.713	0.0	0.0	0.0	1.00	-8.20	0.965	0.731	1
15	30.0	0.720	0.0	0.0	0.0	1.00	-8.20	0.784	0.151	1
16	30.0	0.727	16.4	0.0	16.4	0.28	-8.20	0.542	-0.429	1
17	30.0	0.724	65.5	0.0	65.5	-0.72	-8.20	0.292	-0.999	1
18	30.0	0.709	110.1	0.0	110.1	-1.30	-8.20	0.052	-0.850	1
19	30.0	0.690	0.0	0.0	0.0	-0.09	-8.20	-0.204	-0.431	1
20	30.0	0.690	37.3	0.0	37.3	-0.09	-8.20	-0.270	0.149	1
21	30.0	0.690	36.4	0.0	36.4	-0.08	-8.20	-0.079	0.729	1
22	30.0	0.690	22.5	0.0	22.5	0.13	-8.20	0.201	1.149	1
23	30.0	0.692	14.8	0.0	14.8	0.13	-8.20	0.556	1.300	1
24	30.0	0.699	0.0	0.0	0.0	0.91	-8.20	0.912	1.150	1
25	30.0	0.706	0.0	0.0	0.0	1.01	-8.20	0.976	0.731	1
26	30.0	0.713	0.0	0.0	0.0	1.01	-8.20	0.790	0.151	1
27	30.0	0.720	13.2	0.0	13.2	0.33	-8.20	0.546	-0.429	1
28	30.0	0.718	62.1	0.0	62.1	-0.67	-8.20	0.294	-0.999	1
29	30.0	0.703	109.3	0.0	109.3	-1.30	-8.20	0.053	-0.850	1
30	30.0	0.690	34.3	0.0	34.3	-0.05	-8.20	-0.218	-0.431	1
31	30.0	0.690	0.0	0.0	0.0	-0.05	-8.20	-0.274	0.149	1
32	30.0	0.690	34.3	0.0	34.3	-0.05	-8.20	-0.082	0.729	1
33	30.0	0.690	30.0	0.0	30.0	0.01	-8.20	0.200	1.149	1
34	30.0	0.691	18.2	0.0	18.2	0.01	-8.20	0.558	1.300	1
35	30.0	0.697	0.0	0.0	0.0	0.91	-8.20	0.912	1.150	1
36	30.0	0.704	0.0	0.0	0.0	1.01	-8.20	0.976	0.731	1
37	30.0	0.711	0.0	0.0	0.0	1.01	-8.20	0.790	0.151	1
38	30.0	0.718	12.7	0.0	12.7	0.34	-8.20	0.546	-0.429	1
39	30.0	0.716	61.5	0.0	61.5	-0.66	-8.20	0.293	-0.999	1
40	30.0	0.701	109.1	0.0	109.1	-1.30	-8.20	0.052	-0.850	1
41	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.222	-0.431	1
42	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.276	0.149	1
43	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.083	0.729	1
44	30.0	0.690	29.9	0.0	29.9	0.01	-8.20	0.199	1.149	1
45	30.0	0.691	18.2	0.0	18.2	0.01	-8.20	0.557	1.300	1
46	30.0	0.697	0.0	0.0	0.0	0.91	-8.20	0.912	1.150	1
47	30.0	0.704	0.0	0.0	0.0	1.01	-8.20	0.975	0.731	1
48	30.0	0.711	0.0	0.0	0.0	1.01	-8.20	0.790	0.151	1

NOTE; WL=Water level in M.S.L., QQ=Q1+Q2
Q1,U-G(m)=Over flow and Crest elevation of REGULATING GATES (n=1)
Q2,L-G(m)=Under flow and Bottom elevation of REG./FLOOD GATES
NO.16=Down stream of DIVERSION DAM

*** GATE SIMULATION ***   CASE=1   Max.Qin= 30.0m3/s

(2)

T(hr)	Qin(cms)	DIVERSION DAM(NO.17) WL(m)	Q1(cms)	Q2(cms)	QQ(cms)	U-G(m)	L-G(m)	NO.16 WL(m)	SEA WL(m)	
49	30.0	0.718	12.7	0.0	12.7	0.34	-8.20	0.546	-0.429	1
50	30.0	0.716	61.5	0.0	61.5	-0.66	-8.20	0.293	-0.999	1
51	30.0	0.701	109.1	0.0	109.1	-1.30	-8.20	0.052	-0.850	1
52	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.222	-0.431	1
53	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.276	0.149	1
54	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.084	0.729	1
55	30.0	0.690	29.6	0.0	29.6	0.02	-8.20	0.199	1.149	1
56	30.0	0.691	18.1	0.0	18.1	0.02	-8.20	0.557	1.300	1
57	30.0	0.697	0.0	0.0	0.0	0.91	-8.20	0.911	1.150	1
58	30.0	0.704	0.0	0.0	0.0	1.01	-8.20	0.975	0.731	1
59	30.0	0.711	0.0	0.0	0.0	1.01	-8.20	0.790	0.151	1
60	30.0	0.718	12.8	0.0	12.8	0.34	-8.20	0.546	-0.429	1
61	30.0	0.716	61.6	0.0	61.6	-0.66	-8.20	0.293	-0.999	1
62	30.0	0.701	109.1	0.0	109.1	-1.30	-8.20	0.052	-0.850	1
63	30.0	0.690	33.5	0.0	33.5	-0.04	-8.20	-0.221	-0.431	1
64	30.0	0.690	33.5	0.0	33.5	-0.04	-8.20	-0.275	0.149	1
65	30.0	0.690	33.5	0.0	33.5	-0.04	-8.20	-0.083	0.729	1
66	30.0	0.690	29.9	0.0	29.9	0.01	-8.20	0.199	1.149	1
67	30.0	0.691	18.2	0.0	18.2	0.01	-8.20	0.557	1.300	1
68	30.0	0.697	0.0	0.0	0.0	0.91	-8.20	0.912	1.150	1
69	30.0	0.704	0.0	0.0	0.0	1.01	-8.20	0.975	0.731	1
70	30.0	0.711	0.0	0.0	0.0	1.01	-8.20	0.790	0.151	1
71	30.0	0.718	12.7	0.0	12.7	0.34	-8.20	0.546	-0.429	1
72	30.0	0.716	61.5	0.0	61.5	-0.66	-8.20	0.293	-0.999	1
73	30.0	0.701	109.1	0.0	109.1	-1.30	-8.20	0.052	-0.850	1
74	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.222	-0.431	1
75	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.276	0.149	1
76	30.0	0.690	33.4	0.0	33.4	-0.04	-8.20	-0.084	0.729	1
77	30.0	0.690	29.3	0.0	29.3	0.02	-8.20	0.199	1.149	1
78	30.0	0.691	18.0	0.0	18.0	0.02	-8.20	0.557	1.300	1
79	30.0	0.697	0.0	0.0	0.0	0.91	-8.20	0.911	1.150	1
80	30.0	0.704	0.0	0.0	0.0	1.01	-8.20	0.976	0.731	1
81	30.0	0.711	0.0	0.0	0.0	1.01	-8.20	0.790	0.151	1
82	30.0	0.718	12.8	0.0	12.8	0.34	-8.20	0.546	-0.429	1
83	30.0	0.716	61.6	0.0	61.6	-0.66	-8.20	0.293	-0.999	1
84	30.0	0.701	109.2	0.0	109.2	-1.30	-8.20	0.052	-0.850	1
85	30.0	0.690	33.5	0.0	33.5	-0.04	-8.20	-0.221	-0.431	1
86	30.0	0.690	33.5	0.0	33.5	-0.04	-8.20	-0.276	0.149	1
87	30.0	0.690	33.5	0.0	33.5	-0.04	-8.20	-0.084	0.729	1
88	30.0	0.690	28.9	0.0	28.9	0.03	-8.20	0.199	1.149	1
89	30.0	0.691	17.8	0.0	17.8	0.03	-8.20	0.556	1.300	1
90	30.0	0.697	0.0	0.0	0.0	0.91	-8.20	0.911	1.150	1
91	30.0	0.704	0.0	0.0	0.0	1.01	-8.20	0.975	0.731	1
92	30.0	0.711	0.0	0.0	0.0	1.01	-8.20	0.790	0.151	1
93	30.0	0.718	12.8	0.0	12.8	0.34	-8.20	0.546	-0.429	1
94	30.0	0.716	61.6	0.0	61.6	-0.66	-8.20	0.293	-0.999	1
95	30.0	0.702	109.2	0.0	109.2	-1.30	-8.20	0.052	-0.850	1
96	30.0	0.690	0.0	0.0	0.0	-0.04	-8.20	-0.215	-0.001	1

NOTE; WL=Water level in M.S.L., QQ=Q1+Q2
Q1,U-G(m)=Over flow and Crest elevation of REGULATING GATES (n=1)
Q2,L-G(m)=Under flow and Bottom elevation of REG./FLOOD GATES
NO.16=Down stream of DIVERSION DAM

Table 3-4-2 Gate Simulation (2)

*** GATE SIMULATION *** CASE= 2 Max.Qin= 80.0m3/s

(1)

	DIVERSION DAM(NO.17)							NO.16	SEA	
T(hr)	Qin(cms)	WL(m)	Q1(cms)	Q2(cms)	QQ(cms)	U-G(m)	L-G(m)	WL(m)	WL(m)	
1	32.1	0.703	49.5	0.0	49.5	-0.24	-8.20	0.073	1.300	1
2	34.2	0.696	48.5	0.0	48.5	-0.58	-8.20	0.421	1.150	1
3	36.2	0.698	0.0	0.0	0.0	0.77	-8.20	0.768	0.731	1
4	38.3	0.707	2.5	0.0	2.5	0.54	-8.20	0.664	0.151	1
5	40.4	0.712	42.4	0.0	42.4	-0.46	-8.20	0.462	-0.429	1
6	42.5	0.704	96.7	0.0	96.7	-1.30	-8.20	0.244	-0.999	1
7	44.6	0.690	29.6	0.0	29.6	0.02	-8.20	0.007	-0.850	1
8	46.7	0.694	29.8	0.0	29.8	0.02	-8.20	-0.280	-0.431	1
9	48.7	0.698	30.1	0.0	30.1	0.02	-8.20	-0.303	0.149	1
10	50.8	0.700	70.3	0.0	70.3	-0.50	-8.20	-0.098	0.729	1
11	52.9	0.696	71.6	0.0	71.6	-0.52	-8.20	0.207	1.149	1
12	55.0	0.696	34.4	0.0	34.4	-0.52	-8.20	0.570	1.300	1
13	57.1	0.708	0.0	0.0	0.0	0.92	-8.20	0.919	1.150	1
14	59.2	0.722	0.0	0.0	0.0	1.01	-8.20	0.980	0.731	1
15	61.2	0.736	0.0	0.0	0.0	1.01	-8.20	0.792	0.151	1
16	63.3	0.750	19.9	0.0	19.9	0.24	-8.20	0.549	-0.429	1
17	65.4	0.755	70.5	0.0	70.5	-0.76	-8.20	0.299	-0.999	1
18	67.5	0.747	155.8	0.0	155.8	-1.30	-8.20	0.063	-0.850	1
19	69.6	0.726	153.4	0.0	153.4	-1.30	-8.20	-0.154	-0.431	1
20	71.7	0.707	151.2	0.0	151.2	-1.30	-8.20	-0.212	0.149	1
21	73.7	0.691	31.6	0.0	31.6	-0.01	-8.20	0.004	0.729	1
22	75.8	0.701	38.2	0.0	38.2	-0.10	-8.20	0.264	1.149	1
23	77.9	0.708	46.1	0.0	46.1	-1.10	-8.20	0.622	1.300	1
24	80.0	0.725	0.0	0.0	0.0	0.96	-8.20	0.957	1.150	1
25	80.0	0.744	0.0	0.0	0.0	1.01	-8.20	1.003	0.731	1
26	80.0	0.763	0.0	0.0	0.0	1.01	-8.20	0.804	0.151	1
27	80.0	0.781	25.3	0.0	25.3	0.18	-8.20	0.559	-0.429	1
28	80.0	0.789	76.7	0.0	76.7	-0.82	-8.20	0.310	-0.999	1
29	80.0	0.782	159.7	0.0	159.7	-1.30	-8.20	0.076	-0.850	1
30	80.0	0.763	157.6	0.0	157.6	-1.30	-8.20	-0.143	-0.431	1
31	80.0	0.745	155.5	0.0	155.5	-1.30	-8.20	-0.205	0.149	1
32	80.0	0.727	153.5	0.0	153.5	-1.30	-8.20	0.023	0.729	1
33	80.0	0.720	93.6	0.0	93.6	-1.30	-8.20	0.311	1.149	1
34	80.0	0.721	45.4	0.0	45.4	-1.30	-8.20	0.663	1.300	1
35	80.0	0.739	0.0	0.0	0.0	0.98	-8.20	0.983	1.150	1
36	80.0	0.758	0.0	0.0	0.0	1.02	-8.20	1.008	0.731	1
37	80.0	0.778	0.0	0.0	0.0	1.02	-8.20	0.814	0.151	1
38	80.0	0.795	27.3	0.0	27.3	0.16	-8.20	0.567	-0.429	1
39	80.0	0.802	78.8	0.0	78.8	-0.84	-8.20	0.316	-0.999	1
40	80.0	0.795	161.2	0.0	161.2	-1.30	-8.20	0.083	-0.850	1
41	80.0	0.776	159.0	0.0	159.0	-1.30	-8.20	-0.137	-0.431	1
42	80.0	0.757	156.9	0.0	156.9	-1.30	-8.20	-0.202	0.149	1
43	80.0	0.739	154.9	0.0	154.9	-1.30	-8.20	0.025	0.729	1
44	80.0	0.732	94.9	0.0	94.9	-1.30	-8.20	0.314	1.149	1
45	80.0	0.733	47.9	0.0	47.9	-1.30	-8.20	0.666	1.300	1
46	80.0	0.750	0.0	0.0	0.0	0.98	-8.20	0.985	1.150	1
47	80.0	0.769	0.0	0.0	0.0	1.02	-8.20	1.009	0.731	1
48	80.0	0.789	0.0	0.0	0.0	1.02	-8.20	0.815	0.151	1

NOTE; WL=Water level in M.S.L., QQ=Q1+Q2
Q1,U-G(m)=Over flow and Crest elevation of REGULATING GATES (n=1)
Q2,L-G(m)=Under flow and Bottom elevation of REG./FLOOD GATES
NO.16=Down stream of DIVERSION DAM

*** GATE SIMULATION *** CASE= 2 Max.Qin= 80.0m3/s

(2)

	DIVERSION DAM(NO.17)							NO.16	SEA	
T(hr)	Qin(cms)	WL(m)	Q1(cms)	Q2(cms)	QQ(cms)	U-G(m)	L-G(m)	WL(m)	WL(m)	
49	80.0	0.806	30.4	0.0	30.4	0.12	-8.20	0.568	-0.429	1
50	80.0	0.813	81.9	0.0	81.9	-0.88	-8.20	0.318	-0.999	1
51	80.0	0.805	162.3	0.0	162.3	-1.30	-8.20	0.086	-0.850	1
52	80.0	0.785	160.1	0.0	160.1	-1.30	-8.20	-0.134	-0.431	1
53	80.0	0.766	157.9	0.0	157.9	-1.30	-8.20	-0.200	0.149	1
54	80.0	0.748	155.9	0.0	155.9	-1.30	-8.20	0.027	0.729	1
55	80.0	0.740	95.8	0.0	95.8	-1.30	-8.20	0.315	1.149	1
56	80.0	0.741	49.6	0.0	49.6	-1.30	-8.20	0.668	1.300	1
57	80.0	0.758	0.0	0.0	0.0	0.99	-8.20	0.987	1.150	1
58	80.0	0.777	0.0	0.0	0.0	1.02	-8.20	1.009	0.731	1
59	80.0	0.797	0.0	0.0	0.0	1.02	-8.20	0.815	0.151	1
60	80.0	0.814	32.8	0.0	32.8	0.09	-8.20	0.569	-0.429	1
61	80.0	0.820	84.2	0.0	84.2	-0.91	-8.20	0.320	-0.999	1
62	80.0	0.812	163.1	0.0	163.1	-1.30	-8.20	0.089	-0.850	1
63	80.0	0.792	160.9	0.0	160.9	-1.30	-8.20	-0.132	-0.431	1
64	80.0	0.773	158.7	0.0	158.7	-1.30	-8.20	-0.199	0.149	1
65	80.0	0.754	156.6	0.0	156.6	-1.30	-8.20	0.028	0.729	1
66	80.0	0.746	96.6	0.0	96.6	-1.30	-8.20	0.317	1.149	1
67	80.0	0.747	50.8	0.0	50.8	-1.30	-8.20	0.669	1.300	1
68	80.0	0.764	0.0	0.0	0.0	0.99	-8.20	0.988	1.150	1
69	80.0	0.783	0.0	0.0	0.0	1.02	-8.20	1.009	0.731	1
70	80.0	0.802	0.0	0.0	0.0	1.02	-8.20	0.816	0.151	1
71	80.0	0.819	25.4	0.0	25.4	0.07	-8.20	0.570	-0.429	1
72	80.0	0.825	85.9	0.0	85.9	-0.93	-8.20	0.321	-0.999	1
73	77.9	0.816	163.7	0.0	163.7	-1.30	-8.20	0.090	-0.850	1
74	75.8	0.796	161.3	0.0	161.3	-1.30	-8.20	-0.130	-0.431	1
75	73.8	0.775	159.0	0.0	159.0	-1.30	-8.20	-0.199	0.149	1
76	71.7	0.755	156.7	0.0	156.7	-1.30	-8.20	0.028	0.729	1
77	69.6	0.745	96.4	0.0	96.4	-1.30	-8.20	0.318	1.149	1
78	67.5	0.743	49.8	0.0	49.8	-1.30	-8.20	0.670	1.300	1
79	65.4	0.757	0.0	0.0	0.0	0.99	-8.20	0.988	1.150	1
80	63.3	0.772	0.0	0.0	0.0	1.02	-8.20	1.009	0.731	1
81	61.3	0.787	0.0	0.0	0.0	1.02	-8.20	0.816	0.151	1
82	59.2	0.800	29.2	0.0	29.2	0.13	-8.20	0.569	-0.429	1
83	57.1	0.802	80.0	0.0	80.0	-0.87	-8.20	0.318	-0.999	1
84	55.0	0.789	160.5	0.0	160.5	-1.30	-8.20	0.083	-0.850	1
85	52.9	0.764	157.6	0.0	157.6	-1.30	-8.20	-0.137	-0.431	1
86	50.8	0.739	154.8	0.0	154.8	-1.30	-8.20	-0.203	0.149	1
87	48.8	0.714	152.0	0.0	152.0	-1.30	-8.20	0.024	0.729	1
88	46.7	0.700	90.9	0.0	90.9	-1.30	-8.20	0.311	1.149	1
89	44.6	0.694	36.2	0.0	36.2	-1.30	-8.20	0.660	1.300	1
90	42.5	0.704	0.0	0.0	0.0	0.98	-8.20	0.980	1.150	1
91	40.4	0.714	0.0	0.0	0.0	1.02	-8.20	1.008	0.731	1
92	38.3	0.723	0.0	0.0	0.0	1.02	-8.20	0.813	0.151	1
93	36.3	0.732	11.4	0.0	11.4	0.38	-8.20	0.562	-0.429	1
94	34.2	0.731	60.3	0.0	60.3	-0.62	-8.20	0.306	-0.999	1
95	32.1	0.717	110.4	0.0	110.4	-1.30	-8.20	0.063	-0.850	1
96	30.0	0.690	41.1	0.0	41.1	-0.15	-8.20	-0.157	-0.001	1

NOTE; WL=Water level in M.S.L., QQ=Q1+Q2
Q1,U-G(m)=Over flow and Crest elevation of REGULATING GATES (n=1)
Q2,L-G(m)=Under flow and Bottom elevation of REG./FLOOD GATES
NO.16=Down stream of DIVERSION DAM

Table 3-4-2 Gate Simulation (3)

*** GATE SIMULATION *** CASE= 3 Max.Qin= 300.0m3/s

(1)

T(hr)	Qin(cms)	DIVERSION DAM(NO.17) WL(m)	Q1(cms)	Q2(cms)	QQ(cms)	U-G(m)	L-G(m)	NO.16 WL(m)	SEA WL(m)	
1	58.0	0.704	103.4	0.0	103.4	-0.27	-8.20	0.087	1.300	1
2	59.1	0.690	13.1	0.0	13.1	0.45	-8.20	0.454	1.150	1
3	60.1	0.703	0.0	0.0	0.0	0.78	-8.20	0.779	0.731	1
4	61.2	0.717	6.0	0.0	6.0	0.53	-8.20	0.669	0.151	1
5	62.2	0.722	85.8	0.0	85.8	-0.47	-8.20	0.480	-0.429	1
6	63.2	0.703	184.4	0.0	184.4	-1.30	-8.20	0.299	-0.999	1
7	64.3	0.694	35.9	0.0	35.9	0.21	-8.20	0.024	-0.850	1
8	65.3	0.701	40.3	0.0	40.3	0.18	-8.20	-0.256	-0.431	1
9	66.4	0.696	96.4	0.0	96.4	-0.23	-8.20	-0.269	0.149	1
10	67.4	0.690	69.7	0.0	69.7	-0.06	-8.20	-0.054	0.729	1
11	68.5	0.692	59.5	0.0	59.5	0.02	-8.20	0.233	1.149	1
12	69.5	0.695	33.0	0.0	33.0	0.02	-8.20	0.593	1.300	1
13	70.5	0.711	0.0	0.0	0.0	0.94	-8.20	0.936	1.150	1
14	71.6	0.728	0.0	0.0	0.0	1.01	-8.20	0.994	0.731	1
15	72.6	0.745	0.0	0.0	0.0	1.01	-8.20	0.797	0.151	1
16	73.7	0.760	42.7	0.0	42.7	0.22	-8.20	0.557	-0.429	1
17	74.7	0.757	139.3	0.0	139.3	-0.78	-8.20	0.333	-0.999	1
18	75.7	0.730	214.4	0.0	214.4	-1.30	-8.20	0.141	-0.850	1
19	76.8	0.690	63.2	0.0	63.2	-0.01	-8.20	-0.058	-0.431	1
20	77.8	0.694	63.7	0.0	63.7	-0.01	-8.20	-0.206	0.149	1
21	78.9	0.697	64.1	0.0	64.1	-0.01	-8.20	-0.013	0.729	1
22	79.9	0.701	75.2	0.0	75.2	-0.09	-8.20	0.271	1.149	1
23	81.0	0.702	61.4	0.0	61.4	-0.67	-8.20	0.637	1.300	1
24	82.0	0.719	0.0	0.0	0.0	0.96	-8.20	0.965	1.150	1
25	85.1	0.739	0.0	0.0	0.0	1.01	-8.20	1.005	0.731	1
26	88.2	0.760	0.0	0.0	0.0	1.01	-8.20	0.807	0.151	1
27	91.4	0.779	47.8	0.0	47.8	0.20	-8.20	0.565	-0.429	1
28	94.5	0.780	145.5	0.0	145.5	-0.80	-8.20	0.342	-0.999	1
29	97.6	0.756	219.5	0.0	219.5	-1.30	-8.20	0.151	-0.850	1
30	100.7	0.715	304.3	0.0	304.3	-1.30	-8.20	-0.009	-0.431	1
31	103.9	0.694	72.7	0.0	72.7	-0.08	-8.20	-0.161	0.149	1
32	107.0	0.701	90.0	0.0	90.0	-0.19	-8.20	0.024	0.729	1
33	110.1	0.696	100.4	0.0	100.4	-0.51	-8.20	0.331	1.149	1
34	113.2	0.704	46.4	0.0	46.4	-0.80	-8.20	0.680	1.300	1
35	116.4	0.731	0.0	0.0	0.0	0.99	-8.20	0.993	1.150	1
36	119.5	0.759	0.0	0.0	0.0	1.02	-8.20	1.010	0.731	1
37	122.6	0.788	0.0	0.0	0.0	1.02	-8.20	0.818	0.151	1
38	125.7	0.814	60.6	0.0	60.6	0.13	-8.20	0.577	-0.429	1
39	128.9	0.820	159.8	0.0	159.8	-0.87	-8.20	0.357	-0.999	1
40	132.0	0.802	228.8	0.0	228.8	-1.30	-8.20	0.168	-0.850	1
41	135.1	0.765	315.6	0.0	315.6	-1.30	-8.20	0.016	-0.431	1
42	138.2	0.723	306.2	0.0	306.2	-1.30	-8.20	-0.067	0.149	1
43	141.4	0.693	207.0	0.0	207.0	-1.30	-8.20	0.129	0.729	1
44	144.5	0.707	87.6	0.0	87.6	-0.17	-8.20	0.380	1.149	1
45	147.6	0.724	0.0	0.0	0.0	0.72	-8.20	0.724	1.300	1
46	150.7	0.759	0.0	0.0	0.0	1.00	-8.20	1.003	1.150	1
47	153.9	0.796	0.0	0.0	0.0	1.03	-8.20	1.016	0.731	1
48	157.0	0.833	0.0	0.0	0.0	1.02	-8.20	0.831	0.151	1

NOTE; WL=Water level in M.S.L., QQ=Q1+Q2
Q1,U-G(m)=Over flow and Crest elevation of REGULATING GATES (n=2)
Q2,L-G(m)=Under flow and Bottom elevation of REG./FLOOD GATES
NO.16=Down stream of DIVERSION DAM

*** GATE SIMULATION *** CASE= 3 Max.Qin= 300.0m3/s

(2)

T(hr)	Qin(cms)	DIVERSION DAM(NO.17) WL(m)	Q1(cms)	Q2(cms)	QQ(cms)	U-G(m)	L-G(m)	NO.16 WL(m)	SEA WL(m)	
49	160.4	0.865	60.5	0.0	60.5	0.02	-8.20	0.591	-0.429	1
50	163.7	0.876	182.3	0.0	182.3	-0.98	-8.20	0.379	-0.999	1
51	167.1	0.862	240.9	0.0	240.9	-1.30	-8.20	0.192	-0.850	1
52	170.5	0.828	330.1	0.0	330.1	-1.30	-8.20	0.047	-0.431	1
53	173.9	0.791	321.6	0.0	321.6	-1.30	-8.20	-0.041	0.149	1
54	177.2	0.764	222.0	0.0	222.0	-1.30	-8.20	0.149	0.729	1
55	180.6	0.759	172.3	0.0	172.3	-1.30	-8.20	0.451	1.149	1
56	184.0	0.774	0.0	0.0	0.0	0.78	-8.20	0.782	1.300	1
57	187.4	0.819	0.0	0.0	0.0	1.01	-8.20	1.011	1.150	1
58	190.7	0.864	0.0	0.0	0.0	1.04	-8.20	1.024	0.731	1
59	194.1	0.911	2.2	0.0	2.2	0.84	-8.20	0.850	0.151	1
60	197.5	0.947	88.4	0.0	88.4	-0.16	-8.20	0.614	-0.429	1
61	200.9	0.959	219.0	0.0	219.0	-1.16	-8.20	0.415	-0.999	1
62	204.2	0.948	258.4	0.0	258.4	-1.30	-8.20	0.228	-0.850	1
63	207.6	0.917	350.6	0.0	350.6	-1.30	-8.20	0.093	-0.431	1
64	211.0	0.884	342.9	0.0	342.9	-1.30	-8.20	-0.001	0.149	1
65	214.4	0.858	241.7	0.0	241.7	-1.30	-8.20	0.179	0.729	1
66	217.7	0.857	194.9	0.0	194.9	-1.30	-8.20	0.482	1.149	1
67	221.1	0.873	90.8	0.0	90.8	-1.30	-8.20	0.824	1.300	1
68	224.5	0.923	0.0	0.0	0.0	1.02	-8.20	1.018	1.150	1
69	227.9	0.978	0.0	0.0	0.0	1.04	-8.20	1.030	0.731	1
70	231.2	1.031	26.3	0.0	26.3	0.55	-8.20	0.871	0.151	1
71	234.6	1.068	136.9	0.0	136.9	-0.45	-8.20	0.647	-0.429	1
72	238.0	1.076	259.0	0.0	259.0	-1.30	-8.20	0.468	-0.999	1
73	240.6	1.068	283.0	0.0	283.0	-1.30	-8.20	0.279	-0.850	1
74	243.2	1.035	378.7	0.0	378.7	-1.30	-8.20	0.156	-0.431	1
75	245.7	1.004	371.2	0.0	371.2	-1.30	-8.20	0.055	0.149	1
76	248.3	0.976	266.3	0.0	266.3	-1.30	-8.20	0.222	0.729	1
77	250.9	0.976	222.3	0.0	222.3	-1.30	-8.20	0.522	1.149	1
78	253.5	0.992	137.8	0.0	137.8	-1.30	-8.20	0.869	1.300	1
79	256.1	1.037	36.3	0.0	36.3	-1.30	-8.20	1.033	1.150	1
80	258.7	1.086	90.1	0.0	90.1	-1.30	-8.20	1.050	0.731	1
81	261.2	1.121	140.2	0.0	140.2	-1.30	-8.20	1.009	0.151	1
82	263.8	1.139	220.4	0.0	220.4	-1.30	-8.20	0.778	-0.429	1
83	266.4	1.145	262.5	0.0	262.5	-1.30	-8.20	0.567	-0.999	1
84	269.0	1.142	292.4	0.0	292.4	-1.30	-8.20	0.357	-0.850	1
85	271.6	1.115	398.1	0.0	398.1	-1.30	-8.20	0.225	-0.431	1
86	274.2	1.086	391.0	0.0	391.0	-1.30	-8.20	0.115	0.149	1
87	276.7	1.059	384.5	0.0	384.5	-1.30	-8.20	0.268	0.729	1
88	279.3	1.062	240.7	0.0	240.7	-1.30	-8.20	0.557	1.149	1
89	281.9	1.079	164.1	0.0	164.1	-1.30	-8.20	0.903	1.300	1
90	284.5	1.116	115.2	0.0	115.2	-1.30	-8.20	1.050	1.150	1
91	287.1	1.157	129.6	0.0	129.6	-1.30	-8.20	1.070	0.731	1
92	289.7	1.191	165.5	0.0	165.5	-1.30	-8.20	1.032	0.151	1
93	292.2	1.215	229.3	0.0	229.3	-1.30	-8.20	0.848	-0.429	1
94	294.8	1.224	276.7	0.0	276.7	-1.30	-8.20	0.619	-0.999	1
95	297.4	1.225	308.3	0.0	308.3	-1.30	-8.20	0.406	-0.850	1
96	300.0	1.199	418.8	0.0	418.8	-1.30	-8.20	0.278	-0.431	1

NOTE; WL=Water level in M.S.L., QQ=Q1+Q2
Q1,U-G(m)=Over flow and Crest elevation of REGULATING GATES (n=2)
Q2,L-G(m)=Under flow and Bottom elevation of REG./FLOOD GATES
NO.16=Down stream of DIVERSION DAM

*** GATE SIMULATION *** CASE= 3 Max.Qin= 300.0m3/s

(3)

T(hr)	Qin(cms)	DIVERSION DAM(NO.17) WL(m)	Q1(cms)	Q2(cms)	QQ(cms)	U-G(m)	L-G(m)	NO.16 WL(m)	SEA WL(m)	
97	298.3	1.171	411.9	0.0	411.9	-1.30	-8.20	0.164	0.149	1
98	296.6	1.144	405.3	0.0	405.3	-1.30	-8.20	0.299	0.729	1
99	294.9	1.145	259.4	0.0	259.4	-1.30	-8.20	0.587	1.149	1
100	293.2	1.161	187.4	0.0	187.4	-1.30	-8.20	0.933	1.300	1
101	291.5	1.192	153.6	0.0	153.6	-1.30	-8.20	1.062	1.150	1
102	289.8	1.225	160.5	0.0	160.5	-1.30	-8.20	1.084	0.731	1
103	288.0	1.252	187.0	0.0	187.0	-1.30	-8.20	1.049	0.151	1
104	286.3	1.273	231.9	0.0	231.9	-1.30	-8.20	0.920	-0.429	1
105	284.6	1.278	285.4	0.0	285.4	-1.30	-8.20	0.661	-0.999	1
106	282.9	1.274	316.9	0.0	316.9	-1.30	-8.20	0.442	-0.850	1
107	281.2	1.242	429.6	0.0	429.6	-1.30	-8.20	0.313	-0.431	1
108	279.5	1.207	420.9	0.0	420.9	-1.30	-8.20	0.194	0.149	1
109	277.8	1.174	412.7	0.0	412.7	-1.30	-8.20	0.316	0.729	1
110	276.1	1.168	263.9	0.0	263.9	-1.30	-8.20	0.600	1.149	1
111	274.4	1.179	191.0	0.0	191.0	-1.30	-8.20	0.945	1.300	1
112	272.7	1.204	158.4	0.0	158.4	-1.30	-8.20	1.065	1.150	1
113	271.0	1.232	162.7	0.0	162.7	-1.30	-8.20	1.087	0.731	1
114	269.3	1.255	187.0	0.0	187.0	-1.30	-8.20	1.052	0.151	1
115	267.5	1.271	228.0	0.0	228.0	-1.30	-8.20	0.933	-0.429	1
116	265.8	1.273	283.0	0.0	283.0	-1.30	-8.20	0.665	-0.999	1
117	264.1	1.264	314.0	0.0	314.0	-1.30	-8.20	0.443	-0.850	1
118	262.4	1.229	426.5	0.0	426.5	-1.30	-8.20	0.310	-0.431	1
119	260.7	1.191	416.9	0.0	416.9	-1.30	-8.20	0.190	0.149	1
120	259.0	1.154	407.8	0.0	407.8	-1.30	-8.20	0.313	0.729	1
121	257.8	1.146	258.4	0.0	258.4	-1.30	-8.20	0.596	1.149	1
122	256.6	1.154	183.0	0.0	183.0	-1.30	-8.20	0.939	1.300	1
123	255.4	1.178	146.0	0.0	146.0	-1.30	-8.20	1.062	1.150	1
124	254.2	1.204	150.3	0.0	150.3	-1.30	-8.20	1.083	0.731	1
125	253.0	1.226	176.4	0.0	176.4	-1.30	-8.20	1.046	0.151	1
126	251.8	1.240	225.3	0.0	225.3	-1.30	-8.20	0.901	-0.429	1
127	250.5	1.240	276.5	0.0	276.5	-1.30	-8.20	0.647	-0.999	1
128	249.3	1.229	306.9	0.0	306.9	-1.30	-8.20	0.426	-0.850	1
129	248.1	1.194	417.6	0.0	417.6	-1.30	-8.20	0.290	-0.431	1
130	246.9	1.154	407.8	0.0	407.8	-1.30	-8.20	0.171	0.149	1
131	245.7	1.117	398.6	0.0	398.6	-1.30	-8.20	0.300	0.729	1
132	244.5	1.109	249.6	0.0	249.6	-1.30	-8.20	0.583	1.149	1
133	243.3	1.116	171.5	0.0	171.5	-1.30	-8.20	0.926	1.300	1
134	242.1	1.140	126.7	0.0	126.7	-1.30	-8.20	1.057	1.150	1
135	240.9	1.168	132.9	0.0	132.9	-1.30	-8.20	1.077	0.731	1
136	239.7	1.190	163.0	0.0	163.0	-1.30	-8.20	1.038	0.151	1
137	238.5	1.203	222.0	0.0	222.0	-1.30	-8.20	0.863	-0.429	1
138	237.3	1.201	269.3	0.0	269.3	-1.30	-8.20	0.623	-0.999	1
139	236.0	1.189	298.9	0.0	298.9	-1.30	-8.20	0.404	-0.850	1
140	234.8	1.153	407.6	0.0	407.6	-1.30	-8.20	0.265	-0.431	1
141	233.6	1.113	397.7	0.0	397.7	-1.30	-8.20	0.147	0.149	1
142	232.4	1.075	284.2	0.0	284.2	-1.30	-8.20	0.283	0.729	1
143	231.2	1.067	240.0	0.0	240.0	-1.30	-8.20	0.569	1.149	1
144	230.0	1.073	158.5	0.0	158.5	-1.30	-8.20	0.911	1.300	1

NOTE; WL=Water level in M.S.L., QQ=Q1+Q2
Q1,U-G(m)=Over flow and Crest elevation of REGULATING GATES (n=2)
Q2,L-G(m)=Under flow and Bottom elevation of REG./FLOOD GATES
NO.16=Down stream of DIVERSION DAM

*** GATE SIMULATION *** CASE= 3 Max.Qin= 300.0m3/s

(4)

T(hr)	Qin(cms)	DIVERSION DAM(NO.17) WL(m)	Q1(cms)	Q2(cms)	QQ(cms)	U-G(m)	L-G(m)	NO.16 WL(m)	SEA WL(m)	
145	228.5	1.099	101.7	0.0	101.7	-1.30	-8.20	1.050	1.150	1
146	227.1	1.130	112.4	0.0	112.4	-1.30	-8.20	1.068	0.731	1
147	225.6	1.153	148.7	0.0	148.7	-1.30	-8.20	1.028	0.151	1
148	224.2	1.164	217.6	0.0	217.6	-1.30	-8.20	0.826	-0.429	1
149	222.7	1.160	261.8	0.0	261.8	-1.30	-8.20	0.598	-0.999	1
150	221.3	1.147	290.7	0.0	290.7	-1.30	-8.20	0.380	-0.850	1
151	219.8	1.110	397.0	0.0	397.0	-1.30	-8.20	0.239	-0.431	1
152	218.3	1.069	386.9	0.0	386.9	-1.30	-8.20	0.123	0.149	1
153	216.9	1.031	275.9	0.0	275.9	-1.30	-8.20	0.259	0.729	1
154	215.4	1.021	229.6	0.0	229.6	-1.30	-8.20	0.553	1.149	1
155	214.0	1.027	143.4	0.0	143.4	-1.30	-8.20	0.895	1.300	1
156	212.5	1.056	61.9	0.0	61.9	-1.30	-8.20	1.042	1.150	1
157	211.0	1.092	88.6	0.0	88.6	-1.30	-8.20	1.057	0.731	1
158	209.6	1.116	134.3	0.0	134.3	-1.30	-8.20	1.016	0.151	1
159	208.1	1.124	212.8	0.0	212.8	-1.30	-8.20	0.789	-0.429	1
160	206.7	1.117	254.2	0.0	254.2	-1.30	-8.20	0.570	-0.999	1
161	205.2	1.102	282.2	0.0	282.2	-1.30	-8.20	0.355	-0.850	1
162	203.8	1.065	385.9	0.0	385.9	-1.30	-8.20	0.210	-0.431	1
163	202.3	1.022	375.6	0.0	375.6	-1.30	-8.20	0.097	0.149	1
164	200.8	0.984	266.3	0.0	266.3	-1.30	-8.20	0.238	0.729	1
165	199.4	0.973	218.7	0.0	218.7	-1.30	-8.20	0.537	1.149	1
166	197.9	0.978	126.7	0.0	126.7	-1.30	-8.20	0.878	1.300	1
167	196.5	1.017	0.0	0.0	0.0	1.03	-8.20	1.029	1.150	1
168	195.0	1.064	8.3	0.0	8.3	0.74	-8.20	1.040	0.731	1
169	193.9	1.101	87.8	0.0	87.8	-0.26	-8.20	0.924	0.151	1
170	192.8	1.111	219.6	0.0	219.6	-1.26	-8.20	0.719	-0.429	1
171	191.8	1.099	256.5	0.0	256.5	-1.30	-8.20	0.525	-0.999	1
172	190.7	1.080	281.2	0.0	281.2	-1.30	-8.20	0.319	-0.850	1
173	189.6	1.038	379.6	0.0	379.6	-1.30	-8.20	0.182	-0.431	1
174	188.5	0.994	368.9	0.0	368.9	-1.30	-8.20	0.073	0.149	1
175	187.4	0.955	260.7	0.0	260.7	-1.30	-8.20	0.223	0.729	1
176	186.3	0.942	212.1	0.0	212.1	-1.30	-8.20	0.523	1.149	1
177	185.3	0.946	115.1	0.0	115.1	-1.30	-8.20	0.863	1.300	1
178	184.2	0.984	0.0	0.0	0.0	1.03	-8.20	1.026	1.150	1
179	183.1	1.028	0.0	0.0	0.0	1.05	-8.20	1.037	0.731	1
180	182.0	1.068	55.7	0.0	55.7	0.15	-8.20	0.899	0.151	1
181	180.9	1.084	176.6	0.0	176.6	-0.85	-8.20	0.683	-0.429	1
182	179.8	1.073	253.1	0.0	253.1	-1.30	-8.20	0.499	-0.999	1
183	178.8	1.052	276.5	0.0	276.5	-1.30	-8.20	0.297	-0.850	1
184	177.7	1.008	372.4	0.0	372.4	-1.30	-8.20	0.160	-0.431	1
185	176.6	0.963	361.5	0.0	361.5	-1.30	-8.20	0.054	0.149	1
186	175.5	0.923	254.2	0.0	254.2	-1.30	-8.20	0.211	0.729	1
187	174.4	0.909	204.8	0.0	204.8	-1.30	-8.20	0.511	1.149	1
188	173.3	0.912	102.0	0.0	102.0	-1.30	-8.20	0.851	1.300	1
189	172.3	0.950	0.0	0.0	0.0	1.02	-8.20	1.023	1.150	1
190	171.2	0.991	0.0	0.0	0.0	1.05	-8.20	1.034	0.731	1
191	170.1	1.031	26.8	0.0	26.8	0.53	-8.20	0.882	0.151	1
192	169.0	1.053	134.6	0.0	134.6	-0.47	-8.20	0.655	0.000	1

NOTE; WL=Water level in M.S.L., QQ=Q1+Q2
Q1,U-G(m)=Over flow and Crest elevation of REGULATING GATES (n=2)
Q2,L-G(m)=Under flow and Bottom elevation of REG./FLOOD GATES
NO.16=Down stream of DIVERSION DAM

APPENDIX - 4 : DESIGN OF DIVERSION CANAL

APPENDIX - 4. DESIGN OF DIVERSION CANAL

LIST OF CONTENTS

4. 1 Location and Plane Figure of the Diversion Canal

The diversion canal will be constructed to make a short-cut for the meandering section. It will be located at the site and have the plane figure as shown in Figure 4-1 for the following reasons.

1) The diversion canal will have the plane figure on the upstream side that the left bank side of the diversion dam is in a straight line. The angle of the right bank opening will be 20 degrees with a radius of 1,000 meters, four time the canal width, so as to ensure smooth inflow of the river water. Downstream from the diversion dam, both banks of the canal will contract the river at an angle of 20° and with a curve of 1,000 m radius.

2) The straight portion of the diversion canal will be extended as far as possible so that both the diversion dam and the road bridge can be constructed over the canal.

4. 2 Typical Section of the Diversion Canal

4. 2. 1 Design Conditions

1) Design Flood Discharge

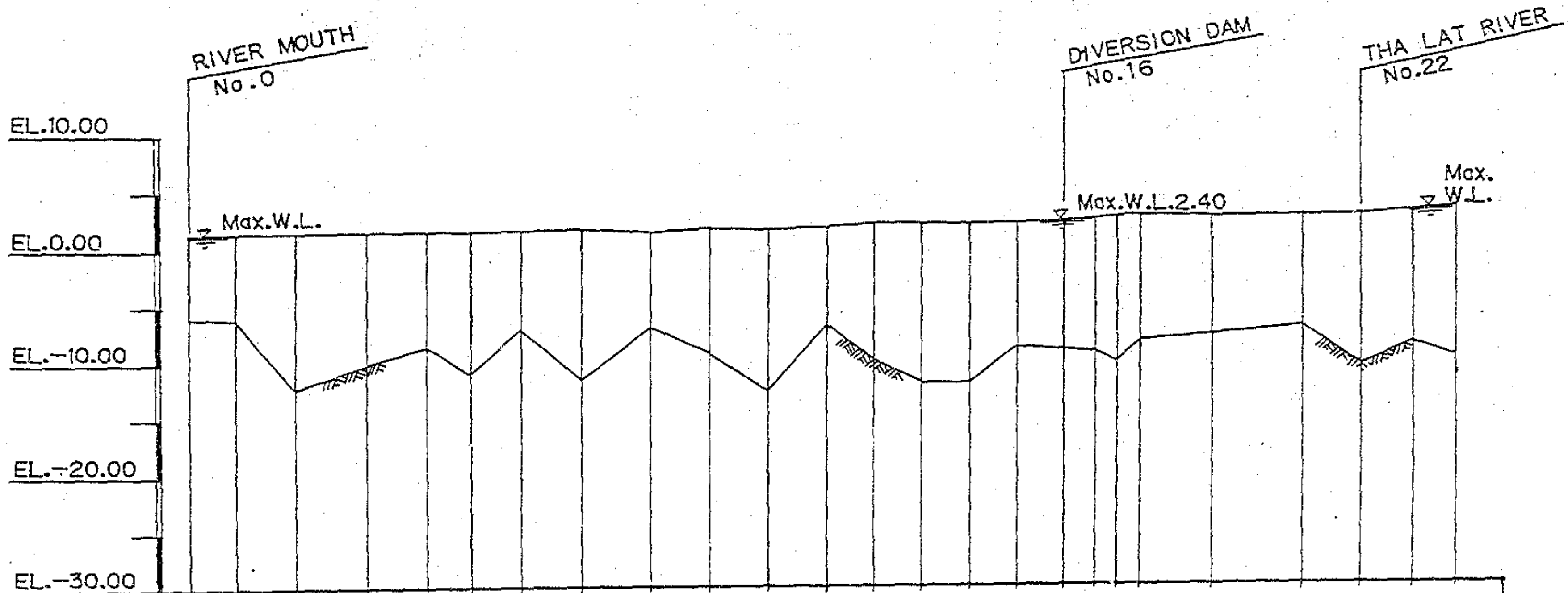
The flood analysis has revealed that the design flood discharge by 50-year probability is Q = 1,600 m^3/s.

2) Design Flood Depth

The flood analysis has found that the maximum water level at the diversion dam site is Max. WL. 2.40 meters, while the design river bed elevation is EL (-) 8.20 meters. Consequently, the design flood depth is H = 10.60 meters.

FIGURE 4-1 PLAN OF DIVERSION CANAL

FIGURE 4-2 PROFILE OF BANG PAKONG RIVER



STATION	No.0	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	No.14	No.15	No.16	No.17	No.18	No.19	No.20	No.21	No.22	No.23	No.24
WATER LEVEL	1.48	1.48	1.48	1.49	1.51	1.57	1.63	1.70	1.70	1.74	1.78	1.84	2.03	2.10	2.16	2.27	2.36	2.46	2.55	2.60	2.65	2.78	2.90	2.98	3.09
RIVER BED ELEVATION	-6.20	-6.20	-12.40	-10.00	-8.70	-11.30	-7.10	-11.50	-6.70	-9.20	-12.60	-6.90	-9.70	-11.60	-11.90	-8.60	-8.80	-9.10	-10.00	-8.20	-7.60	-7.10	-10.60	-8.60	-10.10
ACCUM. DISTANCE (KM)	0	4	9	15	20	24	28	33	39	44	49	54	58	62	66	70	74	77	79	81	87	95	100	104	108

3) Profile Slope

a) River Bed Slope

The average slope of the river bed for a distance of about 10 kilometers around the diversion dam is I_0 = 1/4,000. The portion (L = 5.77 km) between Sta. 2 + 230 and Sta. 8 + 000 will be short-cut for construction of the diversion dam, and the river alignment will be shortened by 3.52 kilometers for constructing the diversion canal (L_2 = 2.25 km). The river slope of I_0 = 1/4,000 cannot be changed because of the stability of the river bed. Under these conditions, the difference in river bed elevation, ΔH = 3520 m × 1/4,000 = approx. 0.9 meters, which will be caused by the construction of the diversion dam, should be treated with a drop structure to be provided at the diversion dam site.

b) Flood Surface Slope

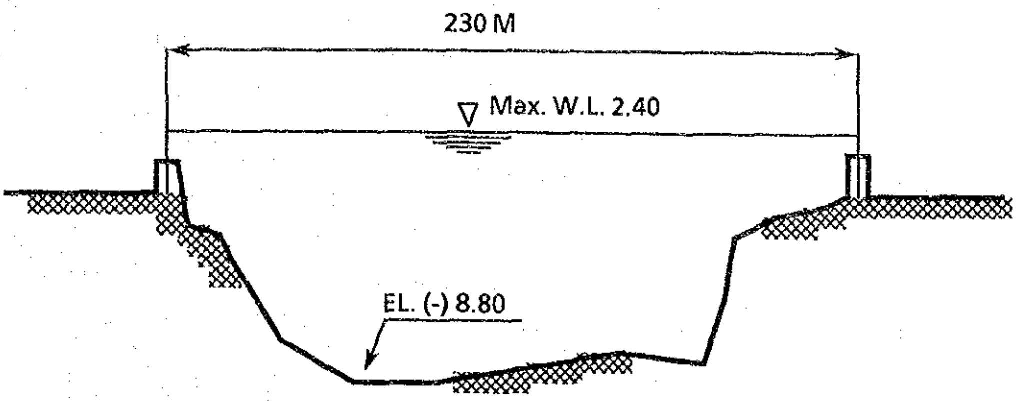
As a result of the flood analysis, the water surface slope of the design flood discharge by Q = 1,600 m^3/s can be shown in Figure 4-2. The flood slope around the diversion dam (No. 15 to No. 18; L = 9.0 km) can be estimated as I = (2.55 - 2.27)/9,000 ≒ 1/32,000.

4. 2. 2 Cross Section of River

1) Existing River Section

The existing river section around the diversion dam is as shown in Figure 4-3.

FIGURE 4-3 EXISTING CROSS SECTION OF RIVER (AT DIVERSION DAM SITE)



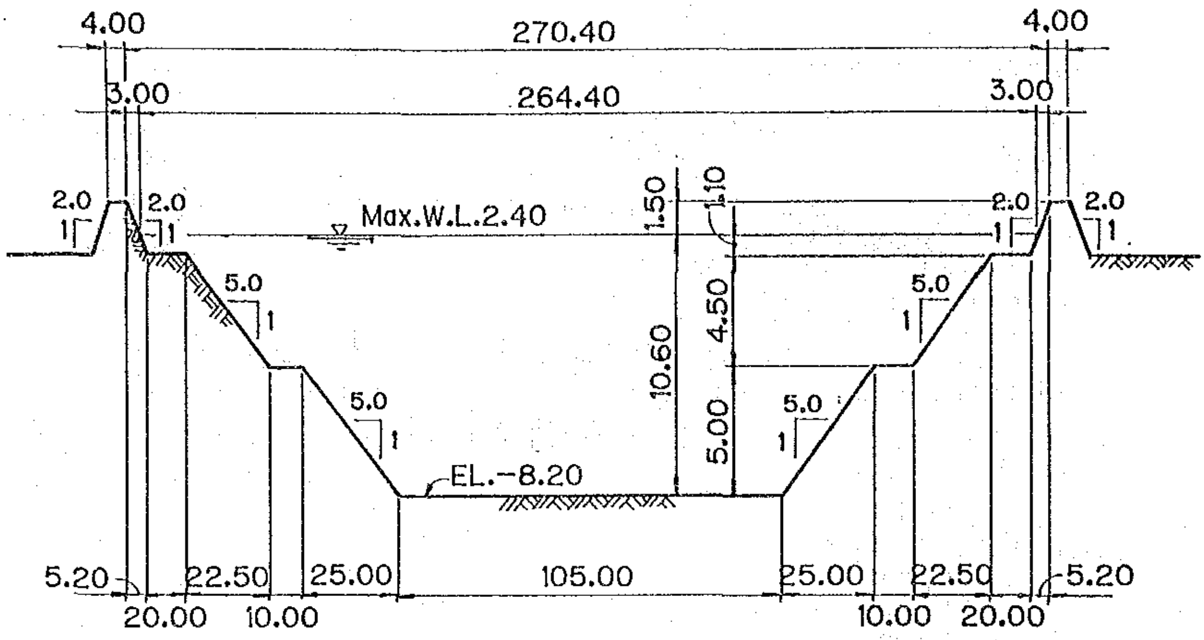
Flow area	; A	=	1,750 m^2
Wetted perimeter	; P	=	233 m
Hydraulic radius	; R	=	7.511 m
Roughness coefficient	; n	=	0.023
Hydraulic grade	; I	=	1/32,000
Flow velocity	; V	=	$1/0.023 \times 7.511^{2/3} \times (1/32,000)^{1/2}$
		=	0.93 m/s
Discharge	; Q	=	$1,750 \times 0.93 = 1,6281 m^3/s \doteqdot 1,600 m^3/s$

2) Design River Section

Around the diversion dam, the river can be found with about 230 m in water surface width, 1,750 m^2 in its cross sectional area, and H = 10.60 m in design flood depth. In other respect, as a result of the stability analysis of the excavated slope, the slope will be 1 : 5.0 with 10 m wide berms at every 5.0 m excavation height.

The design cross-section of the river is illustrated in Figure 4-4 so that Q = 1,600 m^3/s of the design flood discharge can flow down smoothly on conditions of H = 10.60 m of the design flood depth, 1 : 5.0 of the excavated slope and 1 : 32,000 of hydraulic grade, in taking into account the existing river section.

FIGURE 4-4 TYPICAL SECTION OF DIVERSION CANAL



4.2.3 Hydraulic Calculation

Flow area : $A = 1/2(105.0+155.0)\times5.0+1/2(175.0+220.0)$
$\times4.5+1/2(260.0+264.4)\times1.1$
$= 1{,}827.17\,m^2 > 1{,}750\,m^2$

Wetted perimeter : $P = 105.0+(25.5+10.0+22.95+20.0+2.46)\times2$
$= 266.82\,m$

Hydraulic radius : $R = 1827.17/266.82 = 6.848\,m$

Roughness coefficient : $n = 0.023$

Hydraulic grade : $I = 1/32{,}000$

Flow velocity : $V = 1/0.023\times6.848^{2/3}\times(1/32{,}000)^{1/2} = 0.88m/s$

Discharge : $Q = 1{,}827.17\times0.88 = 1{,}608m^3/s > 1{,}600m^3/s$

4.3 Slope Protection Works

4.3.1 Excavated Slope

The excavation for the diversion canal will be made at the layer found at EL(-) 9.0 m to EL 1.5m which are geologically specified as soft clay layers with N-value of 1 to 2 and cohesion of 0.1 to 0.5 kgf/cm^2.

As a result of the excavated slope stability analysis, the excavated slope will be 1 : 5.0 and the 10 m wide berms will be provided at every 5 m height in excavation so as to ensure necessary safety factors. (Refer to Figure 4-6 to -11)

4.3.2 Embankment Slope

The embankment height of dike to be constructed along the diversion canal is as low as about 2.0 m, and the embankment is affected by river flow only in flooding. The embankment slope will be 1:2.0 with sodding cover as slope protection considering the flow velocity is as low as 1.0 m/s or below.

TABLE 4-1 DECREASED COHESION DUE TO EXCAVATION AT DIVERSION CANAL

Depth (m)	Density (t/m^2)		Su' *3 (tf/m^2)	σvm *4 (tf/m^2)	Excavation Depth																			
					2.0 m				4.0 m				6.0 m				8.0 m				10.0 m			
	γt *1	γsat *2			σn *5	μA *6	μB *7	Su *8	σn	μA	μB	Su	σn	μA	μB	Su	σn	μA	μB	Su	σn	μA	μB	Su
0 ~ 2.0	1.74	1.98	2.00	0.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.0 ~ 4.0	1.47	1.48	2.00	2.44	0.48	0.61	0.80	(8) 0.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.0 ~ 6.0	1.47	1.49	2.00	3.41	1.45	0.77	0.80	(9) 1.23	0.49	0.56	0.80	(10) 0.90	-	-	-	-	-	-	-	-	-	-	-	-
6.0 ~ 8.0	1.47	1.53	2.00	4.43	-	-	-	-	1.51	0.72	0.80	(11) 1.15	0.53	0.53	0.80	(14) 0.85	-	-	-	-	-	-	-	-
8.0 ~ 10.0	1.75	1.82	6.50	5.78	-	-	-	-	2.86	0.81	0.80	(12) 4.21	1.88	0.71	0.80	(15) 3.69	0.82	0.56	0.80	(18) 2.91	-	-	-	-
10.0 ~ 12.0	1.75	1.88	6.50	7.48	-	-	-	-	4.56	0.86	0.80	(13) 4.47	3.58	0.80	0.80	(16) 4.16	2.52	0.72	0.80	(19) 3.74	0.88	0.53	0.80	(21)(23) 2.76
12.0 ~ 14.0	2.05	2.05	21.70	9.41	-	-	-	-	-	-	-	-	5.51	0.85	1.00	(17) 18.45	4.45	0.80	1.00	(20) 17.36	2.81	0.70	1.00	(22)(24) 15.19
14.0 ~ 16.0	2.05	2.05	21.70	11.51	-	-	-	-	-	-	-	-	7.61	0.88	1.00	19.10	6.55	0.84	1.00	18.23	4.91	0.77	1.00	16.71
16.0 ~ 18.0	2.05	2.05	21.70	13.61	-	-	-	-	-	-	-	-	9.71	0.90	1.00	19.50	8.65	0.87	1.00	18.88	7.01	0.82	1.00	17.79
18.0 ~ 20.0	2.05	2.05	21.70	15.71	-	-	-	-	-	-	-	-	-	-	-	-	10.75	0.89	1.00	19.31	9.11	0.85	1.00	18.45

Notes ; *1 wet density *2 saturated density *3 initial cohesion *4 preconsolidation pressure *5 effective normal stress after excavation (tf/m^2)
*6 Coefficient of cohesion decrease ($=OCR^{-\alpha}$ $\alpha=0.3$) *7 Aas's correction factor *8 Cohesion for design (decreased cohesion) (tf/m^2)
○ mark of Su row corresponds element figure into FIGURE 4-5

FIGURE 4-5 CALCULATION MODEL FOR STABILITY ANALYSIS

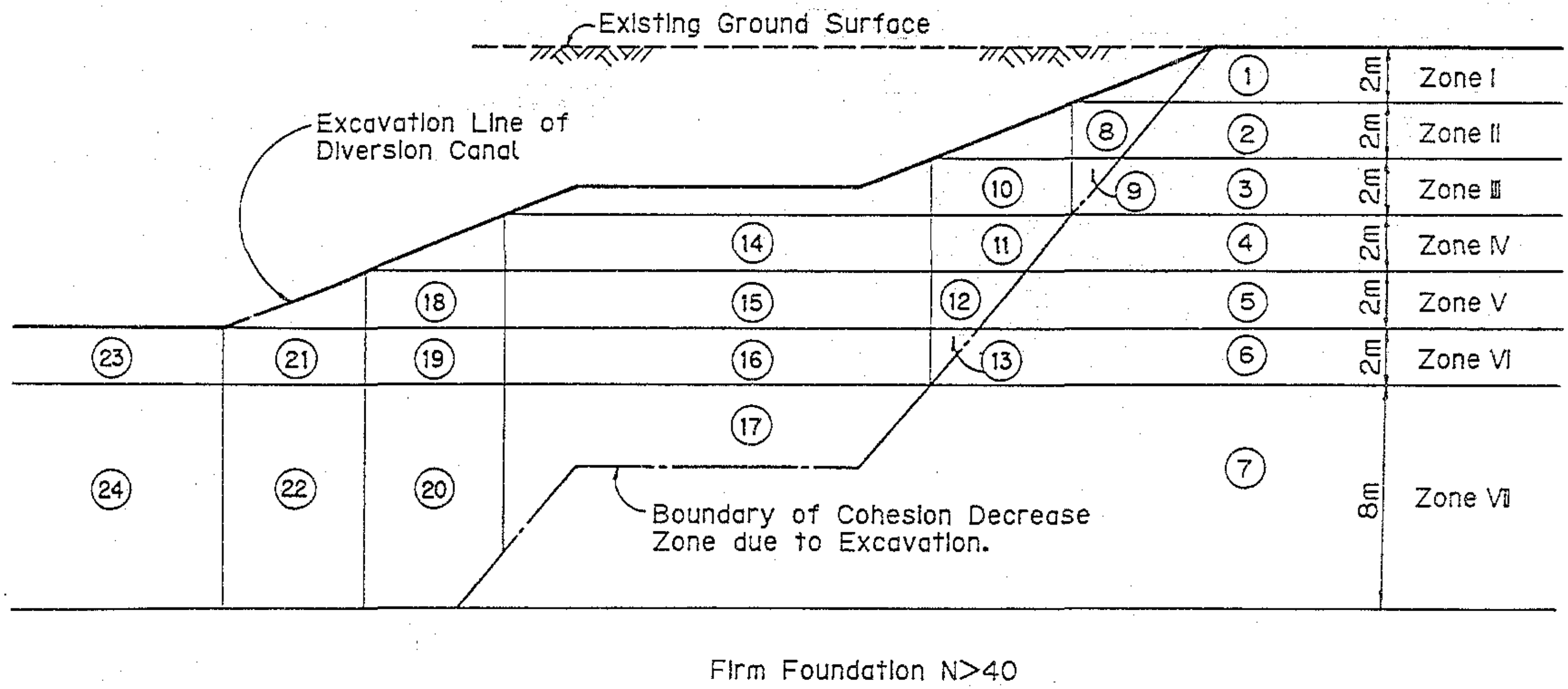


FIGURE 4 - 6 RESULT OF STABILITY ANALYSIS (CASE 1)

Slope ; 1 vertical to 4.0 horizontal
Water level ; H.H.W.L.
Min. Factor of safety FS = 1.738

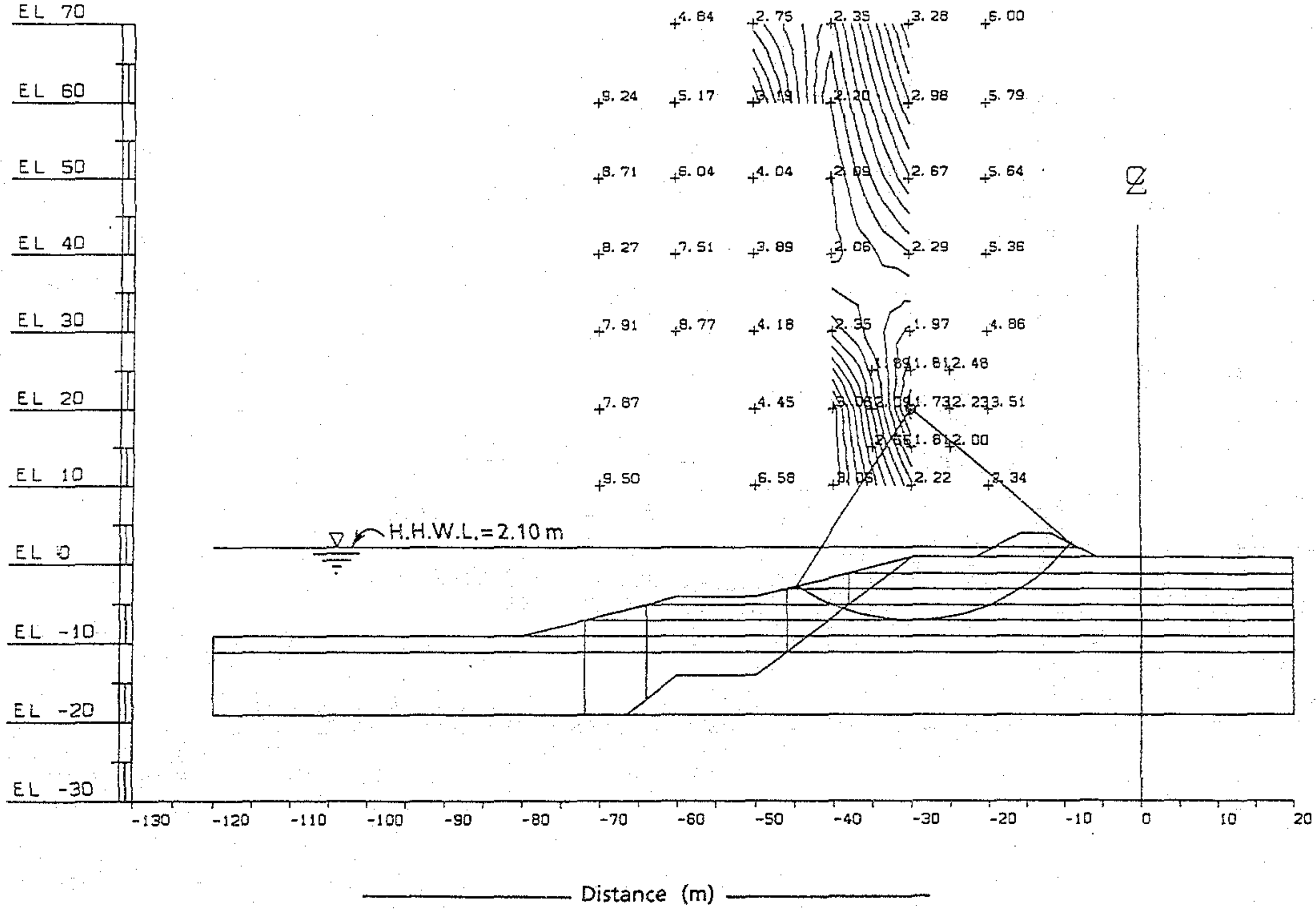


FIGURE 4-7 RESULTS OF STABILITY ANALYSIS (CASE 2)

Slope ; 1 vertical to 4.0 horizontal
Water level ; L.L.W.L.
Min. Factor of safety FS = 1.174

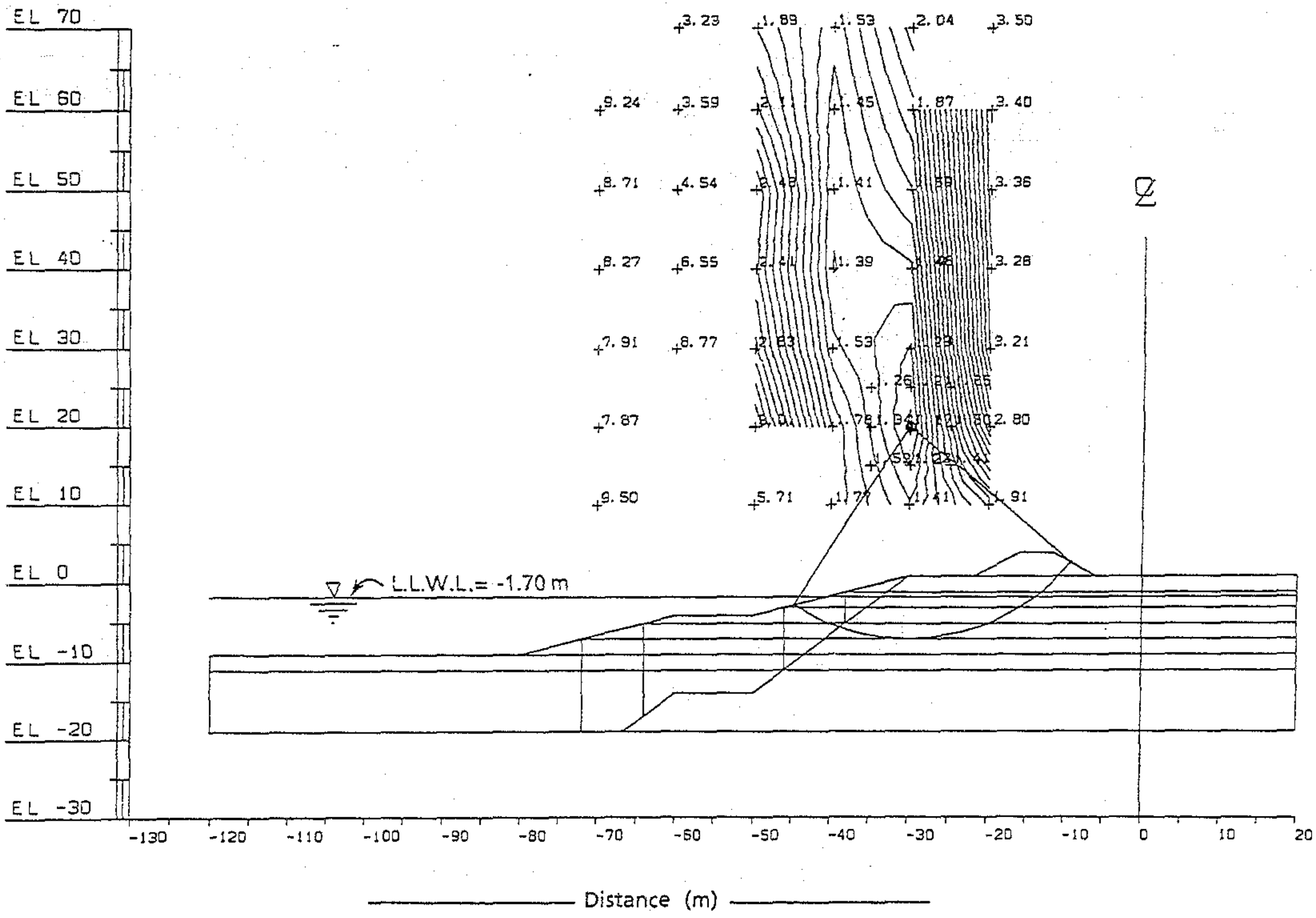


FIGURE 4-8 RESULTS OF STABILITY ANALYSIS (CASE 3)

Slope ; 1 vertical to 4.0 horizontal
Water level ; H.H.W.L.to L.L.W.L.
Min. Factor of safety FS = 1.080

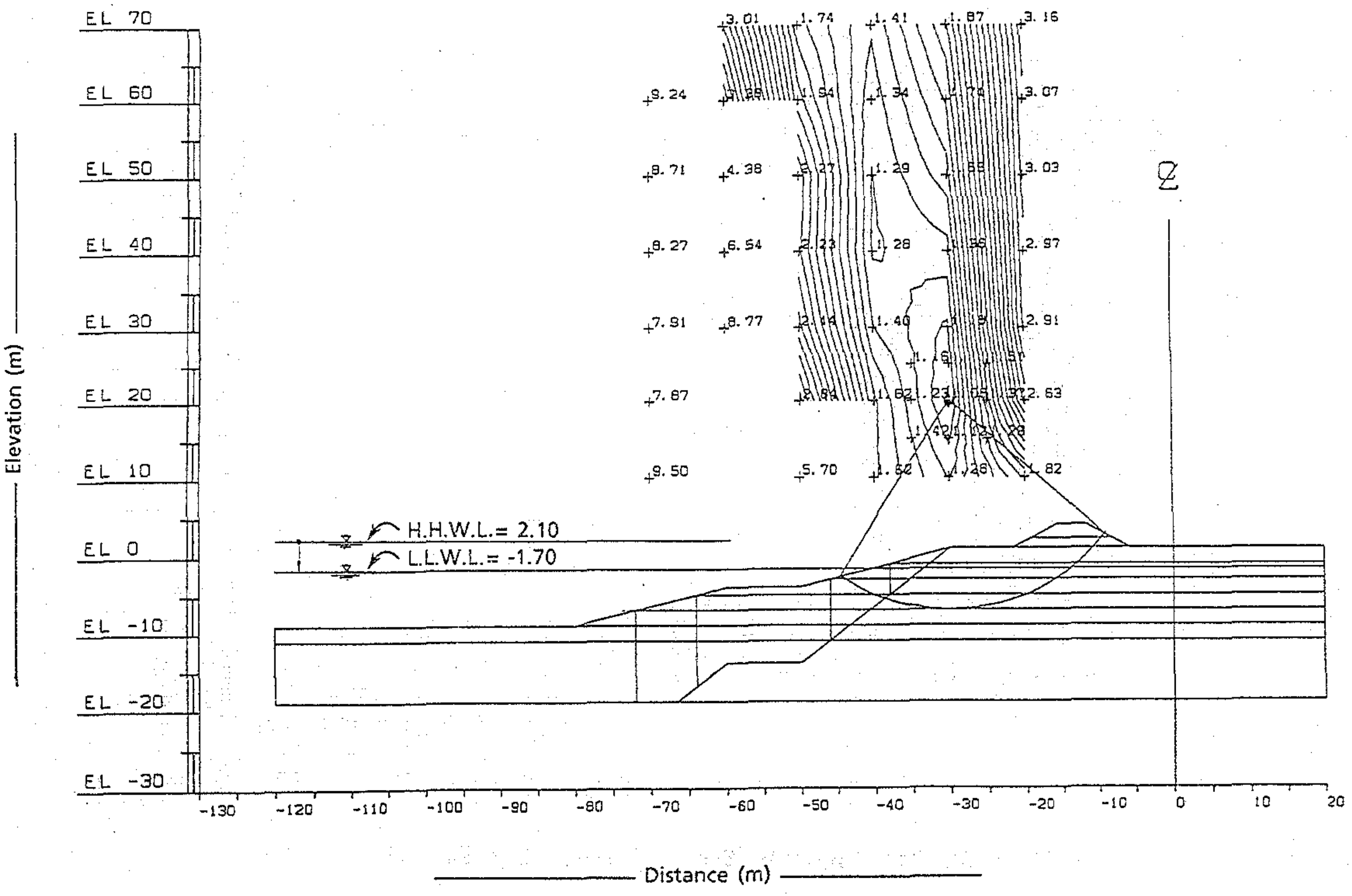


FIGURE 4-9 RESULTS OF STABILITY ANALYSIS (CASE 1)

Slope ; 1 vertical to 5.0 horizontal
Water level ; H.H.W.L.
Min. Factor of safety FS = 1.880

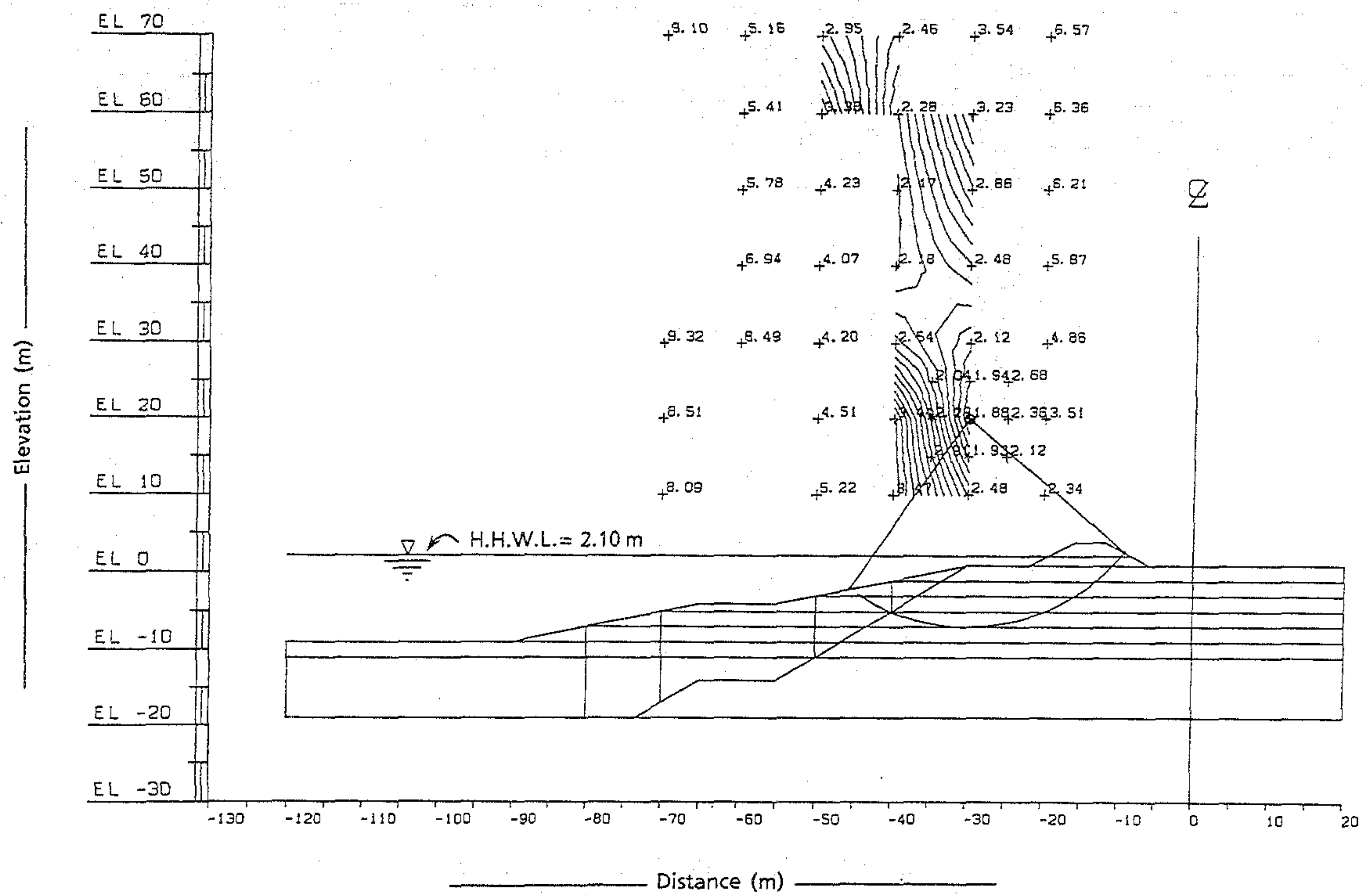


FIGURE 4-10 RESULT OF STABILITY ANALYSIS (CASE 2)

Slope ; 1 vertical to 5.0 horizontal
Water level ; L.L.W.L.
Min. Factor of safety FS = 1.278

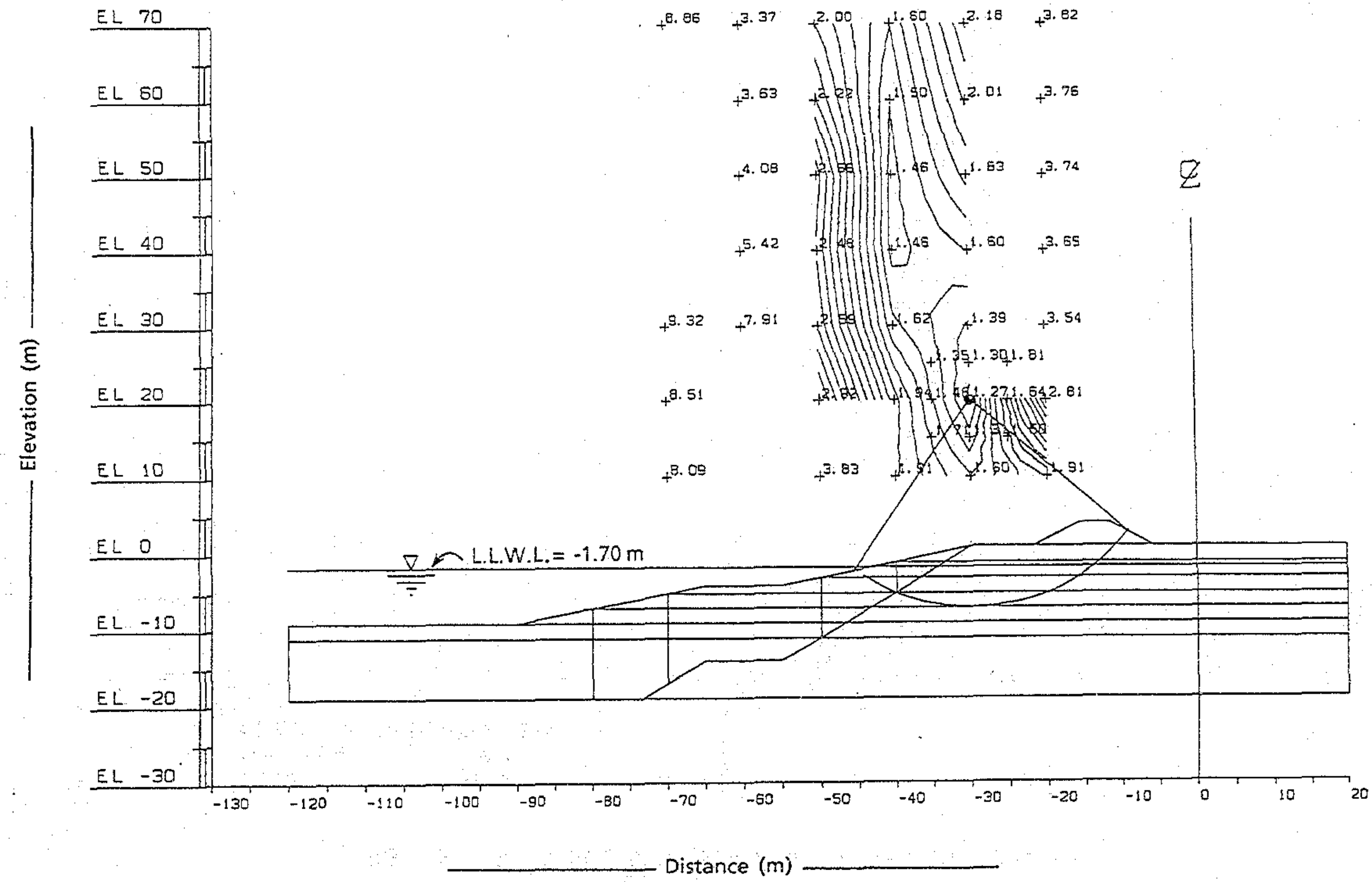
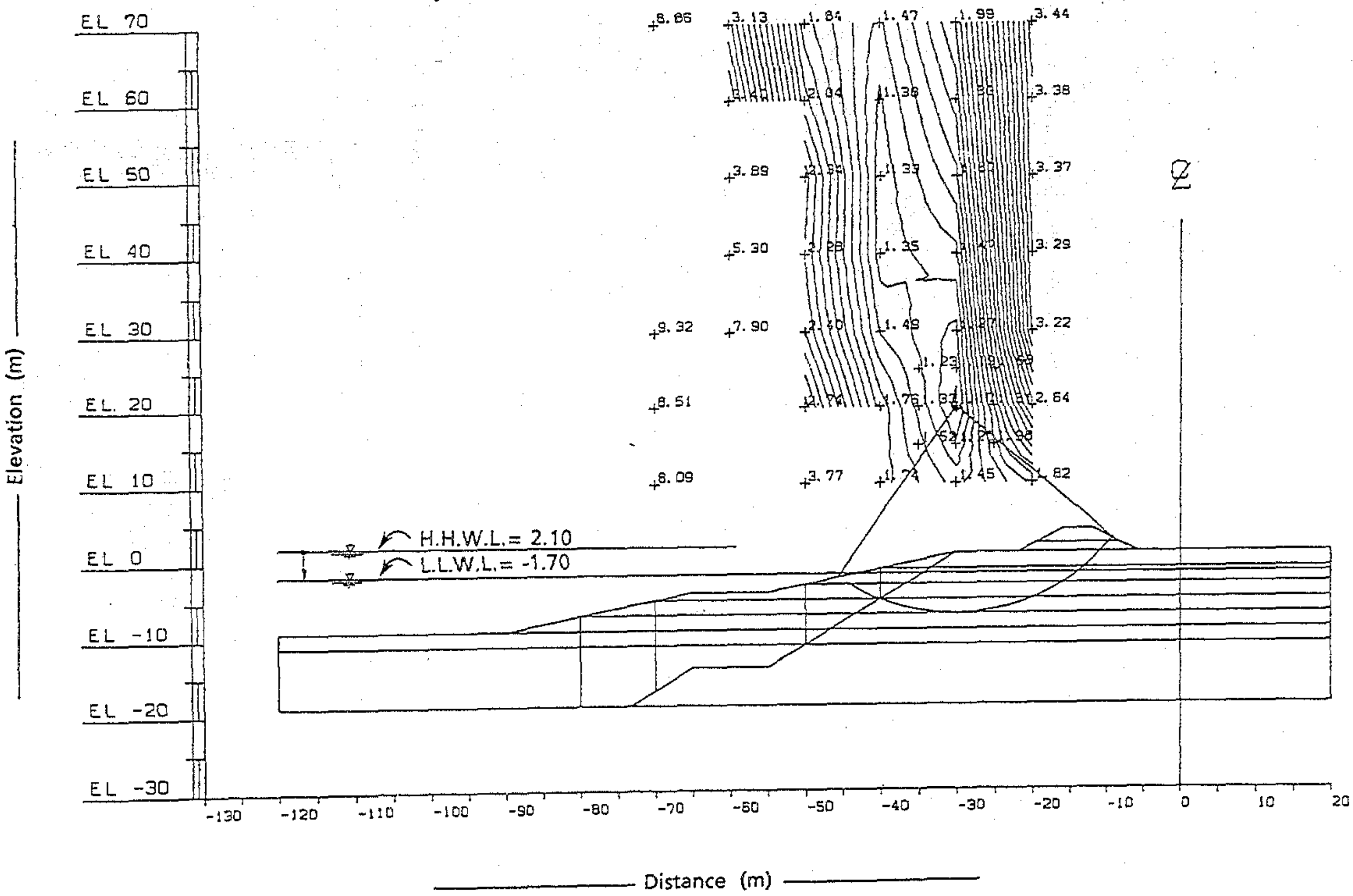


FIGURE 4-11 RESULTS OF STABILITY ANALYSIS (CASE 3)

Slope ; 1 vertical to 5.0 horizontal
Water level ; H.H.W.L.to L.L.W.L.
Min. Factor of safety FS = 1.175



4.3.3 Design of Slope Protection Works

1) Allowable Velocity

a) Unlined Canal

The allowable velocity to erosion and scouring of natural river sides and dikes is different by a variety of soil features and compactness. According to the results of experiments and field studies conducted by E.W. Lane, different allowable velocities in various conditions can be shown in the tables as Table 4-3 to -7 while the constants of the presents foundation soils in Table 4-2.

TABLE 4-2 SOIL CONSTANTS

Position	Depth	Soil	Graing Size mm	Void ratio	Cohesion t/m^2	Water Depth m	Curve
	Dike	Light Clay	0.05	0.5	0.8	0.3	Large
Up-S.	0 to 2m	〃	〃	1.0	〃	1.0	〃
	2 to 5m	〃	〃	1.1	0.7	3.0	〃
	5 to 10m	Heavy clay	0.01	0.8	2.3	6.0	〃
	Dike	Light Clay	0.05	0.5	0.8	0.3	Straight
Middle	0 to 2m	〃	〃	1.0	〃	1.0	〃
	2 to 5m	〃	〃	1.1	0.7	3.0	〃
	5 to 10m	Heavy clay	0.01	0.8	2.3	6.0	〃
	Dike	Light Clay	0.05	0.5	0.8	0.3	Large
Down-S.	0 to 2m	〃	0.01	1.0	〃	1.0	〃
	2 to 5m	〃	〃	1.1	0.7	3.0	〃
	5 to 10m	Heavy clay	0.05	0.8	2.3	6.0	〃

TABLE 4-3 ALLOWABLE VELOCITIES OF LESS COHESIVE SOILS

Materials	Size mm	Velocity m/s
	0.005	0.15
Silt	0.05	0.20
Fine Sand	0.25	0.30
Sand	1.00	0.55
Coarse Sand	2.50	0.65
Small Gravel	5.00	0.80
Gravel	10.00	1.00
Coarse Gravel	15.0	1.20
Small Cobble	25.0	1.50
Cobble	40.0	1.80
Coarse Cobble	75.0	2.40
Boulder	100.0	2.70
〃	150.0	3.30
〃	200.0	3.90

TABLE 4-4 ALLOWABLE VELOCITIES OF CLAYEY SOILS (M/S)

Compactness of riverbed	loose	a little hard	ordinary	hard
Void Ratio	2.0 ~ 1.2	1.2 ~ 0.6	0.6 ~ 0.3	0.3 ~ 0.2
Sandy Clay (Sand 50%)	0.45	0.90	1.30	1.80
Heavy Clay	0.40	0.85	1.25	1.70
Clay	0.35	0.80	1.20	1.65
Light Clay	0.32	0.70	1.05	1.35

TABLE 4-5 REVISION OF ALLOWABLE VELOCITIES AT CURVES TIES

Curve	Revised Coeff.
Straight	1.00
Small	0.95
Middle	0.81
Large	0.78

TABLE 4-6 REVISION OF ALLOWABLE VELOCITIES TO WATER DEPTH (CLAYEY MATERIALS)

Average Water Depth	Revised Coeff.
0.3	0.8
0.5	0.9
0.75	0.95
1.0	1.0
1.5	1.1
2.0	1.1
2.5	1.2
3.0	1.3

TABLE 4-7 REVISION OF ALLOWABLE VELOCITIES TO WATER DEPTH (LESS COHESIVE MATERIALS)

Average Water Depth	Revised Coeff.
0.3	0.8
0.6	0.9
1.0	1.00
1.5	1.10
2.0	1.15
2.5	1.20
3.0	1.25

The allowable velocities at the respective points are shown in Table 4 - 8.

TABLE 4 - 8 LANE'S ALLOWABLE VELOCITIES

Oberv. Point	Depth	Average Allow. Velocity	Revised Coeff by Water Depth	Revised Coeff by Curve	Allow. Velocity
		m/s			m/s
Up-Stre.	Dike	1.05	0.8	0.95	0.80
	0 to 2m	0.70	1.0	〃	0.67
	2 to 5m	0.70	1.2	〃	0.80
	5 to 10m	0.85	1.2	〃	0.97
		m/s			m/s
Middle	Dike	1.05	0.8	1.00	0.84
	0 to 2m	0.70	1.0	〃	0.70
	2 to 5m	0.70	1.2	〃	0.84
	5 to 10m	0.85	1.2	〃	1.02
		m/s			m/s
Down-Stre.	Dike	1.05	0.8	0.95	0.80
	0 to 2m	0.70	1.0	〃	0.67
	2 to 5m	0.70	1.2	〃	0.80
	5 to 10m	0.85	1.2	〃	0.97

b) Sodding works

Sodding works will be executed for the gentle stream parts over the normal water level, and the relevant allowable velocity will be in a range 1.0 to 2.5 m/s.

c) Riprap works

The allowable velocity for riprap works can be obtained by Isbash's equation as,

$$Vmin = E_1 \cdot N \cdot \sqrt{D}$$

Where, Vmin : Allowable velocity (m/s)

E_1 : Coefficient 0.86

N : $N = \sqrt{2g \frac{r_1 - r}{r}} = \sqrt{2 \times 9.8 \ \frac{2.65-1}{1}} = 5.69$

D : 0.3m of diameter of riprap materials

$$Vmin = 0.86 \times 5.69 \times \sqrt{0.3} = 2.68 \text{ m/s}$$

APPENDIX - 5 : DESIGN OF DIVERSION DAM

APPENDIX - 5. DESIGN OF DIVERSION DAM

LIST OF CONTENTS

5.1 Location of the Diversion Dam

The location of the proposed diversion dam was selected, in the Feasibility Study, at a site about 71 kilometers upstream from the Bang Pakong river estuary. The location of the diversion dam is proposed at the point of Sta. 1 + 534.13 of the diversion canal for the following reasons.

1) The diversion dam will probably be located upstream of the diversion canal so as to lessen the effect of the overflow at the gates to the Bang Pakong river downstream from the diversion dam.

2) About 150 meters in the length of the diversion canal upstream from the diversion dam will be constructed in a straight line to smooth the plane figure of the transition portion of the canal.

5.2 Elevation of Gate Sill and Other Major Parts of the Structures

5.2.1 Gate Sill Elevation

The gate sill elevation is designed to ensure the smooth rundown of flood discharge. The gate sill elevation will be EL (-) 8.20 meters considering that the elevation of the diversion canal is EL (-) 8.18 meters at the diversion dam site.

5.2.2 Crest Elevation of the Gate

1) Crest Elevation of the Gate

The crest elevation of the gate is designed according to the high water level (H.W.L.) in the sea and wave height.

High Water Level : H.W.L 1.30 m

Wave Height : By S.M.B. method
(Sverdrup - Munk - Bretschneidr)

$Hw = 0.00086 \cdot V^{1.1} \cdot F^{0.95}$

where, Hw : Wave height (m)
V : Wind velocity 30m/s (Max. 55 knots)
F : Fetch 340 m (double the length of the diversion dam)

$Hw = 0.00086 \times 30^{1.1} \times 340^{0.45} = 0.50 \text{ m}$

The crest elevation of the gate can be obtained as follow:

H.W.L 1.30 m + 0.50 m = EL 1.80 m

2) Crest Elevation of the Lower Gate Leaf

The river maintenance discharge shall be released by operation of the upper gate leaves of the regulating gates, while a large scale operation shall be made restrictively only twice or thrice for a transitional period from the dry season to the wet. And the upper gate leaves shall be operated for the purpose so as to keep the river maintenance discharge, when the river runoff is less than 300 m^3/s.

a) Discharge for River Maintenance

The river maintenance discharge shall be carried out every day for two hours with discharge of 29.88 m^3/s through upper gate leaf operation, in the case that the stored water level is over EL. (-)0.15 m and the downstream water level is below EL. (-)0.25 m.

For securing the above discharge of 29.88 m^3/s with the water level difference between up-and-downstream by 0.1 m and discharging width by 28.3 m × 2 units, the overflow depth at upstream is to be 0.48 m. Under such conditions, the crest elevation of the lower gate leaf must be not higher than EL. (-)0.63 m based on the stored water level by EL. (-)0.15 m.

b) Minor Flood Discharge

When the gates for minor flood discharge is operated in case of river discharge by below 300 m^3/s, the river water shall be released through the upper gate leaves of the regulating gates not to exceed the limited reservoir water level of EL. 1.30 m.

For discharging 300 m^3/s in conditions of EL. 1.30 m of the upstream water level, EL. 1.04 m at downstream water level and discharge width of 28.3 m × 2 units, the overflow depth is required to be 2.60 m at upstream and the crest elevation of the lower gates is designed at EL. (-)1.30 m. For further references, two units of regulating gate leaves are required for effective release of 300 m^3/s of water.

5.2.3 Pier Height

The crest elevation of the piers will be determined according to the following equation.

Crest Elevation = Maximum water level + Freeboard ① + Gate height + Freeboard ② + Crest thickness

where, Maximum water level : Max. W.L. 2.40 m

Freeboard ①	:	Distance between maximum water level and bottom of gate sill hoisted up (1.50 m)
Gate Height	:	EL 1.80 - EL (-) 8.20 = 10.00m
Freeboard ②	:	Distance between gate crest and bottom of crest slab, when the gate includes such structures, as spoiler, sieve, stopping hook, etc. and freeboard of hoist is 2.00 m.
Crest thickness	:	1.50 m

Pier crest elevation = Max. W.L. 2.40 + 1.50 + 10.00 + 2.00 + 1.50
= EL 17.40 m

5.2.4 Crest Elevation of Retaining Wall

Retaining Wall works shall be provided for protecting the embankment at the portion contacting at the normal water level, while sodding works for the flood water level.

1) Upstream Retaining Wall

The crest elevation of the upstream retaining wall is designed at EL. 1.80 m including reservoir limited water level of EL. 1.30 m and freeboard of 0.5 m against wind and waves.

2) Downstream Retaining Wall

The crest elevation of the downstream retaining wall is designed at EL. 1.80 m including maximum downstream discharged water level of EL. 1.28 m and freeboard of 0.5 m.

5.3 Determination of the Gate Span

5.3.1 Cross Section for Flood Discharge

The mean cross-sectional area of the Bang Pakong river is A. = 1,750 m^2, and the total length of the diversion dam is required to be more than 165 meters so that the cross-sectional area of the river can be secured at more than 1,750 m^2 at the point of the diversion dam site.

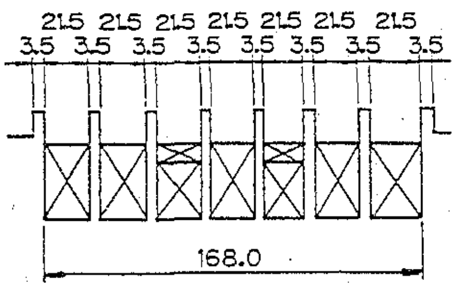
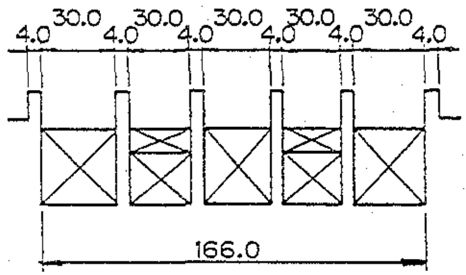
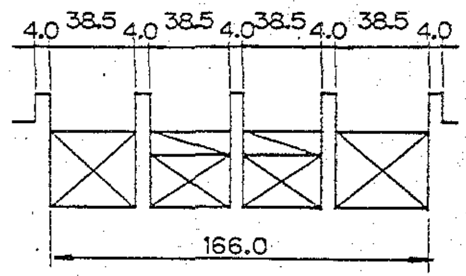
Total Dam Length = Cross-Sectional Area/Water Depth
= 1,750/10.60 = 165 m

5.3.2 Determination of Gate Span

The gate span length will be determined taking into consideration the magnitude of the design flood discharge, the gate manufacturing technique, and economic factors.

In general, the span length of a diversion dam for a river with a design flood discharge of 1,600 m^3/s is more than 20 meters. As a result of an alternative study on three different span lengths of 20, 30, and 40 meters respectively, the span of 30 meters with 5 gates is recommended in view of the manufacturing technique and economic factors as shown in Table 5-1 on Comparison of Gate Span.

TABLE 5 - 1 COMPARISON OF GATE SPAN

Item	Case-A : 20 m scheme	Case-B : 30 m scheme	Case-C : 40 m scheme
Rough Sketch			
Gate Dimensions	Flood Gate : 21.5 m × 10 m ×5 sets Regulating G. : 21.5 m × 10 m × 2 sets	F. G. ; 30.0 m × 10 m × 3 sets R. G. ; 30.0 m × 10 m × 2 sets	F. G. ; 38.5 m × 10 m × 2 sets R. G. ; 38.5 m × 10 m × 2 sets
Stability	Span ratio to leaf height : 1/2.2 > 1/15, stable in structure.	Span ratio to leaf height: 1/3 > 1/15, stable in structure	Span ratio to leaf height: 1/3.9 > 1/15, stable in structure
Operation and Maintenance	Easier in O and M works with hoisting motor capacity of 30 kw per one gate	Normal O and M works with hoisting motor capacity of 44 kw per one gate	More disadvantageous in O and M works with hoisting motor capacity of 60 kw per one gate.
Economically	Flood Gate : 464.0 M.฿ Regulating G. : 220.0 M.฿ Pier : 57.3 M.฿ Total : 741.5 M.฿	Flood Gate : 365.4 M.฿ Regulating G. : 312.0 M.฿ Pier : 46.1 M.฿ Total : 723.5 M.฿	Flood Gate : 390.0 M.฿ Regulating G. : 488.6 M.฿ Pier : 38.4 M.฿ Total : 917.0 M.฿
Overall Appraisal	○	◎	△

5.4 Piers

The structure of the piers should not in any way obstruct gate operation. They should be stable, and if possible reduce problems with the flow of flood discharge.

5.4.1 Pier Length

The length of the upper part of the pier is designed to be 9.0 meters in the direction of the thalweg allowing for space for gate installation and the stability of the piers. The lower part of the piers will have a round shape at both ends of the upper and downstream sides. The total length will be 19.0 meters including the upper length and the length reserved for the construction of the O/M bridge.

5.4.2 Pier Thickness

The pier thickness will be calculated by the following empirical equation with the pier height and gate span length as parameters, which was derived from the data of piers constructed in Japan.

$$t_p = 0.12\,(D_p + 0.2\,B_i) \pm 0.25$$

where, t_p : Pier thickness (m)

D_p : Pier height (EL 16.90 - EL (-) 9.10 = 26.00 m)

B_i : Span length of gate (30.0 m)

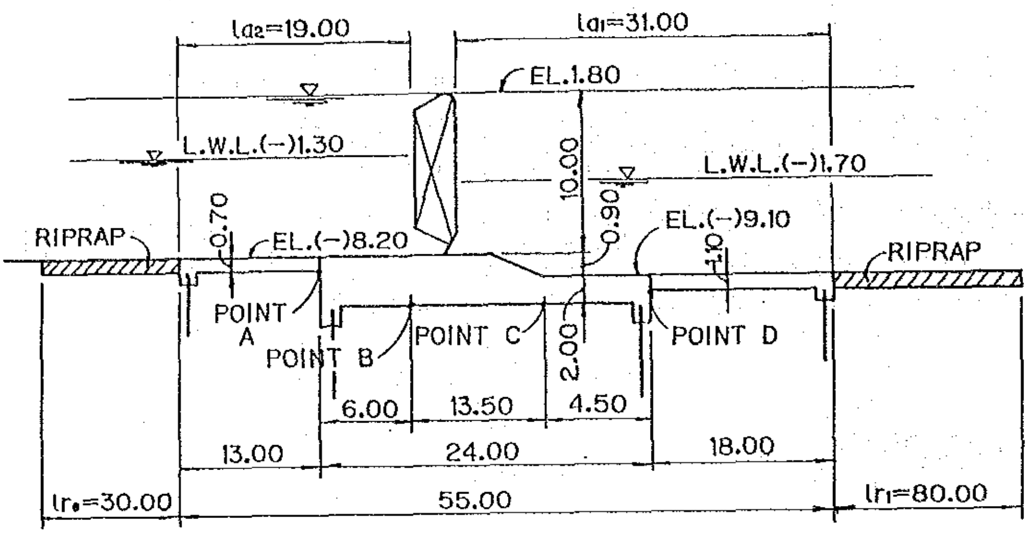
$$t_p = 0.12\,(26.50 + 0.2 \times 30.0) \pm 0.25$$
$$= 3.65 \text{ to } 4.10 \text{ m}$$

The pier thickness is determined to be 4.0 meters taking into account the guide rail depth of the gate leaf and pier stability.

5. 5 Apron and Riprap

The apron and riprap is structured to protect the river bed both upstream and downstream of the gates from scouring.

(Upstream) (Downstream)



5. 5. 1 Downstream

1) Apron Length

The apron length can be obtained by the following equation.

$$l_{a1} = 0.9\,C\sqrt{D_1}$$

where, l_{a1} : Length of downstream apron (m)

C : Bligh's coefficient 18 (fine particle sand or sedimentary sand)

D_1 : Height from lowest low water level to gate crest (EL. 1.80 - L.L.W.L. (-) 1.70 = 3.50 m)

$$l_{a1} = 0.9 \times 18 \times \sqrt{3.50} = 30.3\text{ m} < 31.0\text{ m}$$

2) Creep Length

Sufficient length of creep must be secured in the foundation and back surface of the retaining wall so that the occurrence of piping caused by the creeping that results from the water level differences upstream of the gate and downstream of the gate can be prevented. The minimum creep length to be ensured should be taken as the larger value of the two methods which can be obtained by the following equations respectively.

a) Bligh's Method :

$L_{B1} \geqq C \cdot \triangle H_1$

where, L_{B1} : Creep length measured along the foundation bottom (m)

C : Bligh's coefficient (18)

$\triangle H_1$: Water level differences upstream of the gate and downstream of the gate (E.L. 1.80 - L.L.W.L (-) 1.70 = 3.50 m)

Therefore; $L_{B1} \geqq 18 \times 3.50 = 63.0$ m

At the end of the apron, 3.0 meter-long steel pile shall be driven for prevention of scouring and expansion of the foundation. And the design creep length is:

Design creep length L'_{B1} = $55.0 + 3.0 \times 2 \times 2 + 0.7 + 2.2 + 0.9 + 1.1$

= 71.9 m $> L_{B1} = 63.0$ m

b) Lane's Method

$L_{L1} \geqq C' \triangle H_1$

where, L_{L1} : Weighted creep length (m)

C' : Lane's coefficient 8.5 (fine particle sand or sedimentary sand)

$\triangle H_1$: Water level differences upstream and downstream (3.50 m)

Therefore : $L_{L1} \geqq 8.5 \times 3.50 = 29.8$ m

Design creep length $L'_{L1} = 1/3 \times 55.0 + 3.0 \times 2 \times 2 + 0.7 + 2.2 + 0.9 + 1.1$

$= 35.2 \text{ m} > L_{L1} = 29.8 \text{ m}$

3) Apron Thickness

The apron thickness can be obtained from the following equation with a minimum thickness of 0.50 m.

$$t_1 \geqq \frac{4}{3} \times \frac{\Delta H_1 - H_{f1}}{\gamma - 1}$$

where,

t_1	:	Apron thickness (m)
ΔH_1	:	Water level difference between up and downstream (3.50 m)
H_f	:	Head loss of water percolation up to the check point (m)
γ	:	Specific weight of apron (2.2)

a) Point C

Creep length $l_c = 32.5 + 3.0 \times 2 + 0.7 + 2.2 = 41.4$ m

$$H_{fc} = \frac{lc}{L_1} \times \Delta H_1 = \frac{41.4}{71.9} \times 3.50 = 2.02 \text{ m}$$

$$t_c = \frac{4}{3} \times \frac{3.50 - 2.02}{2.2 - 1} = 1.64 \doteqdot 2.0 \text{ m}$$

b) Point D

Creep length $l_d = 37.0 + 3.0 \times 2 \times 2 + 0.7 + 2.2 + 0.9 = 52.8$ m

$$H_{fd} = \frac{52.8}{71.9} \times 3.50 = 2.57 \text{ m}$$

$$t_d = \frac{4}{3} \times \frac{3.50 - 2.57}{2.2 - 1} = 1.03 \text{ m} \doteqdot 1.1 \text{ m}$$

4) Riprap Length

The riprap will be provided at the places where there may be some fear of local river bed scouring to be caused by diversion dam construction, taking into account the conditions of the river bed and discharges found around the gate. And the riprap will be structured to withstand the river flow and to dissipate any discharge.

a) Bligh's Method;

$l_{r1} = L_{R1} - l_{a1}$

$L_{R1} = 0.67\, C \sqrt{\Delta H_1 \cdot q_1} \cdot f_1$

where,	l_{r1}	:	Riprap length (m)
	L_{R1}	:	Total length of protection structures including apron length (l_{a1}) and riprap length (l_{r1}). (m)
	C	:	Bligh's coefficient (18)
	ΔH_1	:	Height from the water level downstream to the gate crest. (EL 1.80 - L.L.W.L. (-) 1.70 = 3.50 m)
	q_1	:	Design flood discharge per unit width 1600/30 × 5 = 10.67 $m^3/s/m$
	f_1	:	Safety factor (1.5 for movable weir)

Therefore : $L_{R1} = 0.67 \times 18 \times \sqrt{3.50 \times 10.67} \times 1.5 = 110.5$ m

$l_{r1} = 110.5 - 31.0 = 79.5 \text{ m} \doteqdot 80 \text{ m}$

b) Hydraulic Analysis

In studying the flow velocity caused from gate operation, the released water through the upper gate leaves will reach the river bed at the point 430 m downstream of the gates and the velocity will be 1.04 m/s in maximum. Water released from the flood gates for minor floods and flushing operation will become the maximum velocity of 0.64 m/s at the downstream end of the ripraps, which are less than the allowable velocity of 1.0 m/s for the river bed to ensure that the riprap length of 80 m is sufficiently stable.

5. 5. 2 Upstream

1) Apron Length

The apron length can be obtained by the following equation.

$l_{a2} = 0.6\,C\sqrt{D_2}$

where, D_2 ; Height from Min. operating level of the reservior to gate crest.
EL 1.80 - Min. O.L (-) 1.30 = 3.10 m

$l_{a2} = 0.6 \times 18 \times \sqrt{3.10} = 19.0\,m$

2) Creep Length

a) Bligh's Method

$L_{B2} \geqq C \cdot \triangle H_2 = 18 \times 3.10 = 55.8\,m$

Design creep length $L'_{B2} = 55.0 + 3.0 \times 2 \times 2 + 1.1 + 0.9 + 2.2 + 0.7$

$= 71.9\,m > L_{B2} = 55.8\,m$

b) Lane's Method

$L_{L2} \geqq C' \cdot \triangle H_2 = 8.5 \times 3.10 = 26.4\,m$

Design creep length $L'_{L2} = 1/3 \times 55.0 + 3.0 \times 2 \times 2 + 1.1 + 0.9 + 2.2 + 0.7$

$= 35.2\,m > L_{L2} = 26.4\,m$

3) Apron Thickness

$$t_2 \geqq \frac{4}{3} \times \frac{\triangle H_2 - H_{f2}}{\gamma - 1}$$

a) Point A

Creep length $l_a = 42.0 + 3.0 \times 2 \times 2 + 1.1 + 0.9 + 2.2 = 58.2\,m$

$$H_{fa} = \frac{58.2}{71.9} \times 3.10 = 2.51\,m$$

$$t_a = \frac{4}{3} \times \frac{3.10 - 2.51}{2.2 - 1} = 0.66\,m \doteqdot 0.70\,m$$

b) Point B

Creep length $l_b = 36.0 + 3.0 \times 2 + 1.1 + 0.9 = 44.0\,m$

$$H_{fb} = \frac{44.0}{71.9} \times 3.10 = 1.90 \text{ m}$$

$$t_b = \frac{4}{3} \times \frac{3.10 - 1.90}{2.2 - 1} = 1.33 \text{ m} < 2.9 \text{ m}$$

4) Riprap Length

· Bligh's method :

$l_{r2} = L_{R2} - l_{a2}$

$L_{R2} = 0.67 \cdot C \sqrt{\Delta H_2 \cdot q_2} \cdot f_2$

where, C : Bligh's coefficient 18

ΔH_2 : EL 1.80 - Min O.L. (-) 1.30 = 3.10 m

q_2 : $CB\Delta H_2^{3/2} / L = 2.0 \times 30.0 \times 3.10^{3/2} / 166.0 = 1.97 \text{ m}^3/\text{s}/\text{m}$

f_2 : Safety factor, 1.5 in case of gate.

$L_{R2} = 0.67 \times 18 \times \sqrt{3.10 \times 1.97} \times 1.5 = 44.7 \text{ m}$

$l_{r2} = 44.7 - 19.0 = 25.7 \text{ m} \doteqdot 30.0 \text{ m}$

5. 6 Retaining Wall

5. 6. 1 Height of Retaining Wall

The foundation of the retaining wall will be on an elevation 2.0 meters below the apron surface, and an elevation of EL (-) 10.2 m upstream and EL (-) 11.1 downstream.

Since the crest elevation of the wall is EL 1.8 meters, the wall height is 12.0 meters on the upstream side while 12.9 meters on the downstream side, respectively.

5.6.2 Wall Type

There are four types of walls: i) Gravity type, ii) Inverted T-shape type, iii) L-shape type, and iv) Counterfort wall type. And the counterfort wall type is adopted for the Project for the following reasons.

1) This type requires a lower volume of concrete than the other types.
2) An economical height for walls of this type ranges from 7.0 meters to 13 meters.

5.7 Gate

5.7.1 Gate Type

1) Flood Gate

There are three types of gates, the Girder type, Trass type and Shell type. The Shell type is adopted for the following reasons.

a) The Girder type is successfully applicable only when the span is less than 15 meters.

b) The Shell type and Trass type can be applied to those gates whose span ranges from 15 to 80 meters.

c) Due to the fact that flood gates receive hydraulic pressure from both sides, up and downstream, the Girder and Trass types cannot be adopted in this Project.

2) Regulating Gate

Double leaf gates and Flap gates can be adopted as regulating gates to serve for water intake for irrigation, domestic/industrial water supply, and to prevent sea water intrusion. The following table shows the comparison of the above two types of gates with their merits and demerits.

Item	Double Leaf Gate		Shell Type with Flap	
	Normal	Reverse	Normal	Reverse
- Height of Gate	Hc > 1 / 12 L		Hc > 1 / 3 H or 3.0 m	
- Down pull of Lower Leaf	Small	Large	Large	Small
- Effect of Tidal Wave	Small	Medium	Large	Small
- Adherence of Sea Animals	Inside of Upper Leaf	Inside of Lower Leaf	Flap and Lower Leaf	Flap and Lower Leaf
- Stability of Water Flow	Smooth	Smooth	Unsteady	Unsteady

Double leaf gates are high in stability as well as reliability in operation, although inferior to flap gates in economy. Accordingly, double leaf gates will be employed in the Project, especially, the double leaf normal type gates with hydraulic advantages. For reference, two units of regalting gates shall be provided for controlling the water level in the reservoir in drought or normal level of stored water as 300 m^3/s or below.

5.7.2 Specifications for Gate Design

1) Design Conditions of the Gate

a) Design Water Level

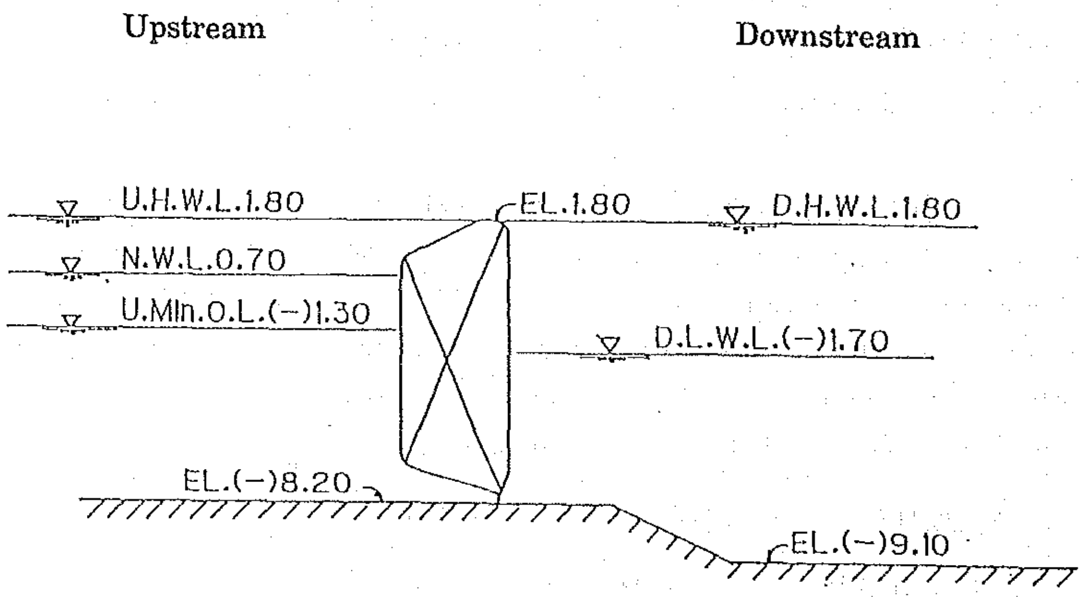
The design water level for the gates is as follows:

- The upstream high water level (U.H.W.L) is designed at EL. 1.80 meters of the crest elevation of the gate.
- The upstream low water level (U.L.W.L) is designed at EL (-) 1.30 meters of the minimum operating level of the reservoir.
- The downstream high water level (D.H.W.L) is EL 1.80 meters of the crest elevation of the gate.
- The downstream low water level (D.L.W.L) is EL (-) 1.70 meters of the lowest low water level in the sea.

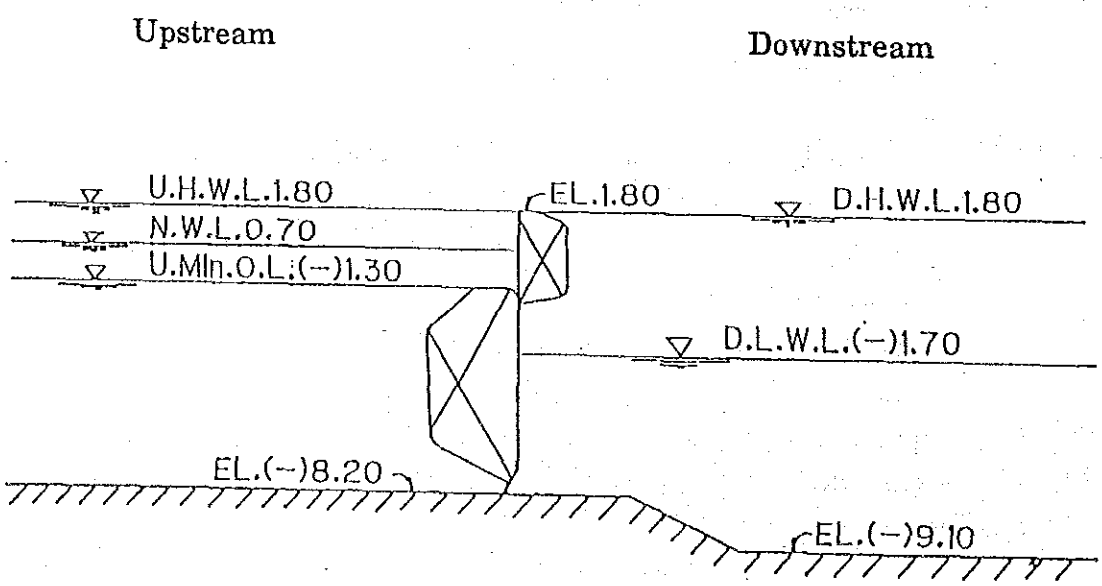
b) Sediment Depth

The sediment at upstream of the gate is not acute because of the large reservoir.

c) Flood Gate



d) Regulating Gate



e) Water Level Conditions for Designing

	Upstream	Downstream	Water level difference
Case I :	H.W.L 1.80 m	L.W.L (-) 1.70 m	3.50 m
Case II :	L.W.L. (-) 1.30 m	H.W.L 1.80 m	3.10 m

2) Major Items of Gate Specifications

Item	Flood Gate	Regulating Gate
Gate type	Single Shell Roller Gate	Double Shell Roller Gate
Clear span	30.0 m	30.0 m
Upper leaf height	-	3.1 m
Lower leaf height	10.0 m	6.9 m
Quantity	3 sets	2 sets
Gate sill elevation	EL. (-) 8.20 m	EL (-) 9.10 m
Gate crest elev. of upper	-	EL 1.80 m
Gate crest elev. of lower	EL. 1.80 m	EL (-) 1.30 m
Sealing Type	3 - sides rubber seal	3 - sides rubber seal
Hoist	2 - motors, 2 - drams wire rope winch	2 - motors, 2 - drams wire rope winch
Operating speed	0.3 m/min	0.3 m/min
Lifting height	12.1 m (EL. 3.90 m)	12.1 m (EL. 3.90 m)
Operation method	Local and remote	Local and remote
Design water level difference	Upstream : 3.50 m Downstream : 3.10 m	Upstream : 3.50 m Downstream : 3.10 m
Operating water level	H.W.L. 1.80 m	H.W.L 1.80 m

5. 8 Hoist House

5. 8. 1 Size of Hoist House

The gate hoist house is designed to protect the hoisting and electric equipment and facilities from exposure to sun shine and rain water which inhibit smooth operation of the gates. The size of the hoist house is decided according to the types of hoisting equipment on the piers and operation methods.

The hoist house for the proposed gates will be 12.5 meters in thalweg direction, 10.0 meters in diversion dam center direction, and 4.5 meters in height.

5.8.2 Structure of Hoist House

The proposed hoist house is designed to be a reinforced concrete building. It will be necessary to provide a chain block for inspection and repairs on the ceiling which will be made of reinforced concrete. The walls will be reinforced concrete block.

Since the hoist house building will have the appearance of a colourless rectangular box, it is deemed better that the total building is designed to meet the architectural design standards of Thailand.

5.9 Operation and Maintenance (O and M) Bridge

The O and M bridge connected with the hoist house is a bridge to be provided for rendering O and M services for the facilities.

5.9.1 Bridge Width

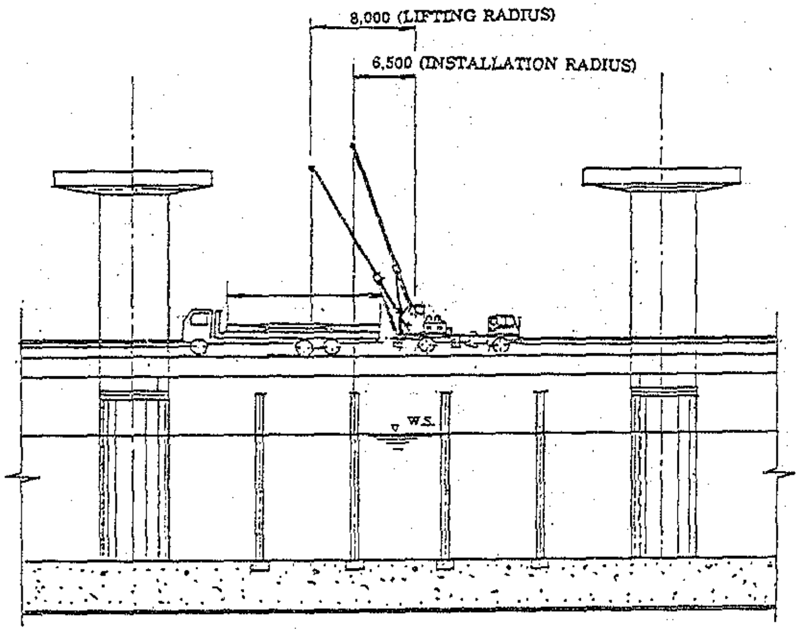
The O and M bridge will have sufficient width to carry out successful O and M works as well as emergency operation of the gates.

The proposed bridge will have a width of 5.0 meters so that a 10-ton truck crane can pass through for installation of stop-log (Refer to Figure 5-1).

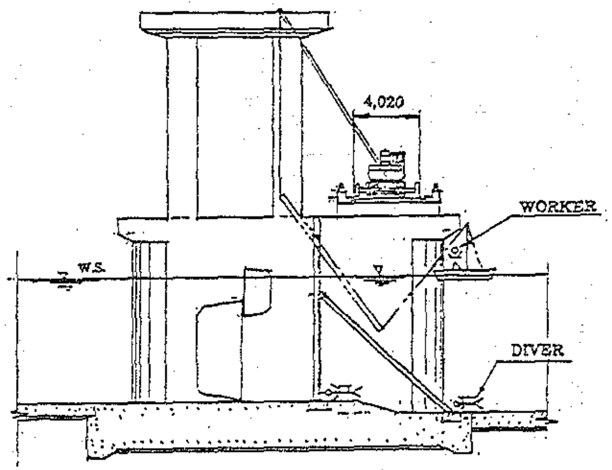
5.9.2 Span

The O and M bridge will have a clear span length of 30.0 meters and a span length of 32.60 m × 5 spans taking into account the gate span length.

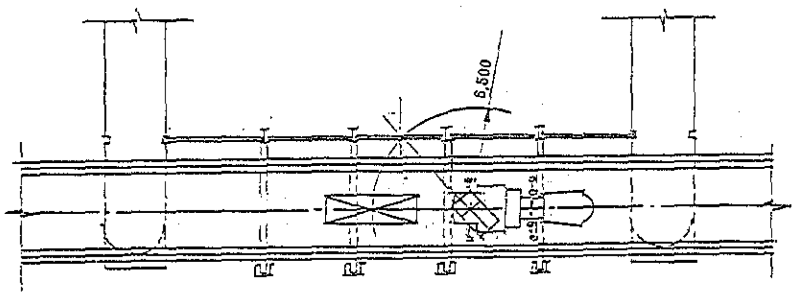
FIGURE 5-1 INSTALLATION PLAN FOR STOP LOG



INSTALLATION PLAN FOR VERTICAL SUPPORTING POST



INSTALLATION PLAN FOR DIAGONAL SUPPORTING POST



INSTALLATION PLAN FOR GATE LEAF

SELECTION OF CRANE FOR INSTALLATION OF STOP LOG

Working Content	Working Conditions		Crane Capacity			Crane Type
	Load (t)	Working Radius (m)	Lifting Load (t)	Working Radius (m)	Boom Length (m)	
Lifting for Ver. Supporting Post	3.80	8.00	3.90	8.00	12.50	10^{T} - Truck Crane
Installation for Ver. Supp. Post	3.80	6.50	4.50	6.50	〃	〃
Lifting for Dia. Supporting Post	1.50	8.00	3.90	8.00	〃	〃
Installation for Dia. Supp. Post	1.50	6.50	4.50	6.50	〃	〃
Installation for Gate Leaf	3.80	6.50	4.50	6.50	〃	〃

5.9.3 Bridge Type

As O and M bridges, in general, steel bridges, I-beam bridges with prestressed concrete and hollow box type bridges with prestressed concrete can be used. For the proposed O and M bridge, the hollow box type bridge with prestressed concrete is recommended for the following reasons and in reference to Table 5-2 Comparison of O & M Bridge Types.

1) The hollow box type bridges are more economical in many respects than the other types of bridges, although the weight is heavier.

2) O and M works such as painting, etc. can be rendered more easily than with other types.

3) Since the beam height of this type is lower than that of the others, it is easier to provide embankments, access roads and so forth.

5.9.4 Beam Seat Elevation

The beam seat elevation is determined as follows with consideration for gate operation safe clearance, wave height, freeboard.

Beam seat elevation = Maximum water level + Freeboard
= Max. W.L. 2.40 m + 1.50 m
= EL 3.90 m

TABLE 5-2 COMPARISON OF O & M BRIDGE TYPES

Scheme	Type of Superstructure	Dimensions of Super.	Economy	Specific Features	Overall Appraisal
A	Prestressed Concrete Bridge Girder I - Section	- Span length : 32.60 m - Beam length : 33.95 m - Span : 5	143%	- Dead load reaction is largest - O and M works are not required - Economically, initial cost is largest - No need for bent method and easy in construction.	△
B	Prestressed Concrete Hollow Box Girder	- Span length : 32.60 m - Beam length : 33.95 m - Span : 5	100%	- O and M works are not required - Most economical - No need for bent method and easy in construction	◎
C	Simple Composite Steel Girder	- Span length : 32.60 m - Beam length : 33.90 m - Span : 5	103%	- Dead load reaction is least - Bent method is required and high technique is necessary in construction	○

5.10 Stability Analysis of Pier

5.10.1 Center Pier

1. DESIGN CRITERIA

1-1 TYPE OF PIER ; CENTER PIER

1-2 DIMENSIIONS (M)

```
A( 1)= 24.00 A( 2)=  2.00 A( 3)=  2.00 A( 4)= 12.50 A( 5)=  3.00
A( 6)=  0.50 A( 7)=  2.00 A( 8)=  1.00 A( 9)=  3.00 A(10)=  2.00
A(11)=  5.00 A(12)= 10.00 A(13)=  5.50 A(14)=  1.75 A(15)= 12.50
A(16)= 13.00 A(17)= 19.00

B( 1)= 12.00 B( 2)=  4.00 B( 3)=  4.00 B( 4)=  4.00 B( 5)=  1.40
B( 6)=  3.00 B( 7)= 10.00

C( 1)=  2.90 C( 2)= 10.60 C( 3)=  0.50 C( 4)=  1.00 C( 5)= 12.00
C( 6)=  1.50 C( 7)=  0.90 C( 8)=  0.70 C( 9)=  1.10 C(10)=  3.00
C(11)=  5.50

AX1  =  5.80 AX2  =  1.60 AX3  =  5.00
AA1  =  2.40 AA2  =  0.80 AA3  =  1.00
BB1  =  0.80 BB2  =  2.40 BB3  =  0.80
```

1-3 DEAD LOADS (T/M3)

```
REINFORCED CONCRETE ; RC =  2.40
PLAIN CONCRETE      ; RC =  2.20
WET EARTH           ; RS =  1.80
SATURATED EARTH     ; RW =  2.00
WATER               ; WO =  1.00
SEA WATER           ; WS =  1.03
```

1-4 COEFFICIENT OF ACTIVE EARTH PRESSURE ; KA= 0.355

1-5 GATES

LOADS		LEFT-SIDE	RIGHT-SIDE
DEAD LOAD	(T)	300.00	350.00
OPERATION LOAD	(T)	400.00	450.00
LIFTING MACHINE	(T)	50.00	100.00
CLEAR SPAN	(M)	30.00	30.00
HIGHT	(M)	10.00	10.00

1-5 LOADS OF OPERATION BRIDGE

```
DEAD LOAD  (T) ; RD =  320.00
LIVE LOAD  (T) ; RL =  100.00
WIND LOAD  (T) ; RH =   20.00
```

1-6 DEAD LOAD OF HOIST HOUSE ; WH =   1.50 (T/M2)

1-7 LIVE LOAD ; Q =   1.00 (T/M2)

1-8 WATER LEVEL

	CASE1	CASE2	CASE3	CASE4	CASE5	CASE6	CASE7
DOWNSTREAM	2.40	-1.70	1.80	0.00	1.80	-1.70	0.00
UPSTREAM	2.40	1.80	-1.30	0.00	1.80	-1.30	0.00

2. DEAD LOAD AND CENTER OF GRAVITY

n	W (t)	χ (m)	W・χ (t・m)	y (m)	W・y (t・m)	z (m)	W・z (t・m)
1	1267.20	12.00	15206.38	1.00	1267.20	6.00	7603.19
2	392.04	8.25	3234.33	2.45	960.50	6.00	2352.24
3	35.64	17.50	623.70	2.30	81.97	6.00	213.84
4	159.84	3.15	503.70	8.20	1310.72	6.00	959.06
5	1858.56	12.00	22302.71	8.95	16634.11	6.00	11151.36
6	12.96	18.50	239.76	2.60	33.70	6.00	77.76
7	4.32	19.75	85.32	2.45	10.58	6.00	25.92
8	173.42	20.85	3615.51	8.65	1500.05	6.00	1040.49
9	9.60	1.50	14.40	14.50	139.20	6.00	57.60
10	2.40	1.67	4.00	13.83	33.20	6.00	14.40
11	28.80	3.00	86.40	14.25	410.40	6.00	172.80
12	28.80	21.00	604.80	14.25	410.40	6.00	172.80
13	2.40	22.33	53.60	13.83	33.20	6.00	14.40
14	9.60	22.50	216.00	14.50	139.20	6.00	57.60
15	161.28	5.00	806.40	21.00	3386.88	6.00	967.68
16	161.28	12.00	1935.36	21.00	3386.88	6.00	967.68
17	450.00	8.50	3825.00	27.75	12487.49	6.00	2700.00
18	-55.76	7.00	-390.30	8.95	-499.02	4.40	-245.33
19	-18.59	8.00	-148.68	8.95	-166.34	7.60	-141.25
20	-23.23	5.50	-127.78	8.95	-207.93	7.60	-176.56
Σ	4660.55		52690.57		41352.35		27985.64

2-1 X-DIRECTION

X = W・X / W = 52690.57 / 4660.55 = 11.31 (M)

2-2 Y-DIRECTION

Y = W・Y / W = 41352.35 / 4660.55 = 8.87 (M)

2-3 Z-DIRECTION

Y = W・Y / W = 27985.64 / 4660.55 = 6.00 (M)

3. CHECK OF SATABILITY

3-1 CASE (1)

LOAD	V (T)	X (M)	V·X (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	4660.55	12.69	59162.65			
2.GATE	350.00	17.00	5950.00			
3.GATE	400.00	17.20	6880.00			
4.LIFTING MACHINE	50.00	17.00	850.00			
5.LIFTING MACHINE	100.00	17.20	1720.00			
6.OPERATION BRIDGE	420.00	5.50	2310.00			
7.HOIST HOUSE	187.50	15.50	2906.25			
8.WATER	2293.14	11.79	27037.63			
9.BUOYANCY	-1566.27	12.39	-19411.09			
10.WIND PRESSURE				36.00	20.00	720.00
11.WIND PRESSURE				36.00	20.00	720.00
12.WIND PRESSURE				13.10	20.95	274.50
13.WIND PRESSURE				13.20	31.25	412.50
14.WIND PRESSURE				20.00	15.00	300.00
TOTAL	6894.91		87405.31	118.30		2427.00

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
10:GATE(LEFT),11:GATE(RIGHT),12:PIER,13:HOIST HOUSE,14:BRIDGE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs = \Sigma V \cdot \mu / \Sigma H =$ 34.97 $\geqq$ $Fsa =$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi = B - (\Sigma V \cdot \chi - \Sigma H \cdot y) / \Sigma V =$ 11.68 (m)

$e = B/2 - \chi =$ 0.32 (m) $\leqq$ $B/6 =$ 4.00 (m)

(3) SOIL REACTION

$Q1 = \Sigma V/B/L \cdot (1 + 6 \cdot e/B) =$ 25.88 (t/m²)

$Q2 = \Sigma V/B/L \cdot (1 - 6 \cdot e/B) =$ 22.00 (t/m²)

3-2 CASE (2)

LOAD	V (T)	X (M)	V・X (T・M)	H (T)	Y (M)	H・Y (T・M)
1.PIER	4660.55	12.69	59162.65			
2.GATE	40.00	17.00	680.00			
3.GATE	46.67	17.20	802.67			
4.LIFTING MACHINE	50.00	17.00	850.00			
5.LIFTING MACHINE	100.00	17.20	1720.00			
6.OPERATION BRIDGE	420.00	5.50	2310.00			
7.HOIST HOUSE	187.50	15.50	2906.25			
8.WATER	1725.90	12.92	22303.18			
9.UPLIFT	-400.59	13.23	-5300.14			
10.WIND PRESSURE				0.00	12.90	0.00
11.WIND PRESSURE				0.00	12.90	0.00
12.WIND PRESSURE				13.61	21.73	295.76
13.WIND PRESSURE				13.20	31.25	412.50
14.WIND PRESSURE				20.00	15.00	300.00
15.WATER PRESSURE				847.24	7.13	6042.67
16.WATER PRESSURE				226.47	4.29	971.00
TOTAL	6830.02		85434.44	1120.51		8021.92

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
10:GATE(LEFT),11:GATE(RIGHT),12:PIER,13:HOIST HOUSE,14:BRIDGE
15:GATE,16:PIER

(1) FACTOR OF SAFETY AGAINST SLIDING

・COEFFICIENT OF FRICTION ; μ= 0.60

$Fs = \Sigma V \cdot \mu / \Sigma H =$ 3.66 ≧ $Fsa =$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi = B - (\Sigma V \cdot \chi - \Sigma H \cdot y) / \Sigma V =$ 12.67 (m)

$e = B/2 - \chi =$ -0.67 (m) ≦ $B/6 =$ 4.00 (m)

(3) SOIL REACTION

$Q1 = \Sigma V / B / L \cdot (1 + 6 \cdot e / B) =$ 19.77 (t/m²)

$Q2 = \Sigma V / B / L \cdot (1 - 6 \cdot e / B) =$ 27.66 (t/m²)

3-3 CASE (3)

LOAD	V (T)	X (M)	V·X (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	4660.55	11.31	52690.57			
2.GATE	40.00	7.00	280.00			
3.GATE	46.67	6.80	317.33			
4.LIFTING MACHINE	50.00	7.00	350.00			
5.LIFTING MACHINE	100.00	6.80	680.00			
6.OPERATION BRIDGE	420.00	18.50	7770.00			
7.HOIST HOUSE	187.50	8.50	1593.75			
8.WATER	1967.03	13.34	26245.58			
9.UPLIFT	-551.77	13.42	-7402.57			
10.WIND PRESSURE				13.61	21.78	296.42
11.WIND PRESSURE				13.20	31.25	412.50
12.WIND PRESSURE				20.00	15.00	300.00
13.WATER PRESSURE				830.85	7.12	5916.91
14.WATER PRESSURE				230.61	4.17	961.95
TOTAL	6919.96		82524.56	1108.27		7887.77

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
10:PIER,11:HOIST HOUSE,12:BRIDGE,13:GATE,14:PIER

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; $\mu = 0.60$

$Fs = \Sigma V \cdot \mu / \Sigma H =$ 3.75 $\geqq$ $Fsa =$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi = (\Sigma V \cdot \chi - \Sigma H \cdot y) / \Sigma V =$ 10.79 (m)

$e = B/2 - \chi =$ 1.21 (m) $\leqq$ $B/6 =$ 4.00 (m)

(3) SOIL REACTION

$Q1 = \Sigma V / B / L \cdot (1 + 6 \cdot e / B) =$ 31.32 (t/m²)

$Q2 = \Sigma V / B / L \cdot (1 - 6 \cdot e / B) =$ 16.73 (t/m²)

3-4 CASE (4)

LOAD	V (T)	X (M)	V·X (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	4660.55	12.69	59162.65			
2.GATE	350.00	17.00	5950.00			
3.GATE	400.00	17.20	6880.00			
4.LIFTING MACHINE	50.00	17.00	850.00			
5.LIFTING MACHINE	100.00	17.20	1720.00			
6.OPERATION BRIDGE	420.00	5.50	2310.00			
7.HOIST HOUSE	187.50	15.50	2906.25			
8.WIND PRESSURE				48.00	20.00	960.00
9.WIND PRESSURE				48.00	20.00	960.00
10.WIND PRESSURE				29.34	16.48	483.70
11.WIND PRESSURE				17.60	31.25	550.00
12.WIND PRESSURE				20.00	15.00	300.00
TOTAL	6168.05		79778.81	162.94		3253.70

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
8:GATE(LEFT),9:GATE(RIGHT),10:PIER,11:HOIST HOUSE,12:BRIDGE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs=\Sigma V\cdot\mu/\Sigma H=$ 22.71 $\geqq$ $Fsa=$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi=B-(\Sigma V\cdot\chi-\Sigma H\cdot y)/\Sigma V=$ 11.59 (m)

$e=B/2-\chi=$ 0.41 (m) $\leqq$ $B/6=$ 4.00 (m)

(3) SOIL REACTION

$Q1=\Sigma V/B/L\cdot(1+6\cdot e/B)=$ 23.59 (t/m²)

$Q2=\Sigma V/B/L\cdot(1-6\cdot e/B)=$ 19.24 (t/m²)

3-5 CASE (5)

LOAD	V (T)	Z (M)	V·Z (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	4660.55	6.00	27985.63			
2.GATE	40.00	2.00	80.00			
3.GATE	46.67	10.00	466.67			
4.LIFTING MACHINE	50.00	4.00	200.00			
5.LIFTING MACHINE	100.00	8.00	800.00			
6.OPERATION BRIDGE	420.00	6.00	2520.00			
7.HOIST HOUSE	187.50	6.00	1125.00			
8.WATER	2207.95	6.00	13247.72			
9.BUOYANCY	-1518.32	11.61	-17622.82			
10.WIND PRESSURE				26.75	19.21	513.89
11.WIND PRESSURE				16.50	31.25	515.62
TOTAL	6194.35		28802.20	43.25		1029.51

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
10:PIER,11:HOIST HOUSE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; $\mu = 0.60$

$Fs = \Sigma V \cdot \mu / \Sigma H = 85.94 \geqq Fsa = 1.50$

(2) STABILITY AGAINST OVERTURNING

$\chi = (\Sigma V \cdot z - \Sigma H \cdot y) / \Sigma V = 4.48$ (m)

$e = B/2 - \chi = 1.52$ (m) $\leqq B/6 = 2.00$ (m)

(3) SOIL REACTION

$Q1 = \Sigma V / B / L \cdot (1 + 6 \cdot e / B) = 37.82$ (t/m²)

$Q2 = \Sigma V / B / L \cdot (1 - 6 \cdot e / B) = 5.20$ (t/m²)

3-6 CASE (6)

LOAD	V (T)	Z (M)	V·Z (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	4660.55	6.00	27985.63			
2.GATE	40.00	2.00	80.00			
3.GATE	46.67	10.00	466.67			
4.LIFTING MACHINE	50.00	4.00	200.00			
5.LIFTING MACHINE	100.00	8.00	800.00			
6.OPERATION BRIDGE	420.00	6.00	2520.00			
7.HOIST HOUSE	187.50	6.00	1125.00			
8.WATER	1484.98	6.00	8909.89			
9.UPLIFT	-68.97	6.00	-413.83			
10.WIND PRESSURE				42.53	16.13	686.04
11.WIND PRESSURE				16.50	31.25	515.62
TOTAL	6920.72		41673.36	59.03		1201.66

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
10:PIER,11:HOIST HOUSE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; $\mu = 0.60$

$Fs = \Sigma V \cdot \mu / \Sigma H = 70.35 \geq Fsa = 1.50$

(2) STABILITY AGAINST OVERTURNING

$\chi = (\Sigma V \cdot z - \Sigma H \cdot y) / \Sigma V = 5.85$ (m)

$e = B/2 - \chi = 0.15$ (m) $\leqq B/6 = 2.00$ (m)

(3) SOIL REACTION

$Q1 = \Sigma V / B / L \cdot (1 + 6 \cdot e / B) = 25.86$ (t/m^2)

$Q2 = \Sigma V / B / L \cdot (1 - 6 \cdot e / B) = 22.20$ (t/m^2)

3-7 CASE (7)

LOAD	V (T)	Z (M)	V·Z (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	4660.55	6.00	27985.63			
2.GATE	350.00	4.00	1400.00			
3.GATE	400.00	8.00	3200.00			
4.LIFTING MACHINE	50.00	4.00	200.00			
5.LIFTING MACHINE	100.00	8.00	800.00			
6.OPERATION BRIDGE	420.00	6.00	2520.00			
7.HOIST HOUSE	187.50	6.00	1125.00			
8.WIND PRESSURE				74.36	11.98	890.71
9.WIND PRESSURE				16.50	31.25	515.62
TOTAL	6168.05		37230.63	90.86		1406.34

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
8:PIER,9:HOIST HOUSE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs = \Sigma V \cdot \mu / \Sigma H =$ 40.73 $\geqq$ $Fsa =$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi = (\Sigma V \cdot z - \Sigma H \cdot y) / \Sigma V =$ 5.81 (m)

$e = B/2 - \chi =$ 0.19 (m) $\leqq$ $B/6 =$ 2.00 (m)

(3) SOIL REACTION

$Q1 = \Sigma V / B / L \cdot (1 + 6 \cdot e / B) =$ 23.47 (t/m²)

$Q2 = \Sigma V / B / L \cdot (1 - 6 \cdot e / B) =$ 19.36 (t/m²)

5.10.2 Abut Pier

1. DESIGN CRITERIA

1-1 TYPE OF PIER ; ABUT PIER

1-2 DIMENSIIONS (M)

```
A( 1)= 24.00 A( 2)=  0.00 A( 3)=  0.00 A( 4)= 16.50 A( 5)=  3.00
A( 6)=  4.50 A( 7)=  0.00 A( 8)=  0.00 A( 9)=  4.00 A(10)=  2.00
A(11)=  5.00 A(12)= 11.00 A(13)=  5.50 A(14)=  1.75 A(15)= 12.50
A(16)= 13.00 A(17)= 19.00

B( 1)= 12.00 B( 2)=  4.00 B( 3)=  4.00 B( 4)=  4.00 B( 5)=  1.40
B( 6)=  3.00 B( 7)= 10.00

C( 1)=  2.90 C( 2)= 10.00 C( 3)=  0.00 C( 4)=  2.10 C( 5)= 12.00
C( 6)=  1.50 C( 7)=  0.90 C( 8)=  0.70 C( 9)=  1.10 C(10)=  3.00
C(11)=  5.50

AX1  =  5.80 AX2  =  0.00 AX3  =  0.00
AA1  =  2.40 AA2  =  0.00 AA3  =  0.00
BB1  =  0.80 BB2  =  3.20 BB3  =  0.00
```

1-3 DEAD LOADS (T/M3)

```
REINFORCED CONCRETE ; RC =  2.40
PLAIN CONCRETE      ; RC =  2.20
WET EARTH           ; RS =  1.80
SATURATED EARTH     ; RW =  2.00
WATER               ; WO =  1.00
SEA WATER           ; WS =  1.03
```

1-4 COEFFICIENT OF ACTIVE EARTH PRESSURE ; KA= 0.355

1-5 GATES

LOADS		LEFT-SIDE	RIGHT-SIDE
DEAD LOAD	(T)	300.00	
OPERATION LOAD	(T)	400.00	
LIFTING MACHINE	(T)	50.00	
CLEAR SPAN	(M)	30.00	
HIGHT	(M)	10.00	

1-5 LOADS OF OPERATION BRIDGE

```
DEAD LOAD  (T) ; RD =  160.00
LIVE LOAD  (T) ; RL =   50.00
WIND LOAD  (T) ; RH =   10.00
```

1-6 DEAD LOAD OF HOIST HOUSE ; WH =   1.50 (T/M2)

1-7 LIVE LOAD ; Q =   1.00 (T/M2)

1-8 WATER LEVEL

	CASE1	CASE2	CASE3	CASE4	CASE5	CASE6	CASE7
DOWNSTREAM	2.40	-1.70	1.80	0.00	1.80	-1.70	0.00
UPSTREAM	2.40	1.80	-1.30	0.00	1.80	-1.30	0.00

2. DEAD LOAD AND CENTER OF GRAVITY

n	W (t)	χ (m)	W · χ (t · m)	y (m)	W · y (t · m)	z (m)	W · z (t · m)
1	1267.20	12.00	15206.38	1.00	1267.20	6.00	7603.19
2	392.04	8.25	3234.33	2.45	960.50	6.00	2352.24
3	35.64	17.50	623.70	2.30	81.97	6.00	213.84
4	0.00	0.00	0.00	7.90	0.00	6.00	0.00
5	2787.84	12.00	33454.07	8.95	24951.16	6.00	16727.03
6	12.96	18.50	239.76	2.60	33.70	6.00	77.76
7	38.88	21.75	845.64	2.45	95.26	6.00	233.28
8	0.00	24.00	0.00	8.35	0.00	6.00	0.00
9	0.00	0.00	0.00	13.95	0.00	6.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	24.00	0.00	13.95	0.00	6.00	0.00
15	161.28	5.00	806.40	21.00	3386.88	6.00	967.68
16	161.28	12.00	1935.36	21.00	3386.88	6.00	967.68
17	450.00	8.50	3825.00	27.75	12487.49	6.00	2700.00
18	-55.76	7.00	-390.30	8.95	-499.02	4.40	-245.33
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ	5251.34		59780.32		46151.99		31597.35

2-1 X-DIRECTION

X = W·X / W = 59780.32 / 5251.34 = 11.38 (M)

2-2 Y-DIRECTION

Y = W·Y / W = 46151.99 / 5251.34 = 8.79 (M)

2-3 Z-DIRECTION

Y = W·Y / W = 31597.35 / 5251.34 = 6.02 (M)

3. CHECK OF SATABILITY

3-1 CASE (1)

LOAD	V (T)	X (M)	V·X (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	5251.34	12.62	66251.87			
2.GATE	350.00	17.00	5950.00			
3.GATE	0.00	0.00	0.00			
4.LIFTING MACHINE	50.00	17.00	850.00			
5.LIFTING MACHINE	0.00	0.00	0.00			
6.OPERATION BRIDGE	210.00	5.50	1155.00			
7.HOIST HOUSE	187.50	15.50	2906.25			
8.WATER AND EARTH	1113.60	12.00	13363.20			
9.WATER	1039.20	11.81	12277.35			
10.BUOYANCY	-1765.75	12.25	-21628.61			
11.WIND PRESSURE				36.00	20.00	720.00
12.WIND PRESSURE				0.00	0.00	0.00
13.WIND PRESSURE				13.10	20.55	269.24
14.WIND PRESSURE				13.20	31.25	412.50
15.WIND PRESSURE				10.00	15.00	150.00
TOTAL	6435.89		81125.00	72.30		1551.74

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
11:GATE(LEFT),12:GATE(RIGHT),13:PIER,14:HOIST HOUSE,15:BRIDGE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs = \Sigma V \cdot \mu / \Sigma H =$ 53.41 ≧ $Fsa =$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi = B - (\Sigma V \cdot \chi - \Sigma H \cdot y) / \Sigma V =$ 11.64 (m)

$e = B/2 - \chi =$ 0.36 (m) ≦ $B/6 =$ 4.00 (m)

(3) SOIL REACTION

$Q1 = \Sigma V / B / L \cdot (1 + 6 \cdot e / B) =$ 24.38 (t/m²)

$Q2 = \Sigma V / B / L \cdot (1 - 6 \cdot e / B) =$ 20.31 (t/m²)

3-2 CASE (2)

LOAD	V (T)	X (M)	V·X (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	5251.34	12.62	66251.87			
2.GATE	40.00	17.00	680.00			
3.GATE	0.00	24.00	0.00			
4.LIFTING MACHINE	50.00	17.00	850.00			
5.LIFTING MACHINE	0.00	24.00	0.00			
6.OPERATION BRIDGE	210.00	5.50	1155.00			
7.HOIST HOUSE	187.50	15.50	2906.25			
8.WATER AND EARTH	1982.40	12.00	23788.79			
9.WATER	777.34	12.86	10000.08			
10.UPLIFT	-400.59	13.23	-5300.14			
11.WIND PRESSURE				0.00	12.90	0.00
12.WIND PRESSURE				0.00	0.00	0.00
13.WIND PRESSURE				13.68	21.74	297.37
14.WIND PRESSURE				13.20	31.25	412.50
15.WIND PRESSURE				10.00	15.00	150.00
16.WATER PRESSURE				423.62	7.13	3021.33
17.WATER PRESSURE				226.47	4.29	971.00
TOTAL	8097.98		100331.75	686.96		4852.20

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
11:GATE(LEFT),12:GATE(RIGHT),13:PIER,14:HOIST HOUSE,15:BRIDGE
16:GATE,17:PIER

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs=\Sigma V\cdot\mu/\Sigma H=$ 7.07 $\geqq$ $Fsa=$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi=B-(\Sigma V\cdot\chi-\Sigma H\cdot y)/\Sigma V=$ 12.21 (m)

$e=B/2-\chi=$ -0.21 (m) $\leqq$ $B/6=$ 4.00 (m)

(3) SOIL REACTION

$Q1=\Sigma V/B/L\cdot(1+6\cdot e/B)=$ 26.65 (t/m^2)

$Q2=\Sigma V/B/L\cdot(1-6\cdot e/B)=$ 29.59 (t/m^2)

3-3 CASE (3)

LOAD	V (T)	X (M)	V·X (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	5251.34	11.38	59780.32			
2.GATE	40.00	7.00	280.00			
3.GATE	0.00	24.00	0.00			
4.LIFTING MACHINE	50.00	7.00	350.00			
5.LIFTING MACHINE	0.00	24.00	0.00			
6.OPERATION BRIDGE	210.00	18.50	3885.00			
7.HOIST HOUSE	187.50	8.50	1593.75			
8.WATER AND EARTH	1986.24	12.00	23834.87			
9.WATER	895.45	13.22	11840.09			
10.UPLIFT	-551.77	13.42	-7402.57			
11.WIND PRESSURE				13.68	21.74	297.37
12.WIND PRESSURE				13.20	31.25	412.50
13.WIND PRESSURE				10.00	15.00	150.00
14.WATER PRESSURE				415.42	7.12	2958.46
15.WATER PRESSURE				230.61	4.17	961.95
TOTAL	8068.75		94161.37	682.92		4780.27

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
11:PIER,12:HOIST HOUSE,13:BRIDGE,14:GATE,15:PIER

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs=\Sigma V\cdot\mu/\Sigma H=$ 7.09 $\geqq$ $Fsa=$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi=(\Sigma V\cdot\chi-\Sigma H\cdot y)/\Sigma V=$ 11.08 (m)

$e=B/2-\chi=$ 0.92 (m) $\leqq$ $B/6=$ 4.00 (m)

(3) SOIL REACTION

$Q1=\Sigma V/B/L\cdot(1+6\cdot e/B)=$ 34.48 (t/m²)

$Q2=\Sigma V/B/L\cdot(1-6\cdot e/B)=$ 21.55 (t/m²)

3-4 CASE (4)

LOAD	V (T)	X (M)	V・X (T・M)	H (T)	Y (M)	H・Y (T・M)
1.PIER	5251.34	12.62	66251.87			
2.GATE	350.00	17.00	5950.00			
3.GATE	0.00	24.00	0.00			
4.LIFTING MACHINE	50.00	17.00	850.00			
5.LIFTING MACHINE	0.00	24.00	0.00			
6.OPERATION BRIDGE	210.00	5.50	1155.00			
7.HOIST HOUSE	187.50	15.50	2906.25			
8.WATER AND EARTH	1981.44	12.00	23777.27			
9.WIND PRESSURE				48.00	20.00	960.00
10.WIND PRESSURE				0.00	0.00	0.00
11.WIND PRESSURE				18.24	21.74	396.49
12.WIND PRESSURE				17.60	31.25	550.00
13.WIND PRESSURE				10.00	15.00	150.00
TOTAL	8030.28		100890.37	93.84		2056.49

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
9:GATE(LEFT),10:GATE(RIGHT),11:PIER,12:HOIST HOUSE,13:BRIDGE

(1) FACTOR OF SAFETY AGAINST SLIDING

・ COEFFICIENT OF FRICTION ; μ= 0.60

$Fs=\Sigma V\cdot\mu/\Sigma H=$ 51.34 $\geqq$ $Fsa=$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi=B-(\Sigma V\cdot\chi-\Sigma H\cdot y)/\Sigma V=$ 11.69 (m)

$e=B/2-\chi=$ 0.31 (m) $\leqq$ $B/6=$ 4.00 (m)

(3) SOIL REACTION

$Q1=\Sigma V/B/L\cdot(1+6\cdot e/B)=$ 30.03 (t/m²)

$Q2=\Sigma V/B/L\cdot(1-6\cdot e/B)=$ 25.74 (t/m²)

3-5 CASE (5)

LOAD	V (T)	Z (M)	V·Z (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	5251.34	6.02	31597.35			
2.GATE	40.00	2.00	80.00			
3.GATE	0.00	0.00	0.00			
4.LIFTING MACHINE	50.00	4.00	200.00			
5.LIFTING MACHINE	0.00	0.00	0.00			
6.OPERATION BRIDGE	210.00	6.00	1260.00			
7.HOIST HOUSE	187.50	6.00	1125.00			
8.WATER AND EARTH	2016.00	10.00	20160.00			
9.WATER	1000.85	2.00	2001.69			
10.BUOYANCY	-1707.00	11.75	-20059.00			
11.WIND PRESSURE				23.83	14.72	350.90
12.WIND PRESSURE				16.50	31.25	515.62
13.WATER PRESSURE				1996.92	4.30	8586.74
14.WATER PRESSURE				-1373.40	4.30	-5905.61
15.EARTH PRESSURE	409.41	12.00	4912.88	709.11	4.59	3253.84
TOTAL	7458.09		41277.91	1372.96		6801.48

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
11:PIER,12:HOIST HOUSE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs=\Sigma V\cdot\mu/\Sigma H=$ 3.26 ≧ $Fsa=$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi=(\Sigma V\cdot z-\Sigma H\cdot y)/\Sigma V=$ 4.62 (m)

$e=B/2-\chi=$ 1.38 (m) ≦ $B/6=$ 2.00 (m)

(3) SOIL REACTION

$Q1=\Sigma V/B/L\cdot(1+6\cdot e/B)=$ 43.73 (t/m²)

$Q2=\Sigma V/B/L\cdot(1-6\cdot e/B)=$ 8.06 (t/m²)

3-6 CASE (6)

LOAD	V (T)	Z (M)	V·Z (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	5251.34	6.02	31597.35			
2.GATE	40.00	2.00	80.00			
3.GATE	0.00	0.00	0.00			
4.LIFTING MACHINE	50.00	4.00	200.00			
5.LIFTING MACHINE	0.00	0.00	0.00			
6.OPERATION BRIDGE	210.00	6.00	1260.00			
7.HOIST HOUSE	187.50	6.00	1125.00			
8.WATER AND EARTH	1952.64	10.00	19526.39			
9.WATER	671.94	2.00	1343.87			
10.UPLIFT	-68.97	6.00	-413.83			
11.WIND PRESSURE				28.12	19.05	535.53
12.WIND PRESSURE				16.50	31.25	515.62
13.WATER PRESSURE				1105.92	3.20	3538.94
14.WATER PRESSURE				-546.76	5.13	-2806.70
15.EARTH PRESSURE	535.93	12.00	6431.14	928.26	4.84	4495.34
TOTAL	8830.37		61149.91	1532.03		6278.74

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
11:PIER,12:HOIST HOUSE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs = \Sigma V \cdot \mu / \Sigma H =$ 3.46 ≧ $Fsa =$ 1.50

(2) STABILITY AGAINST OVERTURNING

$\chi = (\Sigma V \cdot z - \Sigma H \cdot y) / \Sigma V =$ 6.21 (m)

$e = B/2 - \chi =$ -0.21 (m) ≦ $B/6 =$ 2.00 (m)

(3) SOIL REACTION

$Q1 = \Sigma V / B / L \cdot (1 + 6 \cdot e / B) =$ 27.38 (t/m²)

$Q2 = \Sigma V / B / L \cdot (1 - 6 \cdot e / B) =$ 33.94 (t/m²)

3-7 CASE (7)

LOAD	V (T)	Z (M)	V·Z (T·M)	H (T)	Y (M)	H·Y (T·M)
1.PIER	5251.34	6.02	31597.35			
2.GATE	350.00	4.00	1400.00			
3.GATE	0.00	0.00	0.00			
4.LIFTING MACHINE	50.00	4.00	200.00			
5.LIFTING MACHINE	0.00	0.00	0.00			
6.OPERATION BRIDGE	210.00	6.00	1260.00			
7.HOIST HOUSE	187.50	6.00	1125.00			
8.WATER AND EARTH	1824.00	10.00	18240.00			
9.WIND PRESSURE				37.49	19.05	714.04
10.WIND PRESSURE				22.00	31.25	687.50
11.EARTH PRESSURE	692.97	12.00	8315.62	1200.26	4.47	5365.75
TOTAL	8565.81		62137.97	1259.75		6767.30

NOTES ; 2,4:LEFT-SIDE 3,5:RIGHT-SIDE
9:PIER,10:HOIST HOUSE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; $\mu = 0.60$

$Fs = \Sigma V \cdot \mu / \Sigma H = 4.08 \geqq Fsa = 1.50$

(2) STABILITY AGAINST OVERTURNING

$\chi = (\Sigma V \cdot z - \Sigma H \cdot y) / \Sigma V = 6.46$ (m)

$e = B/2 - \chi = -0.46$ (m) $\leqq$ $B/6 = 2.00$ (m)

(3) SOIL REACTION

$Q1 = \Sigma V / B / L \cdot (1 + 6 \cdot e / B) = 22.84$ (t/m²)

$Q2 = \Sigma V / B / L \cdot (1 - 6 \cdot e / B) = 36.64$ (t/m²)

5.11 Pile Foundation Analysis

5.11.1 Center Pier

** Case-1 **

Pile Groupe		1	2	3	4	5	6	7	8	9	10
n (Number of Piles)	(pcs.)	5	5	5	5	5	5	5	5	5	5
D (Diameter)	(mm)	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00
t (Thickness)	(mm)	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
A (Cross Section)	(m^2)	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735
I (Moment of Inertia of Pile Cross Section)	(m^4)	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2
θ (Angle Between Pile and Vertical)	(deg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xi (Coordinate of Pile Head))	(m)	9.00	7.00	5.00	3.00	1.00	-1.00	-3.00	-5.00	-7.00	-9.00
L (Length of Piles)	(m)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Kh (Coefficient of Horizontal Subgrade Reaction)	(kg/cm^3)	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
β	(m^{-1})	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47

Simultaneous Equation:

$$\begin{bmatrix} 600352. & 0. & -634546. \\ 0. & 1741473. & 0. \\ -634546. & 0. & 58809952. \end{bmatrix} \begin{bmatrix} \delta x \\ \delta y \\ \alpha \end{bmatrix} = \begin{bmatrix} 1110.00 \ (H) \\ 6920.00 \ (V) \\ 8380.00 \ (M) \end{bmatrix}$$

Displacement : $\delta x = 0.002023$ (m)
$\delta y = 0.003974$ (m)
$\alpha = 0.000164$ (rad)

		1	2	3	4	5	6	7	8	9	10
Xi (Horizontal Displacement)	(m)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Yi (Vertical Displacement)	(m)	0.005	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.003	0.002
PVi (Vertical Load)	(t/pcs.)	189.91	178.46	167.02	155.57	144.12	132.68	121.23	109.79	98.34	86.89
PHi (Horizontal Load)	(t/pcs.)	22.20	22.20	22.20	22.20	22.20	22.20	22.20	22.20	22.20	22.20
Mi (Moment)	(t·m/pcs.)	-21.26	-21.26	-21.26	-21.26	-21.26	-21.26	-21.26	-21.26	-21.26	-21.26
Σ Hi	(t)			1109.998							
Vi	(t)			6919.984							
Mi	(t·m)			8379.980							

Check of Stress		Pile Groupe - 1	Pile Groupe - 10
Compressive Stress	(kg/cm^2)	1721	1127
Tensile Stress	(kg/cm^2)	0	-126
Allowable Stress	(kg/cm^2)	1900	1900

** Case-2 **

Pile Groupe			1	2	3	4	5
n	(Number of Piles)	(pcs.)	10	10	10	10	10
D	(Diameter)	(mm)	800.00	800.00	800.00	800.00	800.00
t	(Thickness)	(mm)	9.00	9.00	9.00	9.00	9.00
A	(Cross Section)	(m^2)	0.01735	0.01735	0.01735	0.01735	0.01735
I	(Moment of Inertia of Pile Cross Section)	(m^4)	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2
θ	(Angle Between Pile and Vertical)	(deg)	0.00	0.00	0.00	0.00	0.00
Xi	(Coordinate of Pile Head))	(m)	5.00	2.50	0.00	-2.50	-5.00
L	(Length of Piles)	(m)	10.00	10.00	10.00	10.00	10.00
Kh	(Coefficient of Horizontal Subgrade Reaction)	(kg/cm^3)	0.71	0.71	0.71	0.71	0.71
β		(m^{-1})	0.47	0.47	0.47	0.47	0.47

Simultaneous Equation:

$$\begin{bmatrix} 600352. & 0. & -634546. \\ 0. & 1741473. & 0. \\ -634546. & 0. & 23109781. \end{bmatrix} \begin{bmatrix} \delta x \\ \delta y \\ \alpha \end{bmatrix} = \begin{bmatrix} 50.00\ (H) \\ 6200.00\ (V) \\ 9430.00\ (M) \end{bmatrix}$$

Displacement : $\delta x = 0.000530$ (m)

$\delta y = 0.003560$ (m)

$\alpha = 0.000423$ (rad)

			1	2	3	4	5
Xi	(Horizontal Displacement)	(m)	0.001	0.001	0.001	0.001	0.001
Yi	(Vertical Displacement)	(m)	0.006	0.005	0.004	0.003	0.001
PVi	(Vertical Load)	(t/pcs.)	197.60	160.80	124.00	87.20	50.41
PHi	(Horizontal Load)	(t/pcs.)	1.00	1.00	1.00	1.00	1.00
Mi	(Moment)	(t · m/pcs.)	4.61	4.61	4.61	4.61	4.61
Σ	Hi	(t)			50.000		
	Vi	(t)			6199.996		
	Mi	(t · m)			9429.980		

Check of Stress		Pile Groupe - 1	Pile Groupe - 5
Compressive Stress	(kg/cm^2)	1275	426
Tensile Stress	(kg/cm^2)	0	0
Allowable Stress	(kg/cm^2)	1900	1900

5. 11. 2 Abut Pier

** Case-1 **

Pile Groupe		1	2	3	4	5	6	7	8	9	10	11
n (Number of Piles)	(pcs.)	5	5	5	5	5	5	5	5	5	5	5
D (Diameter)	(mm)	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00	80.00
t (Thickness)	(mm)	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
A (Cross Section)	(m^2)	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735	0.01735
I (Moment of Inertia of Pile Cross Section)	(m^4)	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2
θ (Angle Between Pile and Vertical)	(deg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xi (Coordinate of Pile Head))	(m)	10.00	8.00	6.00	4.00	2.00	0.00	-2.00	-4.00	-6.00	-8.00	-10.00
L (Length of Piles)	(m)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Kh (Coefficient of Horizontal Subgrade Reaction)	(kg/cm^2)	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10
β	(m^{-1})	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47

Simultaneous Equation:

$$\begin{bmatrix} 660387. & 0. & -698000. \\ 0. & 1915620. & 0. \\ -698000. & 0. & 78100263. \end{bmatrix} \begin{bmatrix} \delta x \\ \delta y \\ \alpha \end{bmatrix} = \begin{bmatrix} 690.00 \ (H) \\ 8070.00 \ (V) \\ 7430.00 \ (M) \end{bmatrix}$$

Displacement : $\delta x = 0.001156$ (m)
$\delta y = 0.004213$ (m)
$\alpha = 0.000105$ (rad)

		1	2	3	4	5	6	7	8	9	10	11
Xi (Horizontal Displacement)	(m)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Yi (Vertical Displacement)	(m)	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.003
PVi (Vertical Load)	(t/pcs.)	183.46	176.11	168.77	161.43	154.07	146.73	139.38	132.03	124.69	117.34	109.99
PHi (Horizontal Load)	(t/pcs.)	12.55	12.55	12.55	12.55	12.55	12.55	12.55	12.55	12.55	12.55	12.55
Mi (Moment)	(t·m/pcs.)	-11.85	-11.85	-11.85	-11.85	-11.85	-11.85	-11.85	-11.85	-11.85	-11.85	-11.85

Σ	Hi	(t)	689.999
	Vi	(t)	8069.980
	Mi	(t·m)	7429.977

Check of Stress		Pile Groupe - 1	Pile Groupe - 11
Compressive Stress	(kg/cm^2)	1406	983
Tensile Stress	(kg/cm^2)	0	0
Allowable Stress	(kg/cm^2)	1900	1900

** Case-2 **

Pile Groupe			1	2	3	4	5
n	(Number of Piles)	(pcs.)	11	11	11	11	11
D	(Diameter)	(mm)	800.00	800.00	800.00	800.00	800.00
t	(Thickness)	(mm)	9.00	9.00	9.00	9.00	9.00
A	(Cross Section)	(m^2)	0.01735	0.01735	0.01735	0.01735	0.01735
I	(Moment of Inertia of Pile Cross Section)	(m^4)	0.135E-2	0.135E-2	0.135E-2	0.135E-2	0.135E-2
θ	(Angle Between Pile and Vertical)	(deg)	0.00	0.00	0.00	0.00	0.00
Xi	(Coordinate of Pile Head)	(m)	5.00	2.50	0.00	-2.50	-5.00
L	(Length of Piles)	(m)	10.00	10.00	10.00	10.00	10.00
Kh	(Coefficient of Horizontal Subgrade Reaction)	(kg/cm^3)	0.71	0.71	0.71	0.71	0.71
β		(m^{-1})	0.47	0.47	0.47	0.47	0.47

Simultaneous Equation:

$$\begin{bmatrix} 660387. & 0. & -698000. \\ 0. & 1915620. & 0. \\ -698000. & 0. & 25420759. \end{bmatrix} \begin{bmatrix} \delta x \\ \delta y \\ \alpha \end{bmatrix} = \begin{bmatrix} 1380.00 \ (H) \\ 7460.00 \ (V) \\ 10300.00 \ (M) \end{bmatrix}$$

Displacement : $\delta x = 0.002593$ (m), $\delta y = 0.003894$ (m), $\alpha = 0.000476$ (rad)

			1	2	3	4	5
Xi	(Horizontal Displacement)	(m)	0.003	0.003	0.003	0.003	0.003
Yi	(Vertical Displacement)	(m)	0.006	0.005	0.004	0.003	0.002
PVi	(Vertical Load)	(t/pcs.)	218.60	177.12	135.64	94.16	52.68
PHi	(Horizontal Load)	(t/pcs.)	25.09	25.09	25.09	25.09	25.09
Mi	(Moment)	(t·m/pcs.)	-20.13	-20.13	-20.13	-20.13	-20.13
Σ	Hi	(t)			1379.999		
	Vi	(t)			7459.992		
	Mi	(t·m)			10299.988		

Check of Stress		Pile Groupe - 1	Pile Groupe - 5
Compressive Stress	(kg/cm^2)	1853	897
Tensile Stress	(kg/cm^2)	0	-290
Allowable Stress	(kg/cm^2)	1900	1900

FIGURE 5 - 2 BORE-HOLE LOGS FOR PIERS

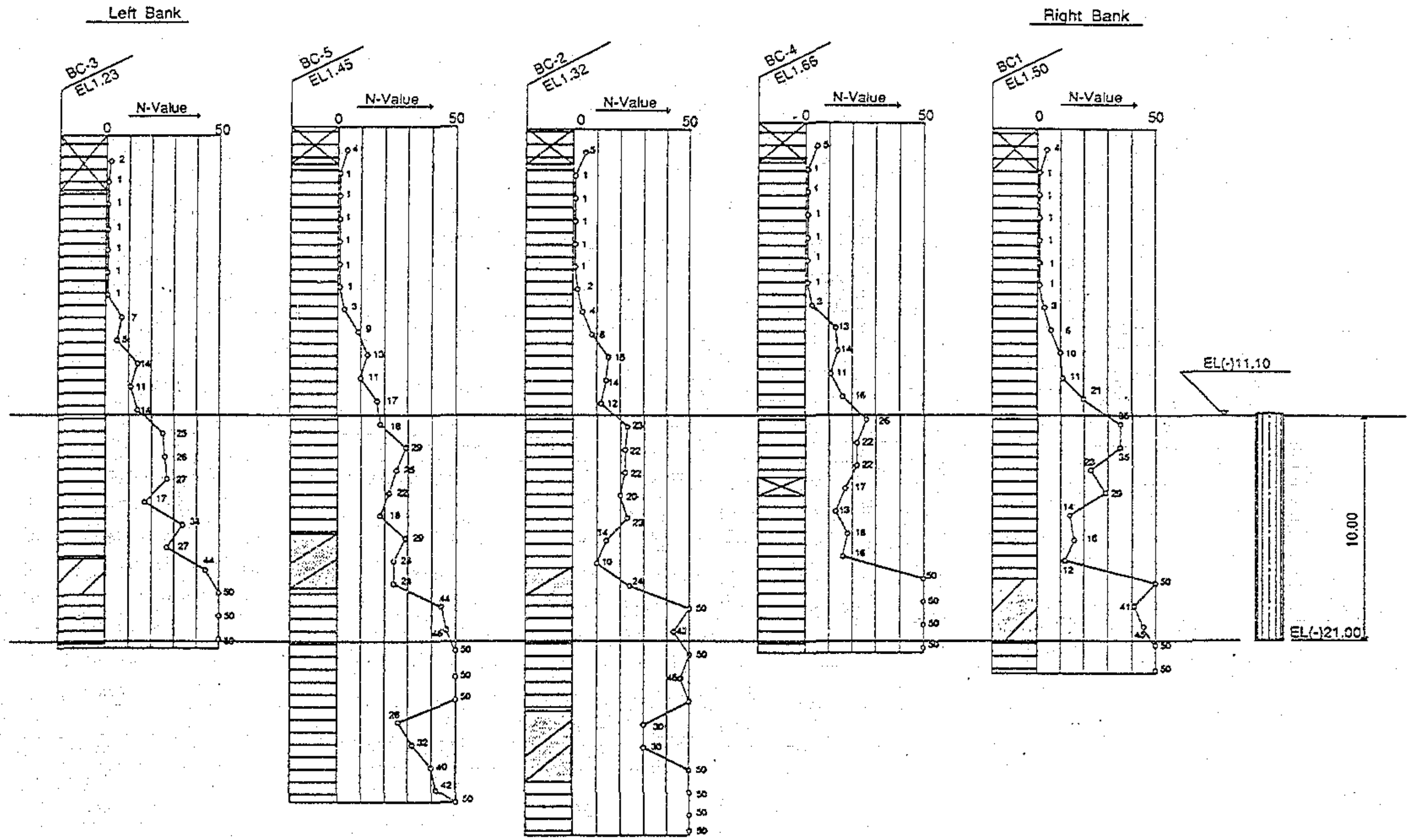
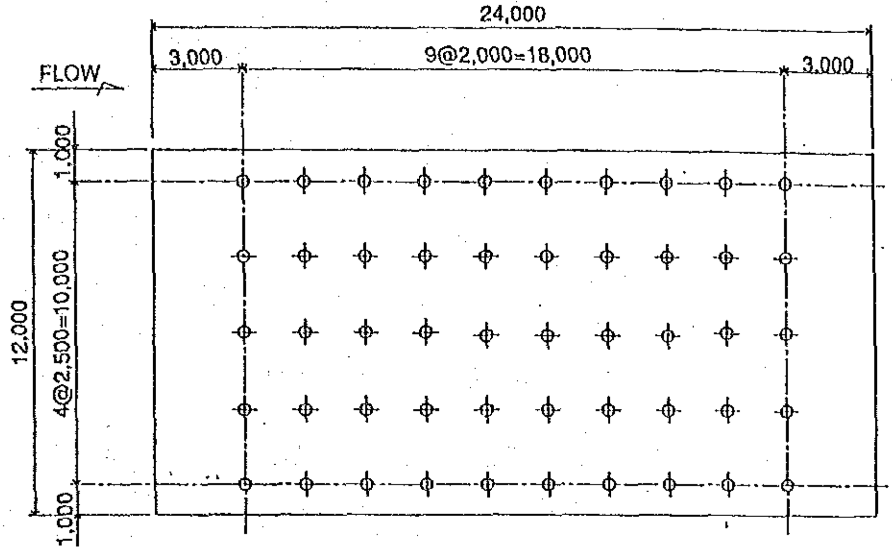


FIGURE 5-3 PILE ARRANGEMENT FOR PIERS

Center Pier



Abut Pier

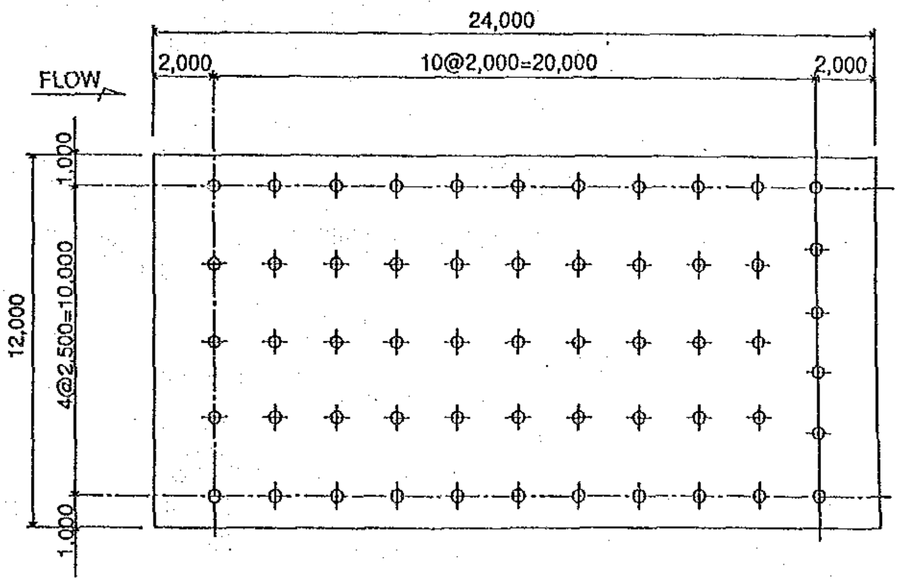
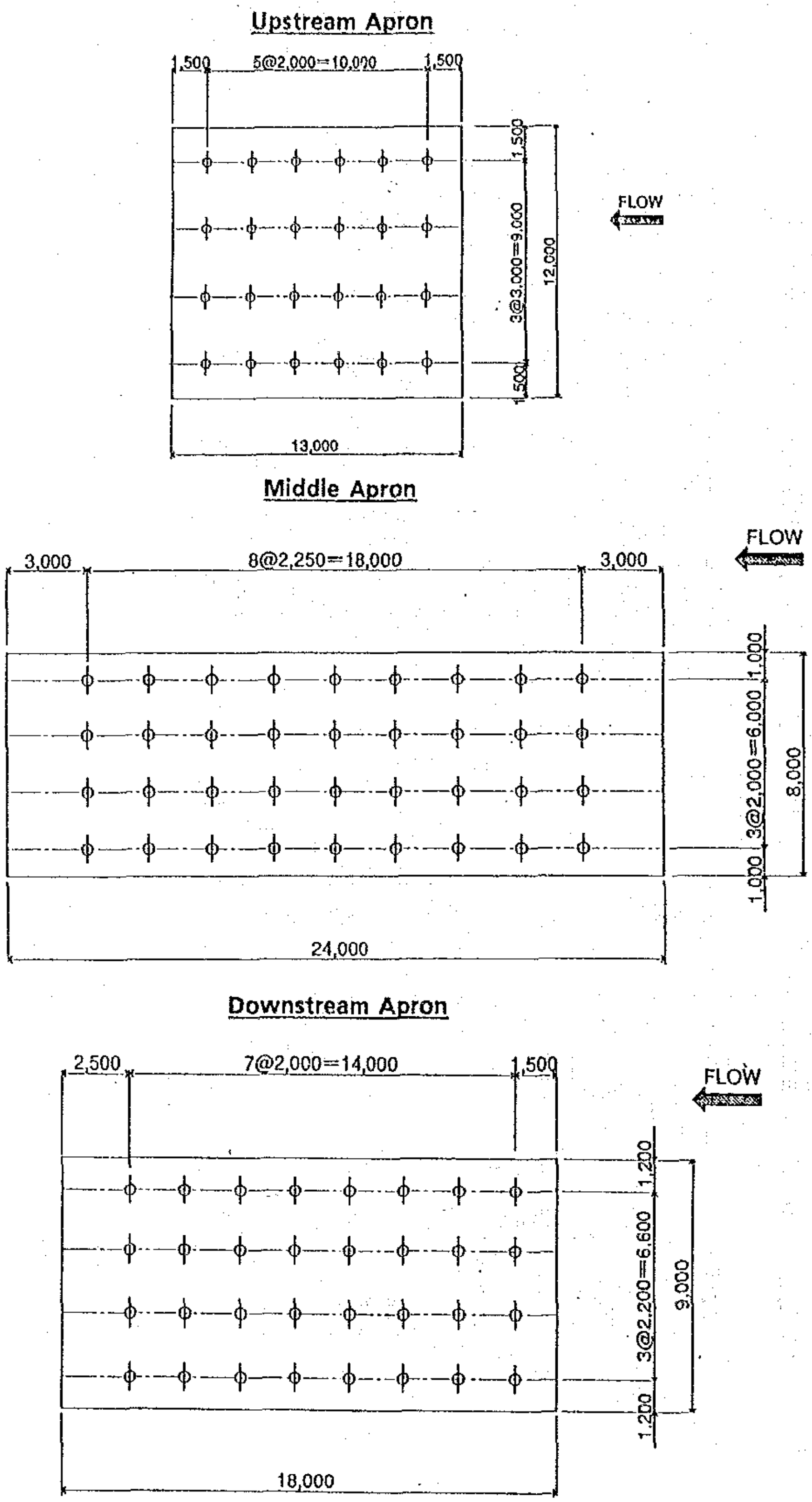


FIGURE 5-4 PILE ARRANGEMENT FOR APRON



5. 12 Stability and structural Analysis of Retaining Wall

5. 12. 1 Stability Analysis

1) Type W1-1 Wall

1. DESIGN CRITERIA

1-1 TYPE OF WALL ; TYPE W1-1

1-2 DIMENSIONS(M)

H1 = 10.50	H2 = 1.50	H3 = 1.50	H4 = 1.00	H5 = 1.00
H6 = 0.50	L1 = 2.00	L2 = 0.50	L3 = 4.00	B = 3.00
T = 1.00	H0 = 0.00	X1 = 0.00	XN = 0.00	

WATER LEVEL(REAR) WL1 = 11.00
(FRONT) WL2 = 8.90

1-3 DEAD LOADS (T/M3)

REINFORCED CONCRETE ; RC = 2.40
WET EARTH ; RS = 1.80
SATURATED EART ; RW = 2.00
WATER ; WO = 1.00

1-4 COEFFICIENT OF ACTIVE EARTH PESSURE ; KA = 0.355 (0.367)

1-5 LIVE LOAD ; Q= 1.00 (T/M2)

2. DEAD LOAD AND CENTER OF GRAVITY

N	W (T)	X (M)	W·X (T·M)	Y (M)	H·Y (T·M)
1	37.80	2.25	85.05	6.75	255.15
2	0.00	1.33	0.00	1.50	0.00
3	21.60	1.00	21.60	0.75	16.20
4	5.40	2.25	12.15	0.75	4.05
5	0.60	2.67	1.60	1.17	0.70
6	28.80	4.50	129.60	0.50	14.40
7	48.00	3.83	184.00	4.33	208.00
	142.20		434.00		498.50

2-1 X-DIRECTION

X = W·X/W = 434.00 / 142.20 = 3.05 (M)

2-2 Y-DIRECTION

Y = W·Y/W = 498.50 / 142.20 = 3.51 (M)

3.CHECK OF STABILITY

LOAD	V (T)	X (M)	V·X (T·M)	H (T)	Y (M)	H·Y (T·M)
1.WALL	142.20	3.05	434.00			
2.EARTH AND WATER	320.85	4.63	1485.32			
3.EARTH AND WATER	44.40	1.00	44.40			
4.LIVE LOAD	12.00	4.50	54.00			
5.EMBANKMENT	0.00	0.00	0.00			
6.BUOYANCY	-54.60	3.12	-170.37			
7.EARTH PRESSURE	69.19	6.50	449.73			
8.EARTH PRESSURE				148.38	4.13	612.79
9.WATER PRESSURE				181.50	3.67	665.50
10.WATER PRESSURE				-118.81	2.97	-352.48
TOTAL	534.04		2297.09	211.06		925.81

NOTES ; 2,9;REAR SIDE,3,10;FRONT SIDE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; $\mu = 0.60$

$Fs = \mu \cdot \Sigma V / \Sigma H = 1.52$

(2) STABILITY AGAINST OVERTURNING

$\chi = (\Sigma V \cdot x - \Sigma H \cdot y) / \Sigma V = 2.57$ (m)

$e = L/2 - \chi = 0.68$ (m) $L/6 = 1.08$ (m)

(3) SOIL REACTION

$Q1 = \Sigma V / L / B \times (1 + 6e/L) = 44.63$ (t/m²)

$Q2 = \Sigma V / L / B \times (1 + 6e/L) = 10.14$ (t/m²)

2) Type W2-1 Wall

1. DESIGN CRITERIA

1-1 TYPE OF WALL ; TYPE W2-1

1-2 DIMENSIONS(M)

H1 =	11.00	H2 =	1.00	H3 =	1.00	H4 =	1.00	H5 =	1.00
H6 =	0.50	L1 =	0.00	L2 =	0.50	L3 =	6.50	B =	3.93
T =	1.00	H0 =	0.00	X1 =	0.00	XN =	0.00		

WATER LEVEL(REAR) WL1 = 11.00
(FRONT) WL2 = 8.90

1-3 DEAD LOADS (T/M3)

REINFORCED CONCRETE ; RC = 2.40
WET EARTH ; RS = 1.80
SATURATED EART ; RW = 2.00
WATER ; WO = 1.00

1-4 COEFFICIENT OF ACTIVE EARTH PESSURE ; KA = 0.355 (0.367)

1-5 LIVE LOAD ; Q= 1.00 (T/M2)

2. DEAD LOAD AND CENTER OF GRAVITY

N	W (T)	X (M)	W·X (T·M)	Y (M)	H·Y (T·M)
1	51.88	0.25	12.97	6.50	337.19
2	0.00	0.00	0.00	1.00	0.00
3	0.00	0.00	0.00	0.50	0.00
4	4.72	0.25	1.18	0.50	2.36
5	0.88	0.67	0.59	1.17	1.03
6	61.31	3.75	229.91	0.50	30.65
7	78.00	2.67	208.01	4.33	338.00
	196.78		452.66		709.23

2-1 X-DIRECTION

X = W·X/W = 452.66 / 196.78 = 2.30 (M)

2-2 Y-DIRECTION

Y = W·Y/W = 709.23 / 196.78 = 3.60 (M)

3.CHECK OF STABILITY

LOAD	V (T)	X (M)	V·X (T·M)	H (T)	Y (M)	H·Y (T·M)
1.WALL	196.78	2.30	452.66			
2.EARTH AND WATER	713.73	3.90	2785.76			
3.EARTH AND WATER	0.00	0.00	0.00			
4.LIVE LOAD	25.54	3.75	95.80			
5.EMBANKMENT	0.00	0.00	0.00			
6.BUOYANCY	-75.90	2.46	-187.08			
7.EARTH PRESSURE	90.64	7.00	634.48			
8.EARTH PRESSURE				194.38	4.13	802.75
9.WATER PRESSURE				237.76	3.67	871.80
10.WATER PRESSURE				-155.65	2.97	-461.75
TOTAL	950.80		3781.61	276.49		1212.80

NOTES ; 2,9;REAR SIDE,3,10;FRONT SIDE

(1) FACTOR OF SAFETY AGAINST SLIDING

· COEFFICIENT OF FRICTION ; μ= 0.60

$Fs=\mu\cdot\Sigma V/\Sigma H=$ 2.06

(2) STABILITY AGAINST OVERTURNING

$\chi=(\Sigma V\cdot x-\Sigma H\cdot y)/\Sigma V=$ 2.70 (m)

$e=L/2-\chi=$ 0.80 (m) $L/6=$ 1.17 (m)

(3) SOIL REACTION

$Q1=\Sigma V/L/B\times(1+6e/L)=$ 58.21 (t/m²)

$Q2=\Sigma V/L/B\times(1+6e/L)=$ 10.91 (t/m²)

3) Type W3 Wall

1. DESIGN CRITERIA

1-1 TYPE OF WALL ; TYPE W-3

1-2 DIMENSIONS (M)

H1=0.60	H2=0.60	H3=0.60	H4=6.40	H5=0.60
B1=0.30	B2=0.80	B3=0.60	B4=2.10	BT=3.50
HT=7.00	X1=0.00	H0=0.00		

WATER LEVEL(HRONT) WL1=7.00

(REAR) WL2=7.00

1-3 DEAD LOADS (T/M^3)

REINFORCED CONCRETE ; RC=2.40 WET EARTH ; RS=1.80

SATURATED EARTH ; RW=2.00 WATER ; W0=1.00

1-4 COEFFICIENT OF ACTIVE EARTH PRESSURE ; KA=0.355 (0.367)

1-5 LIVE LOAD ; Q= 0.30 (T/M^2)

2. CHECK OF STABILITY

LOAD	V (T)	X (M)	V・X (T・M)	H (T)	Y (M)	H・Y (T・M)
WALL	11.95	1.34	15.96			
EARTH AND WATER	28.80	2.37	68.35			
LIVE LOAD	0.72	2.30	1.66			
BUOYANCY	-19.38	1.75	-33.91			
EARTH PRESSURE	3.99	3.50	13.97			
EARTH PRESSURE				8.56	2.43	20.77
TOTAL	26.09		66.03	8.56		20.77

(1) FACTOR OF SAFETY AGAINST SLIDING

$FS=\mu \cdot \Sigma V / \Sigma H=1.85 \geqq FSA=1.5$

(2) STABILITY AGAINST OVERTURNING

$\chi = (\Sigma V \cdot x - \Sigma H \cdot y) / \Sigma V=1.74$ (m)

$e = B/2 - \chi = 0.01$ (m) $\leqq$ $B/6 = 0.58$ (m)

(3) SOIL REACTION

$Q1 = \Sigma V/B\ (1+6e/B) = 7.64$ (t/m^2)

$Q2 = \Sigma V/B\ (1-6e/B) = 7.26$ (t/m^2)