5.9 Calculation of Energy Output

B) Dam Scheme

For the calculation of annual electric energy output in a feasibility study level, it is normally accepted to adopt monthly discharges after seasonal regulation by the available effective storage of the reservoir.

In order to get the monthly discharges thus available for power generation, normally the mass curve method is applied. In this Matuno project study the same method is applied considering the irrigation water requirement in the downstream reaches.

For the economic comparison, the four different effective storage capacities were examined. They are shown below:

	High Water Level (EL. m)	Low Water Level (EL. m)	Effective Storage (10^6m^3)
Case I	525	480	116
Case II	520	480	97
Case III	510	480	64
Case IV	500	480	37

The available monthly discharges after regulation with the above effective storage capacity were calculated and the mass curves for the analyses are shown in the attached Fig. 5-7 to Fig. 5-10 and Table 5-4 to 5-13 using the 20 years' data from 1957 to 1976.

The results of annual energy calculation are shown in the following table:

High Water Level (EL. m)	Annual Energy (GWh)	Annual Mean Power (kW)
525	536.0	60,800
520	527.8	59,900
510	510.8	58,000
500	491.5	55,800

The annual average power output is about 60 MW, so that the installed capacity was planned to be 180 MW taking into consideration of the plant factor of 0.33 for the Luzon Grid as explained in the Interim Report.

As for the firm energy output, the probable droughty year occurred once in 10 years is adopted. The balance between the total annual energy and the firm energy is taken as the secondary energy. The breakdown for each case is shown in the following table.

	HWL (EL. m)	Firm Energy (GWh)	Secondary Energy (GWh)	Annual Total (GWh)
Case I	525	359.1	176.9	536.0
Case II	520	353.6	174.2	527.8
Case III	510	342.2	168.6	510.8
Case IV	500	329.3	162.2	491.5

B_2 Dam Scheme

By the same method, energy output for B_2 dam scheme is calculated as shown below.

Case	N.H.W.L.(m)	L.W.L.(m)	T.W.L.(m)	E(G.W.h.)
1	500.00	475.00	300.00	394.4
2	490.00	475.00	300.00	369.4
3	480.00	475.00	300.00	343.1

Table 5-1 Relation Between Overflow Depth and Discharge

(In case of free flow)

Reservoir Water Level (m)	H (m)	Discharge Coeffi- cient C	Adjusted Dis- charge Coeffi- cient C'	$H^{3/2}$	Discharge $Q=nC'BH^{3/2}$ (m^3/sec.)	
					n = 1	n = 4
504.0	0					
505.0	1.0	1.74	1.74	1.00	20.63	83.52
506.0	2.0	1.78	1.78	2.83	60.45	241.80
507.0	3.0	1.81	1.81	5.20	112.95	451.78
508.0	4.0	1.84	1.83	8.00	175.68	702.72
509.0	5.0	1.88	1.87	11.18	250.88	1,003.52
510.0	6.0	1.91	1.90	14.70	335.16	1,340.64
511.0	7.0	1.94	1.93	18.52	428.92	1,715.69
512.0	8.0	1.97	1.95	22.63	529.54	2,118.17
513.0	9.0	2.00	1.98	27.00	641.52	2,566.08
514.0	10.0	2.04	2.02	31.62	766.47	3,065.88
515.0	11.0	2.07	2.04	36.48	893.03	3,572.13
516.0	12.0	2.10	2.06	41.57	1,027.61	4,110.44
517.0	13.0	2.12	2.08	46.87	1,169.88	4,679.50
518.0	14.0	2.15	2.11	52.38	1,326.26	5,305.05
519.0	15.0	2.18	2.13	58.09	1,484.78	5,939.12
520.0	16.0	2.21	2.16	64.0	1,658.88	6,635.52
521.0	17.0	2.24	2.18	70.09	1,833.56	7,334.22
522.0	18.0	2.27	2.21	76.37	2,025.33	8,101.32
523.0	19.0	2.29	2.22	82.82	2,206.33	8,825.32
524.0	20.0	2.32	2.25	89.44	2,414.88	9,659.52
524.7	20.7	2.36	2.28	94.18	2,576.76	10,307.04

Note: n is the number of gates.

Table 5-2 Relation Between Gates Opening Depth and Discharge

(In case of pressure flow)

Reservoir Water Level (m)	a (m)	H/a	C	Discharge (m^3/sec) $Q = nCab\sqrt{2g\,(H - a/2)}$				
				n = 1	n = 2	n = 3	n = 4	
520.0	0							
520.0	1.0	16.00	0.78	163.14	326.28	489.42	652.57	
520.0	2.0	8.00	0.77	316.87	633.74	950.61	1,267.48	
520.0	3.0	5.33	0.74	449.10	898.20	1,347.30	1,796.40	
520.0	4.0	4.00	0.71	612.24	1,224.48	1,836.72	2,448.96	
520.0	5.0	3.20	0.68	663.67	1,327.34	1,991.01	2,554.68	
520.0	6.0	2.67	0.67	770.03	1,540.06	2,310.09	3,080.12	
520.0	7.0	2.29	0.65	854.63	1,709.26	2,563.89	3,418.52	
520.0	8.0	2.00	0.64	942.26	1,884.52	2,826.78	3,769.04	
520.0	9.0	1.78	0.63	1,021.51	2,043.02	3,064.53	4,086.04	
520.0	10.0	1.60	0.61	1,074.82	2,149.64	3,224.46	4,299.28	
520.0	11.0	1.45	0.60	1,136.18	2,272.36	3,408.54	4,544.72	
520.0	12.0	1.33	0.59	1,189.44	2,378.88	3,568.32	4,757.76	pressure flow
520.0	13.0	1.23	0.58	1,234.65	2,469.30	3,703.95	4,938.60	
520.0	14.0	1.14	0.57	1,271.84	2,543.68	3,815.52	5,087.36	
520.0	15.0	1.07	0.56	1,301.06	2,602.12	3,903.18	5,204.24	
520.0	16.0			1,658.88	3,317.76	4,976.64	6,635.52	free flow
521.0	17.0			1,833.56	3,667.12	5,500.68	7,334.24	
522.0	18.0			2,025.33	4,050.66	6,075.99	8,101.32	
523.0	19.0			2,206.33	4,412.66	6,618.99	8,825.32	
524.0	20.0			2,414.88	4,829.76	7,244.64	9,659.52	
524.7	20.7			2,576.76	5,153.52	7,730.28	10,307.04	

Note: n is the number of gates.

Table 5-3 Relation Between Gate Opening Time and Discharge

R.W.L. (m)	T (min)	Gate Opening (m)				Discharge (m^3/sec)				
		No.2	No.3	No.1	No.4	Gate No.2	Gate No.3	Gate No.1	Gate No.4	Total
520.0	1.0	1.0	0	0	0	163.14	0	0	0	163.14
"	2.0	2.0	1.0	0	0	316.87	163.14	0	0	480.61
"	3.0	3.0	2.0	1.0	0	449.10	316.87	163.14	0	929.11
"	4.0	4.0	3.0	2.0	1.0	612.24	449.10	316.87	163.14	1,541.35
"	5.0	5.0	4.0	3.0	2.0	663.67	612.24	449.10	316.87	2,041.88
"	6.0	6.0	5.0	4.0	3.0	770.03	63.67	612.24	449.10	2,495.04
"	7.0	7.0	6.0	5.0	4.0	854.63	770.03	663.67	612.24	2,900.57
"	8.0	8.0	7.0	6.0	5.0	942.26	854.63	770.03	663.67	3,230.59
"	9.0	9.0	8.0	7.0	6.0	1,021.51	942.26	854.63	770.03	3,588.43
"	10.0	10.0	9.0	8.0	7.0	1,074.82	1,021.51	942.26	854.63	3,893.22
"	11.0	11.0	10.0	9.0	8.0	1,136.18	1,074.82	1,021.51	942.26	4,174.77
"	12.0	12.0	11.0	10.0	9.0	1,189.44	1,136.18	1,074.82	1,021.51	4,421.95
"	13.0	13.0	12.0	11.0	10.0	1,234.65	1,189.44	1,136.18	1,074.82	4,635.09
"	14.0	14.0	13.0	12.0	11.0	1,271.84	1,234.65	1,189.44	1,136.18	4,832.11
"	15.0	15.0	14.0	13.0	12.0	1,301.06	1,271.84	1,234.65	1,189.44	4,996.99
"	16.0	16.0	15.0	14.0	13.0	1,658.88	1,301.06	1,271.84	1,234.65	5,466.43
521.0	17.0		16.0	15.0	14.0	1,833.56	1,658.88	1,301.06	1,271.84	6,065.34
522.0	18.0			16.0	15.0	2,025.33	1,833.56	1,658.88	1,301.06	6,818.83
523.0	19.0				16.0	2,206.33	2,025.33	1,833.56	1,658.88	7,724.10
524.0	20.0					2,414.88	2,206.33	2,025.33	1,833.56	8,480.10
524.7	21.0					2,576.76	2,414.88	2,206.33	2,025.33	9,223.30
"	22.0					"	2,576.76	2,414.88	2,206.33	9,774.73
"	23.0					"	"	2,576.76	2,414.88	10,145.16
"	24.0					"	"	"	2,576.76	10,307.04

Remarks: When the large inflow like design flood enters the reservoir, the gates should be operated in the first time from the middle part of G_2 or G_3 as shown in Fig. 5-2. And the opening difference of adjoining gates are set to be 1.0 m, while the gate opening speed is decided to be 1.0 m per minutes.

Table 5-4 Calculation of Energy Output

Year	Inflow (m3/sec)	Available Discharge (m3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1957				
Jan.	34.86	34.86	520.0	44.70
Feb.	22.90	27.00	517.0	30.81
Mar.	20.41	"	511.5	33.18
Apr.	20.39	"	505.5	31.13
May	18.88	"	496.5	30.64
June	17.71	"	484.0	27.61
July	25.18	"	481.0	28.02
Aug.	30.52	"	487.0	31.12
Sept.	47.47	"	509.0	31.70
Oct.	36.08	27.00	516.5	34.03
Nov.	38.81	27.00(11 days) 38.80(19 days)	520.0	12.29 30.50
Dec.	26.67	28.80	518.5	36.66
Sub-Total:				402.39
1958				
Jan.	22.75	28.80	513.5	35.76
Feb.	21.32	"	507.5	31.32
Mar.	20.77	"	499.0	33.14
Apr.	22.09	"	491.0	30.67
May	22.45	"	481.0	29.89
June	28.63	"	480.5	28.84
July	29.57	28.80	482.0	30.07
Aug.	100.9	28.80(15 days) 100.90(16 days)	520.0	17.78 66.78
Sept.	64.65	64.65	"	80.23
Oct.	100.9	100.90	"	129.38
Nov.	58.11	58.11	"	72.11
Dec.	34.67	34.67	520.0	44.46
Sub-Total:				630.52

Table 5-5 Calculation of Energy Output

Year	Inflow (m^3/sec)	Available Discharge (m^3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1959				
Jan.	28.39	28.39	520.0	36.40
Feb.	22.38	25.60	517.7	29.33
Mar.	25.30	"	517.5	32.43
Apr.	16.43	"	510.0	30.21
May	22.68	"	507.5	30.82
June	14.33	"	495.0	27.88
July	18.23	"	485.0	27.21
Aug.	23.61	"	482.0	26.73
Sept.	37.48	"	498.0	28.35
Oct.	36.64	25.60	509.5	31.14
Nov.	63.10	25.60(10 days) 63.10(20 days)	519.5 520.0	10.56 52.20
Dec.	69.41	69.41	520.0	89.00
Sub-Total:				452.26
1960				
Jan.	44.79	44.79	520.0	57.43
Feb.	50.63	50.63	520.0	60.73
Mar.	37.35	42.00	516.5	52.93
Apr.	30.51	"	506.5	48.68
May	27.96	"	490.5	46.09
June	35.58	"	480.5	42.05
July	41.84	42.00	480.0	43.32
Aug.	98.74	42.00(20 days) 98.70(11 days)	520.0	34.75 44.93
Sept.	56.70	56.70	520.0	70.36
Oct.	59.26	59.26	520.0	75.99
Nov.	33.94	33.94	520.0	42.12
Dec.	18.54	20.60	517.5	26.09
Sub-Total:				645.47

Table 5-6 Calculation of Energy Output

Year	Inflow (m^3/sec)	Available Discharge (m^3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1961				
Jan.	11.05	20.60	510.5	25.19
Feb.	7.54	"	498.3	21.33
Mar.	16.62	"	493.5	22.99
Apr.	14.23	"	484.3	21.10
May	18.32	"	480.5	21.31
June	23.88	"	486.0	21.31
July	29.17	"	497.5	23.51
Aug.	29.72	"	507.0	24.74
Sept.	36.05	20.60	520.0	25.56
Oct.	61.85	61.85	520.0	79.31
Nov.	21.48	21.48	520.0	26.66
Dec.	16.10	22.60	515.0	28.27
Sub-Total:				341.28
1962				
Jan.	11.27	22.60	504.0	26.71
Feb.	8.97	"	489.5	22.27
Mar.	18.23	"	483.0	23.74
Apr.	25.80	"	488.0	23.66
May	21.16	"	485.5	24.09
June	20.35	22.60	482.0	22.83
July	78.25	22.60(19 days) 78.25 (12 days)	519.0 520.0	17.68 38.84
Aug.	48.08	48.08	520.0	61.65
Sept.	52.22	52.22	"	64.80
Oct.	34.56	34.56	"	44.32
Nov.	65.90	65.90	"	81.78
Dec.	29.49	30.90	519.0	39.43
Sub-Total:				491.80

Table 5-7 Calculation of Energy Output

Year	Inflow (m³/sec)	Available Discharge (m³/sec)	Reservoir Warter Level (m)	Energy Output (GWH)
1963				
Jan.	21.82	30.90	511.5	37.98
Feb.	32.04	"	512.3	34.44
Mar.	24.91	"	507.0	37.10
Apr.	18.88	"	494.0	33.47
May	22.03	"	480.0	31.87
June	61.30	20.90	515.0	37.41
July	48.90	30.90(11 days) 48.90(20 days)	520.0	14.06 40.45
Aug.	76.63	76.63	"	98.26
Sept.	86.20	86.20	"	106.97
Oct.	47.08	47.08	"	60.37
Nov.	30.32	30.32	"	37.63
Dec.	56.25	56.25	520.0	72.13
Sub-Total:				642.14
1964				
Jan.	16.87	27.90	511.0	34.20
Feb.	16.93	"	501.0	30.36
Mar.	21.65	"	493.5	31.14
Apr.	19.16	"	480.5	27.93
May	29.54	"	483.5	29.39
June	42.47	27.90	503.0	31.74
July	55.11	27.90(23 days) 55.11 (8 days)	520.0	26.54 18.24
Aug.	77.20	77.20	520.0	98.99
Sept.	66.48	66.48	"	82.50
Oct.	86.34	86.34	"	110.71
Nov.	94.90	94.90	"	117.77
Dec.	73.60	73.60	520.0	94.38
Sub-Total:				733.89

Table 5-8 Calculation of Energy Output

Year	Inflow (m^3/sec)	Available Discharge (m^3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1965				
Jan.	67.46	67.46	520.0	86.50
Feb.	39.01	39.01	520.0	45.18
Mar.	21.06	33.00	510.0	40.25
Apr.	18.88	"	495.5	36.04
May	22.01	"	479.0	33.83
June	33.38	"	480.0	32.94
July	46.95	"	499.5	38.07
Aug.	26.64	33.00	492.5	36.63
Sept.	69.81	33.00(24 days) 69.81 (7 days)	520.0	32.76 20.21
Oct.	45.22	45.22	520.0	57.99
Nov.	32.53	32.53	520.0	40.37
Dec.	21.58	28.00	515.0	35.03
Sub-Total:				535.80
1966				
Jan.	27.16	28.00	514.3	34.90
Feb.	22.07	"	510.0	30.84
Mar.	19.16	"	500.5	32.48
Apr.	13.24	28.00	481.0	28.12
May	80.03	28.00(21 days) 80.03(10 days)	519.5 520.0	24.26 33.10
June	25.93	31.50	516.0	38.32
July	28.34	"	515.0	39.40
Aug.	30.20	"	512.0	38.81
Sept.	19.65	"	501.0	35.46
Oct.	16.25	31.50	479.0	32.29
Nov.	96.65	31.50(17 days) 96.65(13 days)	519.0 520.0	22.04 51.97
Dec.	46.01	46.01	520.0	59.00
Sub-Total:				500.99

Table 5-9 Calculation of Energy Output

Year	Inflow (m^3/sec)	Available Discharge (m^3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1967				
Jan.	25.37	28.50	517.5	36.10
Feb.	15.28	"	507.0	30.91
Mar.	9.26	"	483.5	30.02
Apr.	26.64	"	480.0	28.45
May	36.12	28.50	492.0	31.54
June	85.04	28.50(15 days) 85.04(15 days)	519.0 520.0	17.60 52.76
July	69.52	69.52	520.0	89.15
Aug.	56.09	56.09	"	71.92
Sept.	69.40	69.40	"	86.12
Oct.	67.66	67.66	"	86.76
Nov.	80.95	80.95	"	100.45
Dec.	18.75	18.75	520.0	24.04
Sub-Total:				685.82
1968				
Jan.	58.03	58.03	520.0	74.41
Feb.	11.77	23.00	512.0	26.51
Mar.	13.76	"	502.5	26.97
Apr.	13.17	"	490.5	24.42
May	16.58	"	480.5	23.80
June	44.99	23.0	508.0	26.87
July	99.66	23.00 (5 days) 99.66(26 days)	518.5 520.0	4.72 107.18
Aug.	70.41	70.41	520.0	90.29
Sept.	70.08	70.08	"	86.96
Oct.	28.99	28.99	"	37.17
Nov.	13.91	13.91	"	17.26
Dec.	8.50	8.50	520.0	10.90
Sub-Total:				557.46

Table 5-10 Calculation of Energy Output

Year	Inflow (m^3/sec)	Available Discharge (m^3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1969				
Jan.	6.50	6.50	520.0	8.33
Feb.	- 0.46	10.10	512.3	11.26
Mar.	- 0.06	"	502.5	11.84
Apr.	3.54	"	495.0	11.00
May	8.17	"	493.0	11.24
June	1.85	"	480.5	10.11
July	39.99	10.10	515.0	12.63
Aug.	50.93	10.10 (4 days) 50.93(27 days)	519.0 520.0	1.66 56.88
Sept.	62.32	62.32	520.0	77.34
Oct.	59.03	59.03	"	75.69
Nov.	25.73	25.73	"	31.93
Dec.	25.30	25.30	520.0	32.44
Sub-Total:				352.35
1970				
Jan.	11.46	11.46	520.0	14.70
Feb.	2.54	13.30	512.0	14.80
Mar.	3.68	"	503.0	15.64
Apr.	5.06	"	593.5	14.37
May	4.46	"	480.0	13.72
June	39.57	13.30	511.5	15.82
July	28.56	13.30(22 days) 28.56 (9 days)	520.0	12.10 10.63
Aug.	55.65	55.65	520.0	71.36
Sept.	30.60	30.60	"	37.97
Oct.	98.83	98.83	"	126.73
Nov.	72.41	72.41	"	89.86
Dec.	39.42	39.42	520.0	50.55
Sub-Total:				488.25

Table 5-11 Calculation of Energy Output

Year	Inflow (m^3/sec)	Available Discharge (m^3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1971				
Jan.	24.35	33.30	513.0	41.24
Feb.	25.81	"	507.0	36.12
Mar.	30.22	"	503.5	39.26
Apr.	19.42	"	487.0	34.65
May	31.26	"	483.5	35.08
June	31.15	"	480.0	33.24
July	44.25	"	496.0	37.69
Aug.	56.49	33.30	518.0	42.28
Sept.	46.54	33.30 (5 days) 46.54(25 days)	520.0	6.89 48.13
Oct.	100.90	100.90	"	129.38
Nov.	72.93	72.93	"	90.50
Dec.	57.57	57.57	520.0	73.82
Sub-Total:				648.28
1972				
Jan.	40.12	40.12	520.0	51.45
Feb.	20.43	26.00	416.0	30.58
Mar.	15.70	"	507.0	31.22
Apr.	13.19	"	493.0	28.00
May	18.93	"	482.5	27.23
June	24.96	26.00	480.0	25.95
July	100.90	26.00(15 days) 100.90(16 days)	520.0	16.13 66.78
Aug.	79.47	79.47	520.0	101.90
Sept.	100.68	100.68	"	124.94
Oct.	31.37	31.37	"	40.23
Nov.	30.22	30.22	"	37.50
Dec.	17.32	17.32	520.0	22.21
Sub-Total:				604.12

Table 5-12 Calculation of Energy Output

Year	Inflow (m^3/sec)	Available Discharge (m^3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1973				
Jan.	8.37	15.70	514.0	19.54
Feb.	9.81	"	509.5	17.25
Mar.	7.69	"	501.2	18.28
Apr.	3.64	"	487.0	16.34
May	11.83	"	480.0	16.19
June	15.83	"	480.5	15.72
July	23.18	"	492.0	17.38
Aug.	29.02	15.70	507.0	18.85
Sept.	49.92	15.70(14 days) 49.92(16 days)	520.0	9.09 33.04
Oct.	100.90	100.90	"	129.38
Nov.	77.34	77.34	"	95.97
Dec.	48.92	48.92	520.0	62.73
Sub-Total:				469.76
1974				
Jan.	28.26	28.26	520.0	36.24
Feb.	19.42	23.00	517.5	26.31
Mar.	5.96	"	501.7	26.85
Apr.	10.87	"	487.0	23.94
May	19.06	"	480.5	23.80
June	45.76	23.00	508.2	26.89
July	64.63	23.00(10 days) 64.63(21 days)	519.5 520.0	9.49 56.14
Aug.	72.64	72.64	520.0	93.15
Sept.	26.62	26.62	"	33.03
Oct.	45.25	45.25	"	58.02
Nov.	48.36	48.36	"	60.01
Dec.	48.25	48.25	520.0	61.87
Sub-Total:				535.74

Table 5-13 Calculation of Energy Output

Year	Inflow (m^3/sec)	Available Discharge (m^3/sec)	Reservoir Water Level (m)	Energy Output (GWH)
1975				
Jan.	40.14	40.14	520.0	51.47
Feb.	21.23	21.23	520.0	24.59
Mar.	13.89	15.50	519.0	19.78
Apr.	16.73	"	519.7	19.21
May	9.71	"	515.0	19.39
June	- 3.17	"	497.5	17.12
July	3.28	"	479.0	15.89
Aug.	40.32	15.50	510.5	18.95
Sept.	80.50	15.50 (5 days) 80.50(25 days)	519.3 520.0	3.19 83.25
Oct.	21.17	21.17	520.0	27.15
Nov.	23.60	23.60	"	29.29
Dec.	29.47	29.47	520.0	37.79
Sub-Total:				367.07
1976				
Jan.	33.03	33.03	520.0	42.35
Feb.	8.05	25.3	506.0	28.27
Mar.	13.84	"	493.5	28.29
Apr.	16.52	"	480.5	25.33
May	53.72	25.30	514.0	31.49
June	51.19	25.30 (9 days) 51.19(21 days)	520.0	9.42 44.47
July	45.72	45.72	"	58.63
Aug.	46.91	46.91	"	60.15
Sept.	32.39	32.39	"	40.19
Oct.	32.92	32.92	520.0	42.21
Nov.	23.53	25.00	519.0	30.87
Dec.	4.73	25.00	500.0	28.92
Sub-Total:				470.59
Total:				10,555.98
Average:				527.80

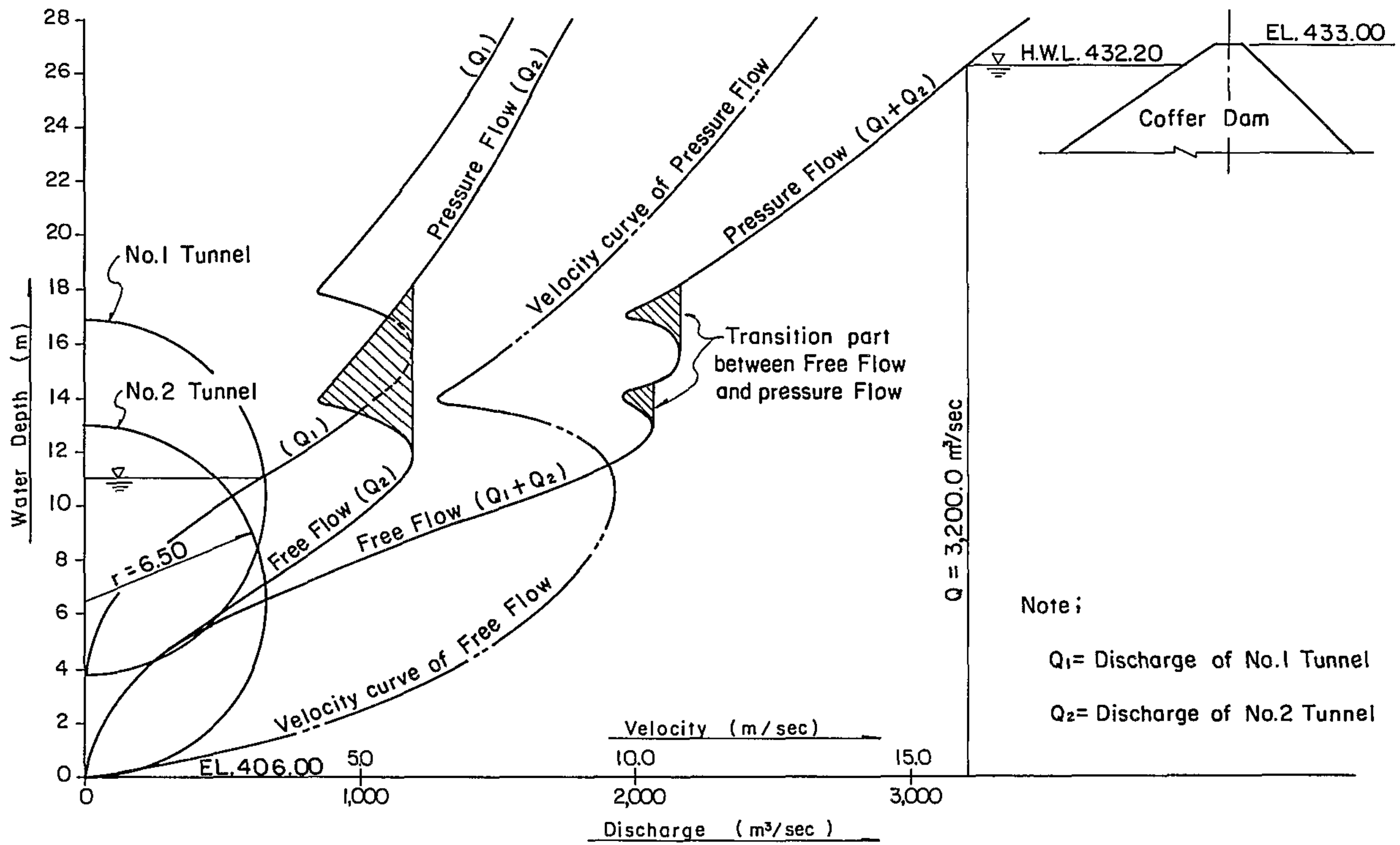


FIG. 5-1 H~Q CURVE OF DIVERSION TUNNEL FOR B-DAM SITE

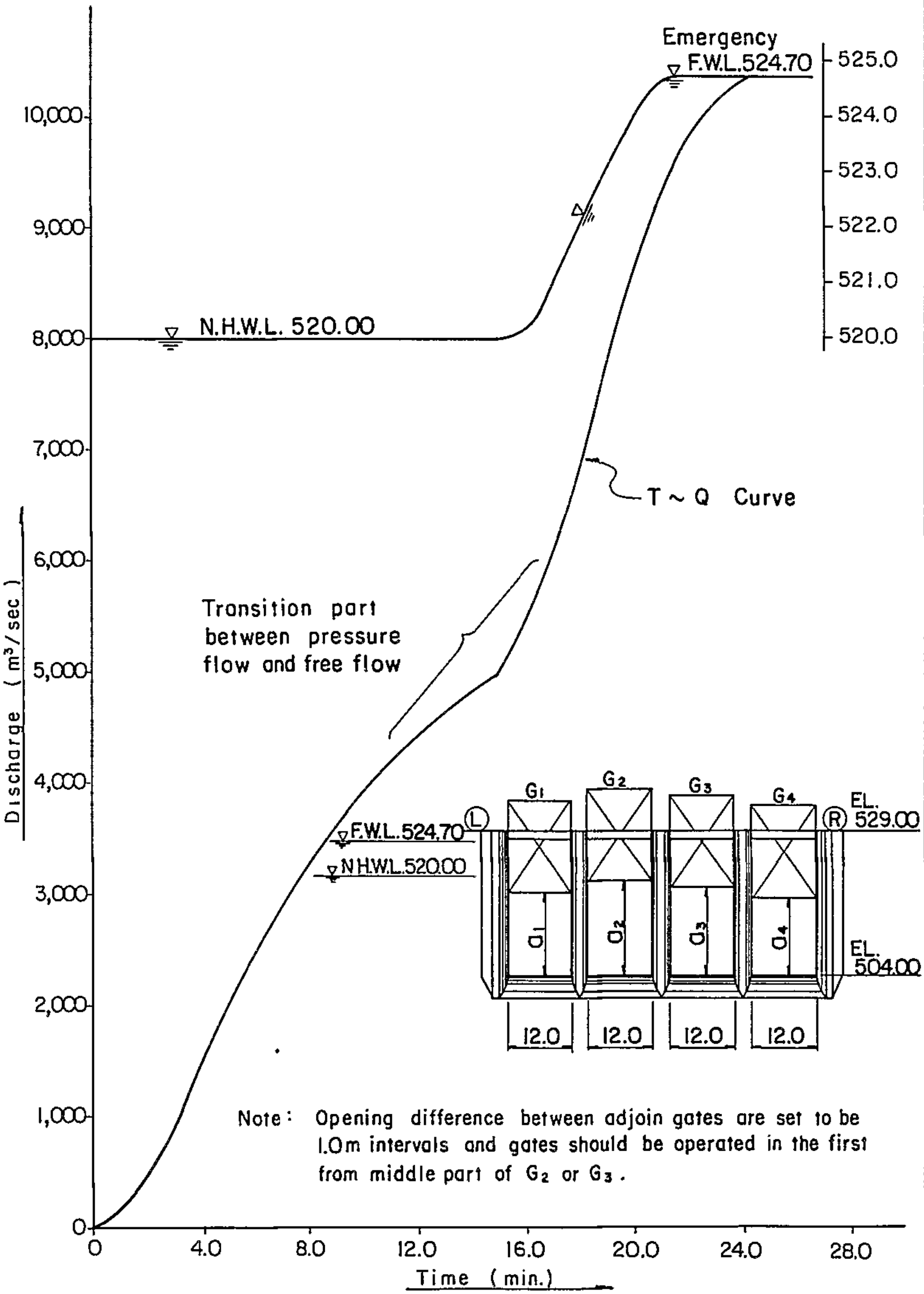


FIG. 5-2 RELATION BETWEEN TIME & DISCHARGE AT SPILLWAY

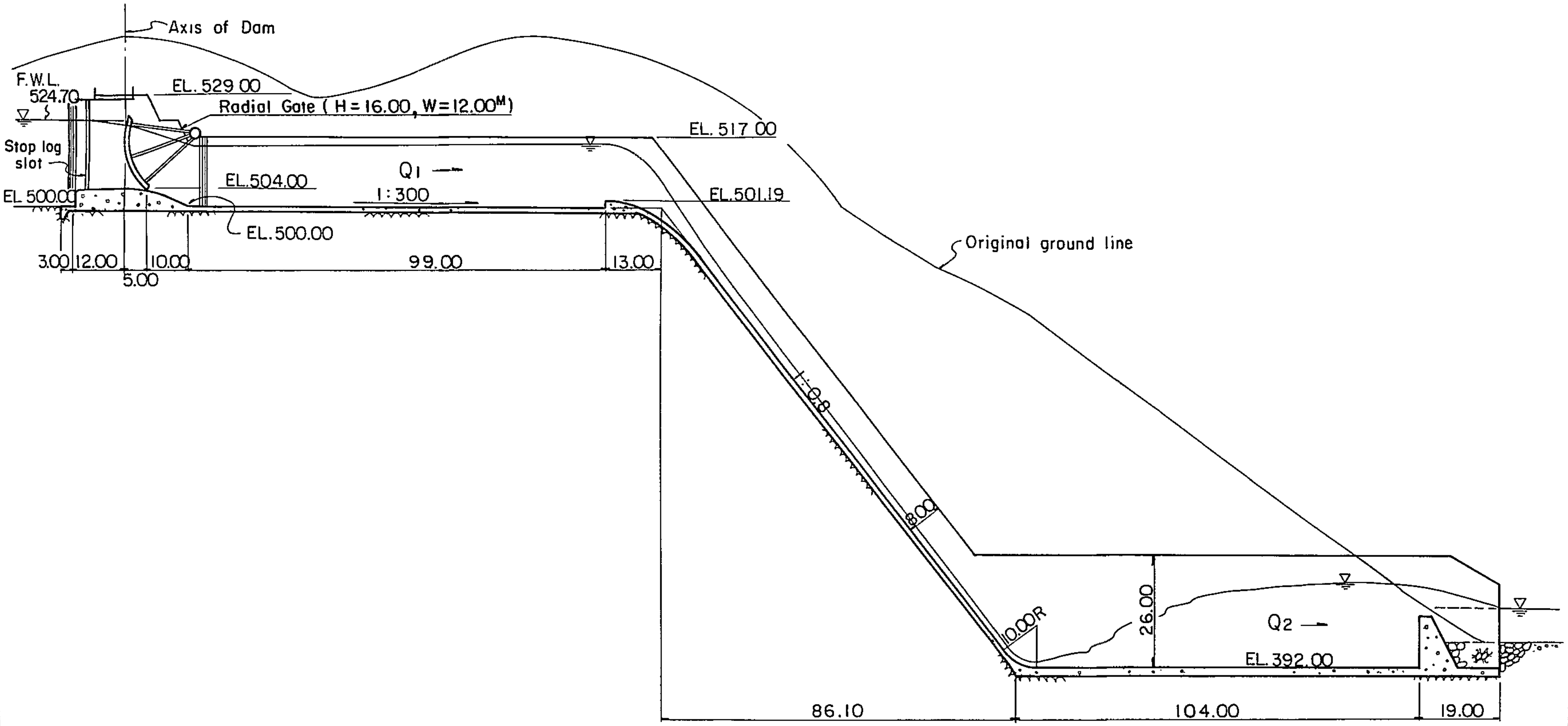
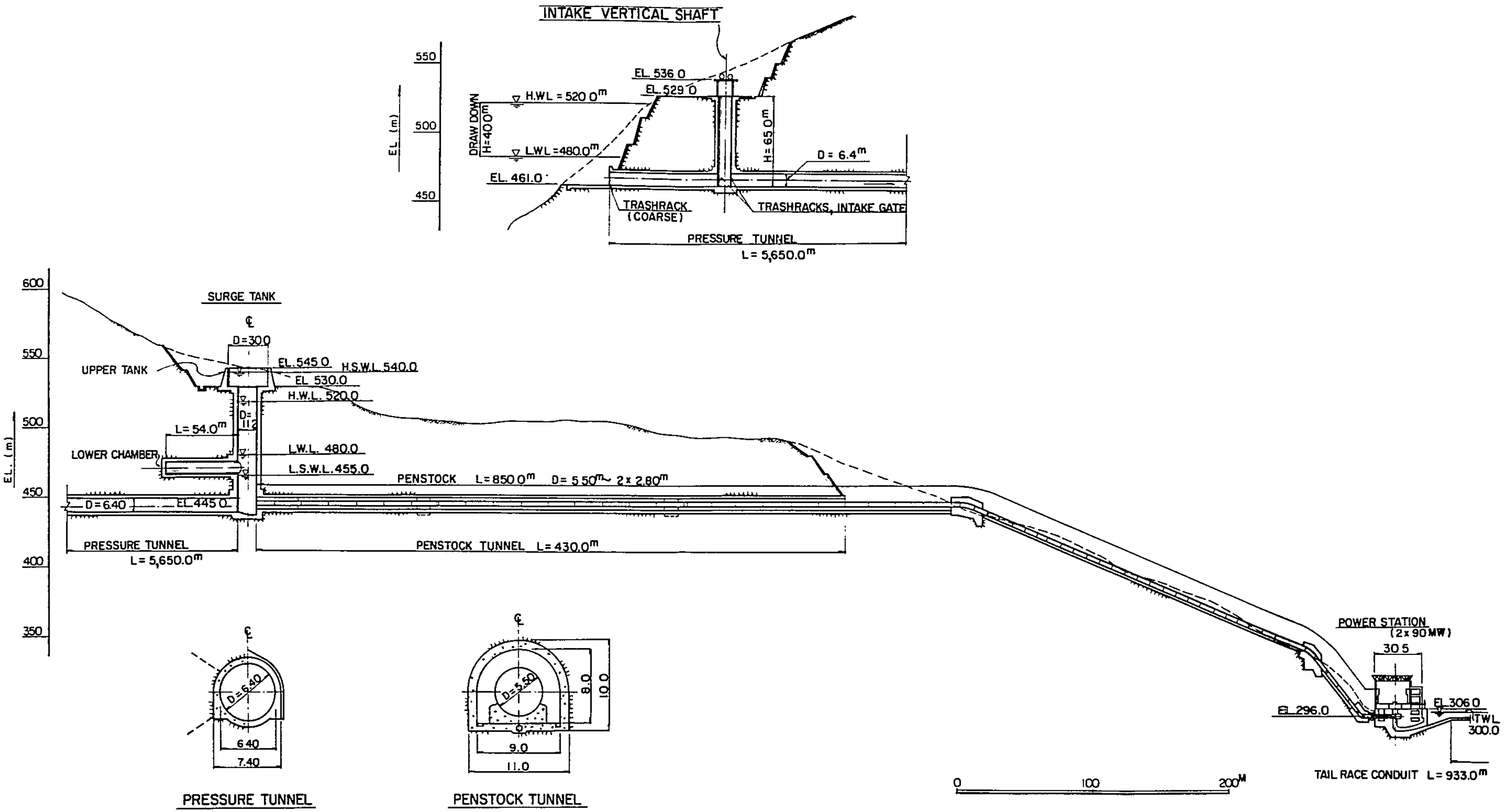
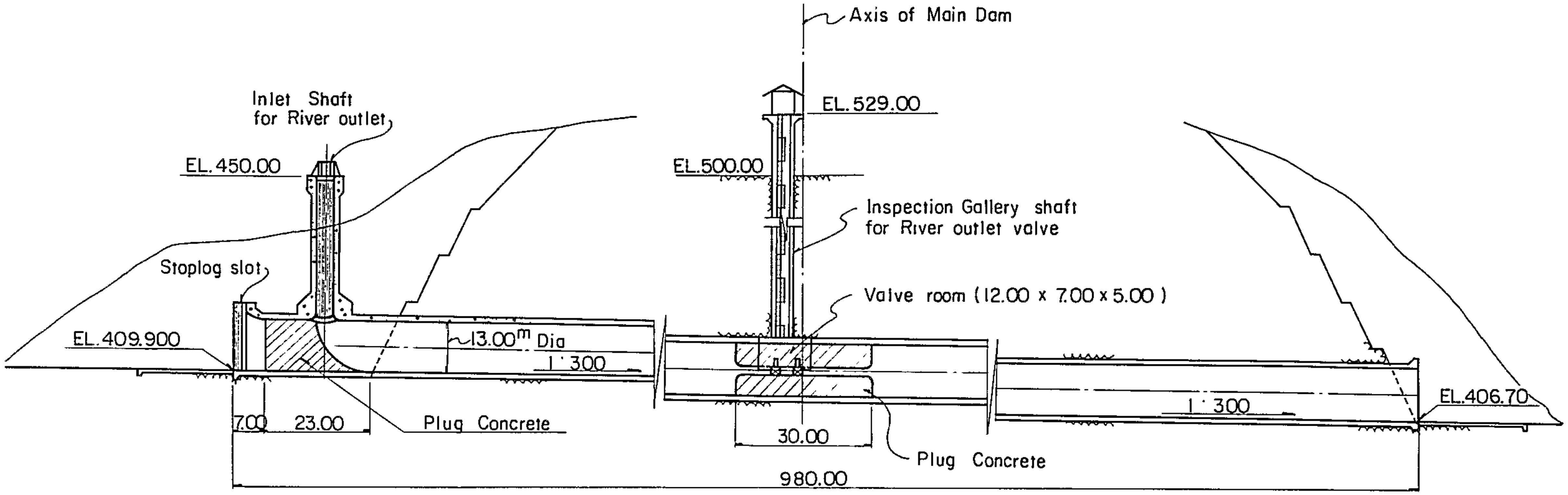


FIG. 5-3 LONGITUDINAL SECTION OF SPILLWAY

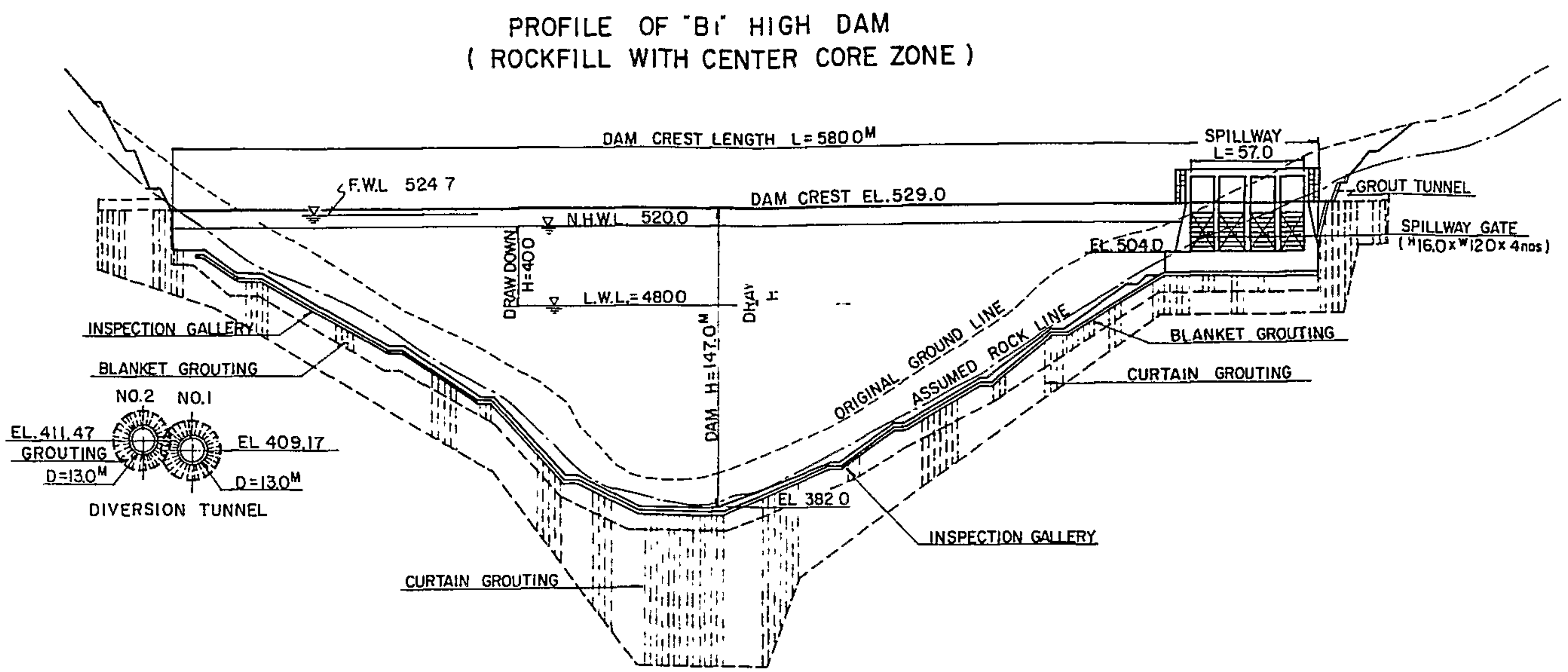
FIG. 5-4 LONGITUDINAL SECTION OF PRESSURE TUNNEL AND PENSTOCK





Note; No.2 diversion tunnel will be re-used as river outlet after compretion of dam construction.

FIG. 5-5 LONGITUDINAL SECTION OF RIVER OUTLET



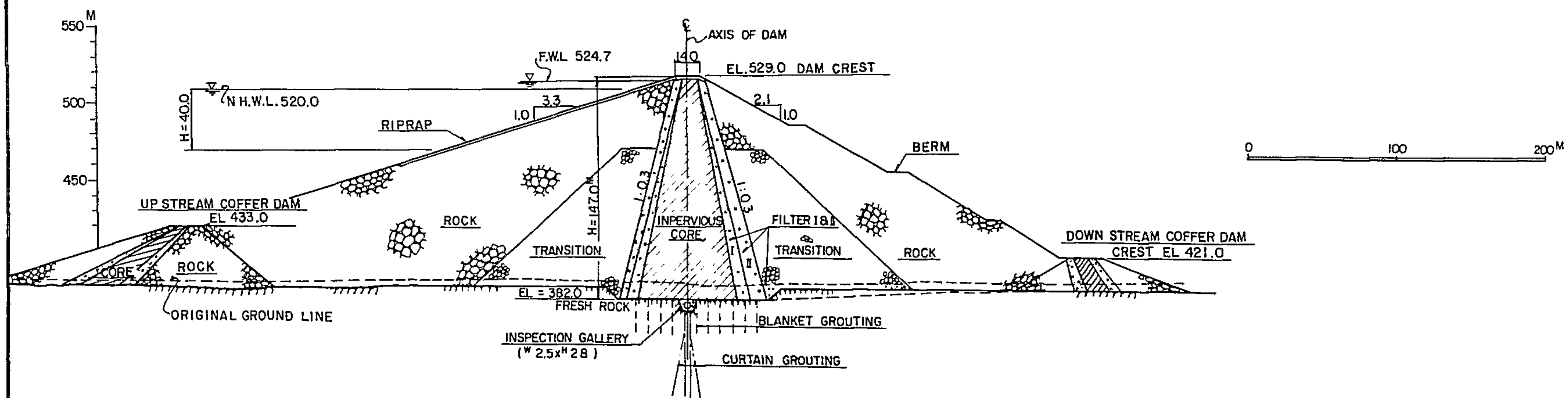


FIG. 5-6 TYPICAL CROSS SECTION AND PROFILE

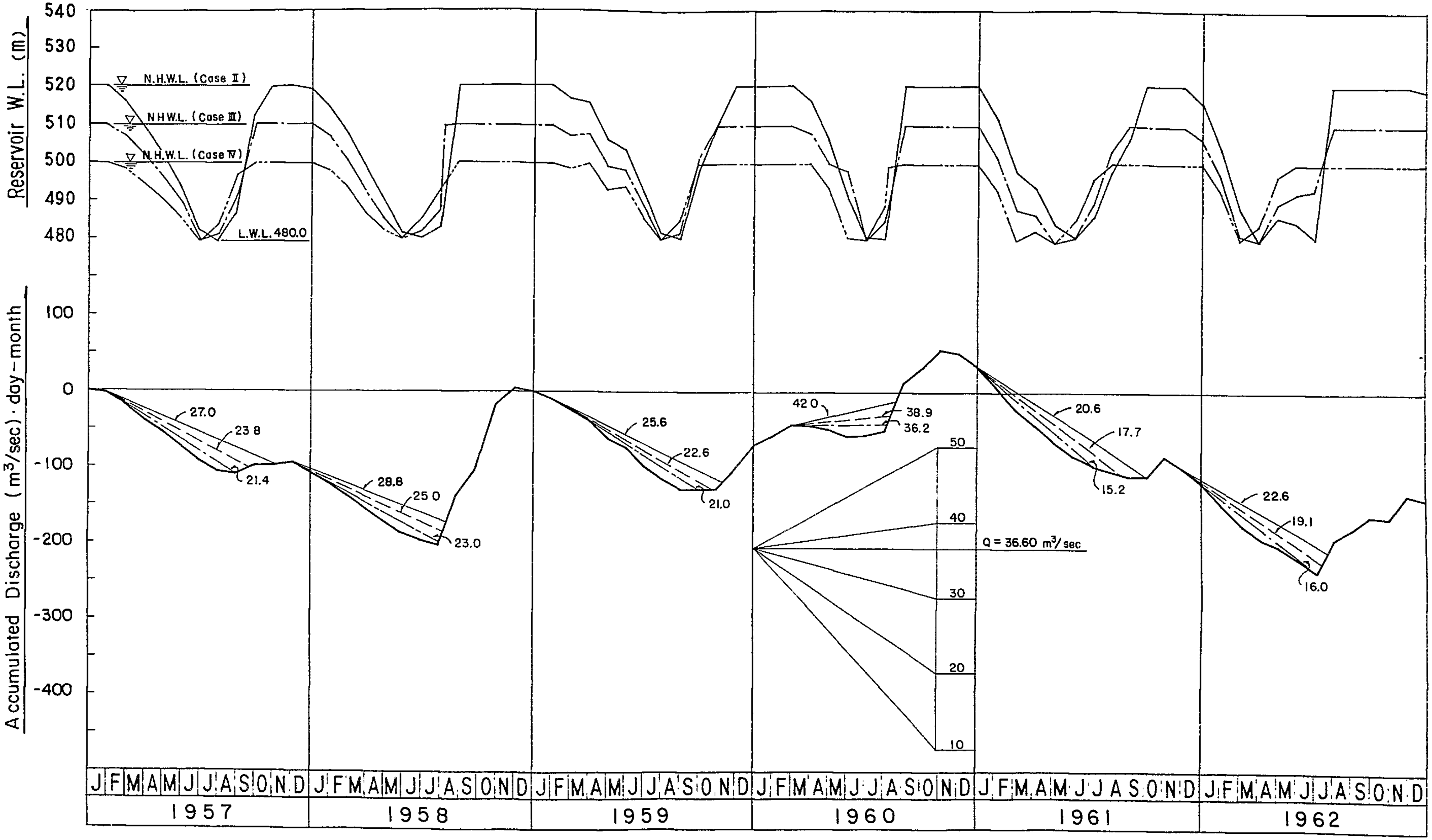


FIG. 5-7 DISCHARGE MASS CURVE (I)

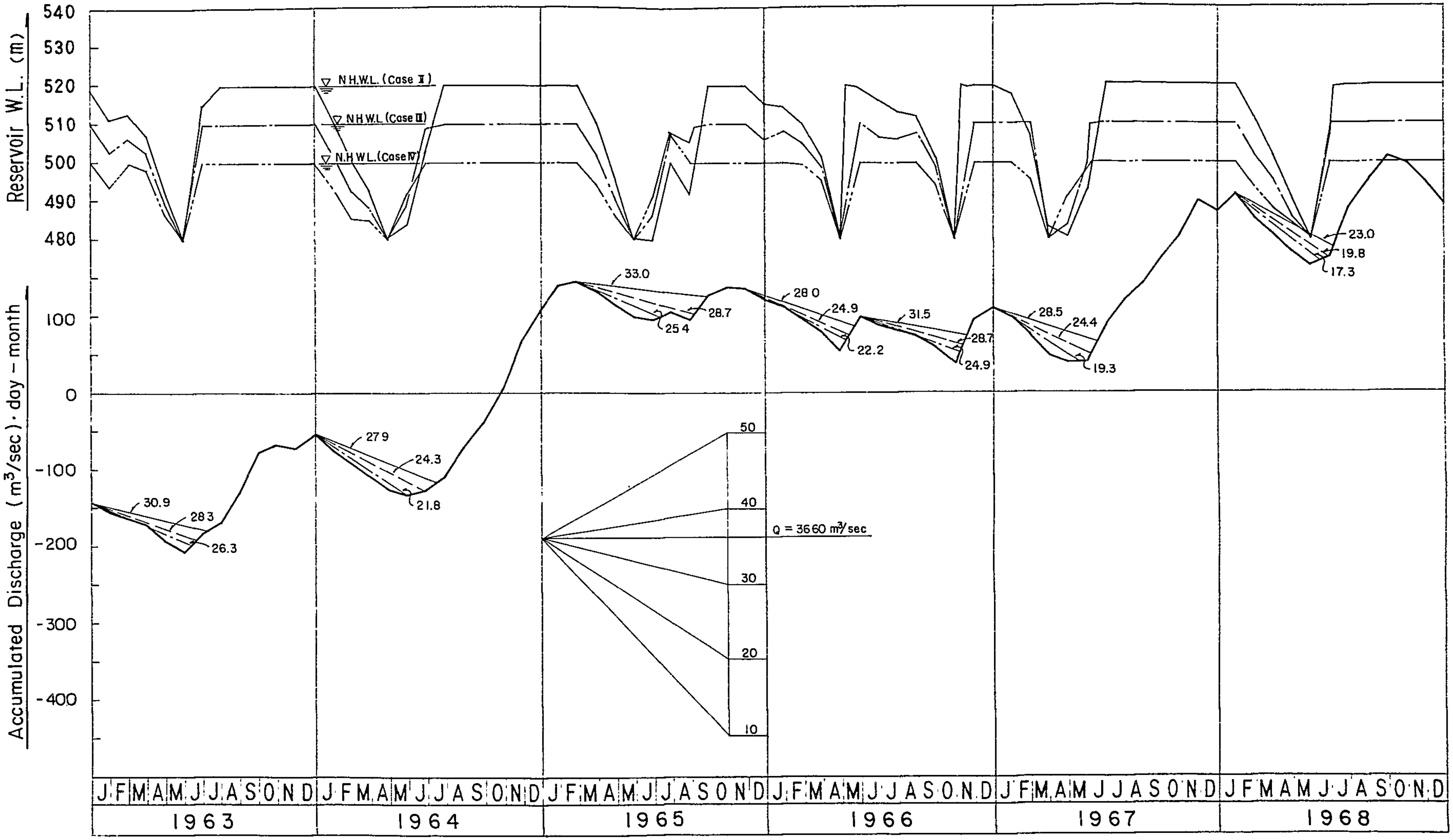


FIG. 5-8 DISCHARGE MASS CURVE (2)

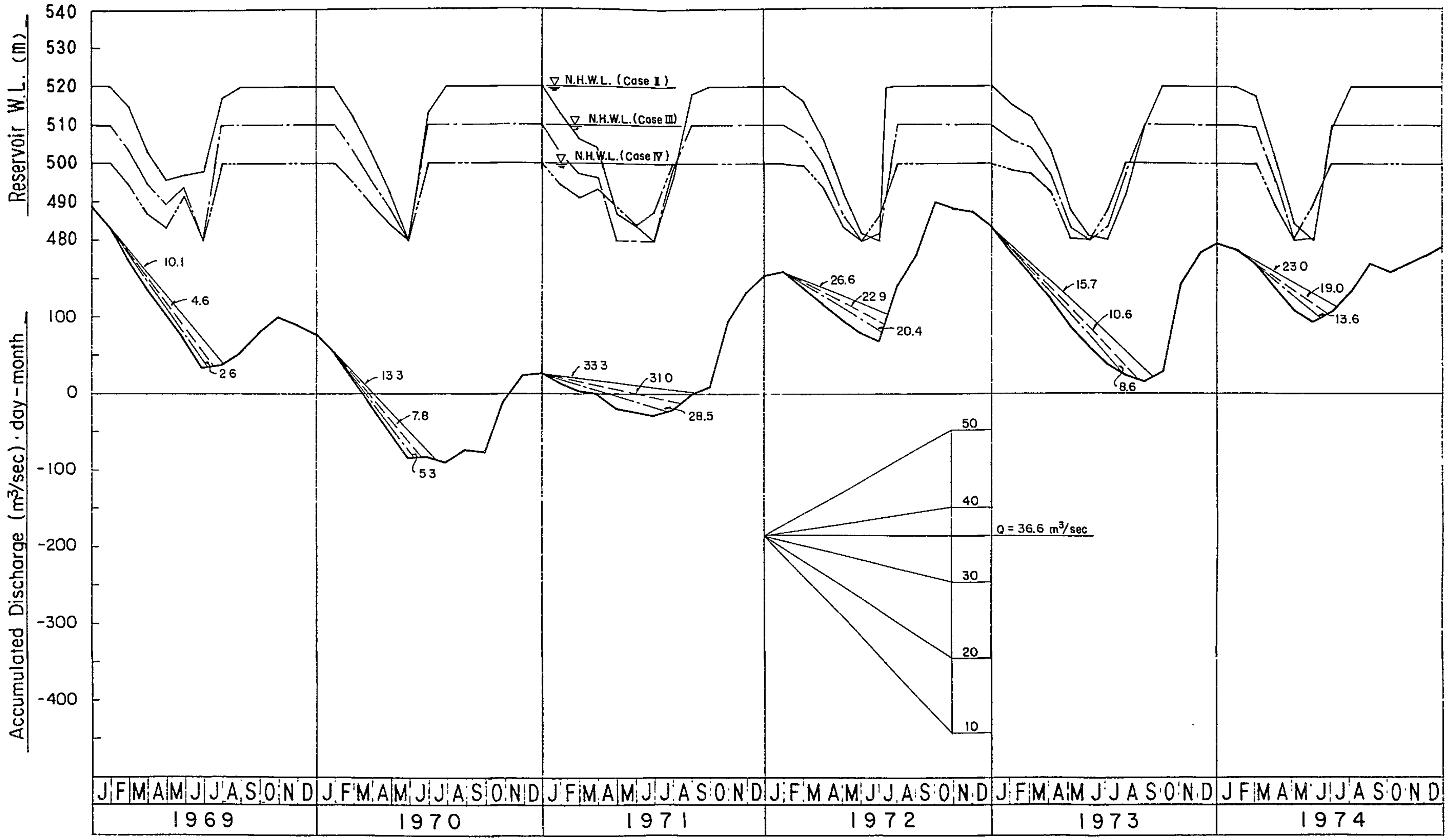


FIG. 5-9 · DISCHARGE MASS CURVE (3)

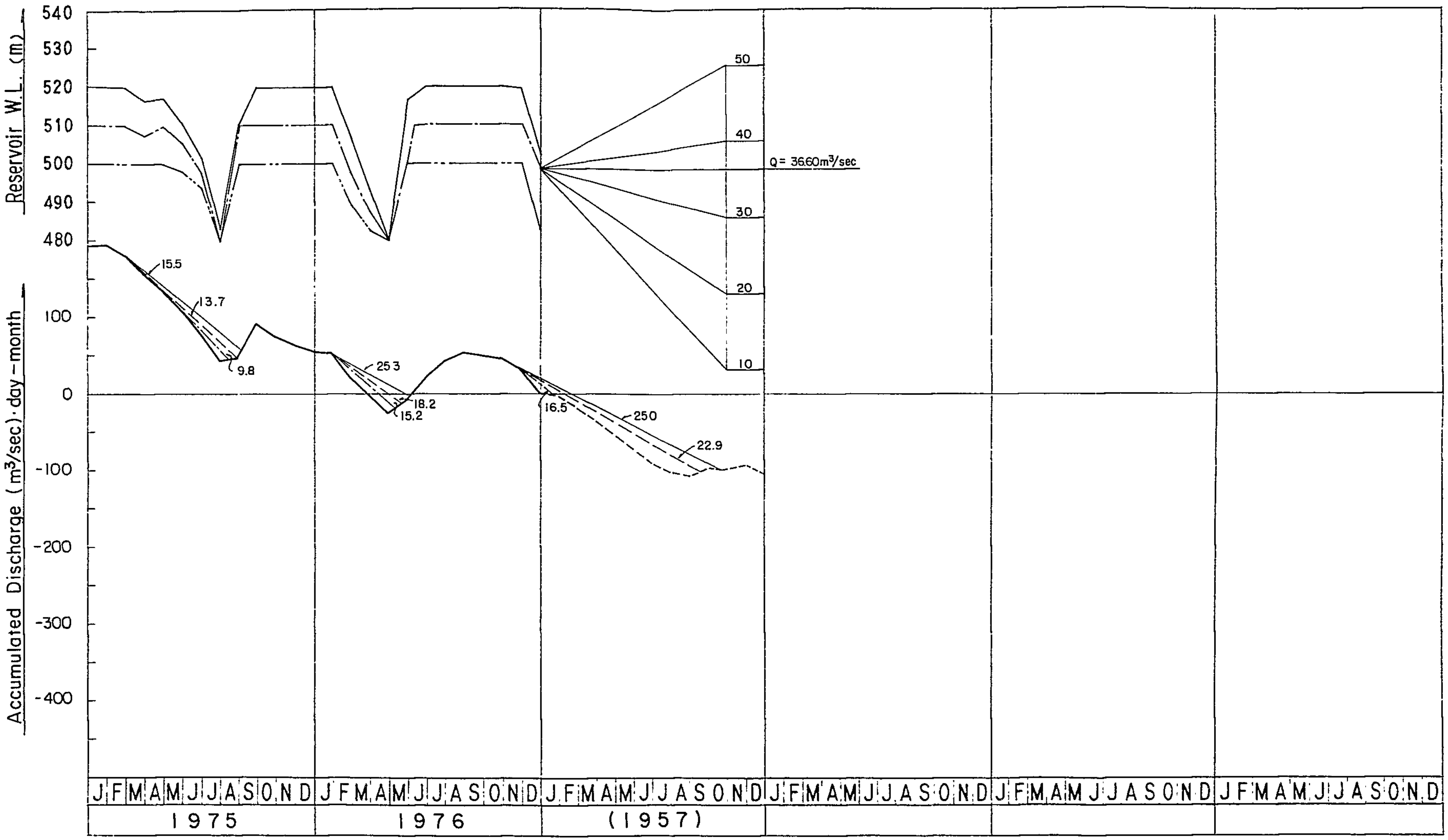


FIG. 5-10 DISCHARGE MASS CURVE (4)

II-6 OPTIMIZATION STUDY

II-6 OPTIMIZATION STUDY

6.1 Cases selected for Comparison for B_1 Dam

As approximately analyzed in the previous studies reported in the Interim Report submitted in April 1983, the cases of high water levels at 510 m and 520 m at B_1 damsite may have the highest benefit-cost ratio. Therefore the detailed economic comparison was made for the following four different cases:

	H.W.L. (EL. m)	L.W.L. (EL. m)	Econimic Const. Cost (10^6\$)
Case I	525	480	261.7
Case II	520	480	255.0
Case III	510	480	252.2
Case IV	500	480	250.4

The annual average energy outputs for the above four cases were calculated from 20 years discharge records as shown below:

	Firm Energy Output (GWh)	Secondary Energy (GWh)	Total Energy (GWh)
Case I	359.09	176.86	535.95
Case II	353.63	174.17	527.80
Case III	342.24	168.56	510.80
Case IV	329.30	162.19	491.49

6.2 Criteria for Benefit and Cost Estimation

5.2.1 Benefit Estimation Criteria

For evaluating the benefits to be derived from power generation, the least alternative power cost shall first be determined by comparison among the different types of power generation. The three different types, namely oil-fired, coal-fired and gas-turbine thermal plants are taken for comparison with the installed capacity of around 100 to 200 MW.

a) Unit Construction Cost

The latest unit construction costs for the different alternative plants are estimated at the price level of early 1983 based on the past actual construction costs.

Oil-fired thermal plant:	US$745/KW
Coal-fired thermal plant:	US$990/KW
Gas-turbine thermal plant:	US$445/KW

b) Energy Production Cost

The energy production cost by the above respective plant is estimated under the following on-going conditions:

		Oil-fired thermal	Coal-fired thermal	Gas-turbine
A)	Econimic life of the plant	30 years	30 years	15 years
B)	Capital recovery factor	0.1061	0.1061	0.1315
C)	Annual O & M cost	0.0365	0.0525	0.0250
	Fuel Cost	$34/barrel	$62/t	$38/barrel
	Heating Value	18,300 BTU/lb	11,540 BTU/lb	18,400 BTU/lb
	Thermal Efficiency(%)	38	37	25

The energy production cost varies also according to the annual operating hours. In order to compare with the hydropower plant, the cases of different plant factors of 25%, 33%, 42% and 50% are examined, the results of which are shown in the following table.

KWH Cost for Different Plants

Plant Factor (hours/day)	Oil-fired thermal	Coal-fired thermal	Gas-turbine
25% (6 hours)	111.74	115.97	118.35
33% (8 hours)	96.90	93.04	109.65
42% (10 hours)	88.01	79.28	104.44
50% (12 hours)	82.07	70.11	100.96

Note: Estimated on the basis of the annualized kw cost plus OM cost and fuel cost after the adjustment to make equivalent to hydropower.

As shown in the above table the least cost alternative for the Matuno Hydropower Station with the average plant factor of about 33% is the coal-fired thermal plant.

c) Power Benefit

As shown in the above comparison, the coal-fired thermal power plant is considered the least cost alternative for the hydropower project. The power benefit is, therefore, estimated by evaluating the investment cost and energy production cost for the least cost alternative.

Required investment cost and the energy production cost are calculated on the basis of the following conditions.

kw cost for coal-fired thermal plant: US$990
Annual O & M cost = 5.25% of investment
Fuel cost (coal) = US$62 per metric ton with heating value of 11,540 BTU/lb with thermal efficiency of 37%.

The result of the calculation is as follows:

Investment Cost = 990 US$/kw

Energy Production Cost

O & M cost = 22.8 mill/kwh

Fuel cost = 24.3 mill/kwh

Total = 47.1 mill/kwh

For the evaluation of Matuno hydropower plant, all the cost and benefit are evaluated at the zero year at the certain discount rate. The benefit of the firm energy is evaluated by applying the above full production cost of 47.1 U.S. Mill/kwh, but that of the secondary energy is evaluated by fuel cost (24.3 U.S. Mill/kwh) only since the secondary energy contributes to the system by reducing the fuel consumption of the thermal plant.

As for the kw benefit, the following capital recovery cost for a coal-fired plant is adopted per kw per annum. Under the conditions of annual interest rate of 10 percent with the amortization period of 30 years, the annual capital recovery rate becomes to be 0.1061 for the investment of 990 US$/kw of a coal-fired plant. It makes annual capital recovery amount to be 105.04 US$/kw/year.

When the kw value of hydropower plant is compared with that of a coal-fired plant, the difference of operation loss between both plants shall be taken into consideration as shown below:

Mode of generation	Transmission Loss (%)	Forced outage (%)	Maintenance outage (%)	Station use (%)	Total loss (%)
Coal-fired	2.0	5.0	14.0	9.0	27.14
Hydropower	3.0	1.0	2.7	0.3	6.84

The kw value of hydropower plant, therefore, is deemed to be equal to 1.279 kw of the coal-fired kw value as the reslut of the following calculation:

$$\text{Adjustment factor} = \frac{1 - 0.0684}{1 - 0.2714} = 1.279$$

Then the kw benefit of hydropower plant becomes to be 134.34 \$/kw/year as the product of 105.04 \$/kw/year of coal-fired plant with the above adjustment factor.

6.2.2 Cost Estimation Criteria

The annual O & M cost is estimated in two parts of the facilities. As for the civil engineering structures, such as dam, spillway, tunnel, surge tank, penstock, power house substructure and superstructure, tailrace, etc., the annual maintenance and operation cost is assumed to be proportional to the construction cost by multiplying with 0.2% per annum.

As for the power generation, the actual unit rate of 7.9 US \$/kw per annum is multiplied by the installed capacity.

6.3 Result of Benefit-Cost Ratio Calculated

For the four different cases, the benefit-cost ratioes under the discount rates of 10, 12, 14 and 15 percent are calculated as shown in the following table:

B/C Ratio Calculation Sheet for B1 Dam

H.W.L. (EL,m)	Const. Cost (10^6\$)	Present Value (10^6\$)	Annual Net Benefit (10^6\$/Year)	Present Value of Net Benefit (10^6\$)	B/C
(1) B/C Ratio under 10% Discount Rate					
525	261.7	321.32	52.17	517.26	1.610
520	255.0	313.11	51.73	512.89	1,638
510	252.2	309.66	50.80	503.67	1.627
500	250.4	307.45	49.71	492.86	1.603
(2) B/C Ratio under 12% Discount Rate					
525		334.75		433.25	1.294
520		326.18		429.59	1.317
510		322.60		421.87	1.308
500		320.30		412.82	1.289
(3) B/C Ratio under 14% Discount Rate					
525		348.72		372.11	1.067
520		339.79		368.97	1.086
510		336.06		362.34	1.078
500		333.66		354.56	1.063
(4) B/C Ratio under 15% Discount Rate					
525		355.91		347.48	0.976
520		346.80		344.55	0.994
510		342.99		338.35	0.986
500		340.54		331.09	0.972

As clearly seen in the table, the Case II (high water level = EL.520 m) shows the highest benefit-cost ratio in all cases. The benefit-cost ratio at 10% discount rate is 1.638 and that at 15% discount rate is 0.994. It suggests that the Case II will have approximately 15% of internal rate of return.

Thus the high water level of EL.520 m is selected as the most economical case for the project for B_1 dam.

6.4 Economic Evaluation of B_2 Dam Project

The same economic evaluation was applied on the following three different heights of B_2 dam project:

Case	H.W.L. (EL.m)	Firm Energy (GWh)	Second Energy (GWh)	Total (GWh)
Case I	500	264.25	130.17	394.42
Case II	490	247.53	121.87	369.40
Case III	480	229.90	113.19	343.09

In this B_2 dam project, the high water level is limitted to EL.500 m as the topography does not permit higher dam. The installed capacity is set at 140 MW as the plant factor of 33 percent is applied on the annual average power supply capacity.

The calculation of benefit-cost ratio under the different discount rates of 10, 12, 13 and 14 percentsare shown in the next table.

As the results show, the highest ratio is attained by the Case I (high water level = EL.500 m) in all cases. And it suggests that higher dam than EL.500 m will be more economical. But the topography around the B_2 damsite does not allow the higher dam.

The above calculation result suggests that the internal rate of return for B_2 dam project may be around 13.5 percent which is about 10 percent lower than the B_1 dam project.

Thus the Case II (high water level = EL.520 m) of the B_1 dam project is recommended as the most economical height of the project.

B/C Ratio Calculation Sheet for B_2 Dam

H.W.L. (EL.m)	Const. Cost (10^6\$)	Present Value (10^6\$)	Annual Benefit (10^6\$)	Present Value (10^6\$)	B/C
(1) 10% Discount Rate					
500	220.3	270.50	39.29	389.55	1.440
490	218.4	268.16	37.89	375.67	1.401
480	216.5	265.83	36.43	361.20	1.359
(2) 12% Discount Rate					
500		281.80		326.28	1.158
490		279.37		314.66	1.126
480		276.94		302.53	1.092
(3) 13% Discount Rate					
500		287.61		301.56	1.049
490		285.13		290.81	1.020
480		282.65		279.61	0.989
(4) 14% Discount Rate					
500		293.55		280.24	0.955
490		291.02		270.26	0.929
480		288.49		259.84	0.901

II-7 CONSTRUCTTON PLAN AND SCHEDULE

II-7 CONSTRUCTTON PLAN AND SCHEDULE

7.1 Main Features of Matuno Dam and Hydropower Project

By the economical comparison studies, the high water level of the reservoir was selected to be EL. 520 m. The installed power capacity was selected at 180 MW under the plant factor of 33 per cent.

The other main features are shown in the following: (Ref. Fig. 7-1 to 7-7)

Dam:	Type: Rockfill with a centre core zone	
	Crest Elevation:	EL. 529 m
	Height from foundation:	147 m
	Crest length:	580 m
	Crest width:	14 m
	Dam volume:	10,000,000 m^3
Reservoir:	HWL: EL. 520 m	
	LWL: EL. 480 m	
	Surface area: 3.5 km^2	
	Gross storage capacity: 137 x 10^6 m^3	
	Dead storage capacity: 40 x 10^6 m^3	
	Effective storage capacity: 97 x 10^6 m^3	
	Maximum flood WL: EL. 524.70 m	
Diversion Tunnels:	Two number of concrete-lined circular tunnels	
	Inside diameter: 13.0 m	
	Length: No.1 Tunnel 930 m	
	No.2 Tunnel 980 m	
Spillway:	Gated overflow weir and concrete-lined chute type spillway with a stilling basin	
	Gates: Radial gates, 4 Nos	
	Gate size: 16 m (H) x 12 m (W)	
	Crest Elevation: EL. 504 m	
	Design Flood Discharge: 10,300 m^3/sec	

Intake Structure:	Concrete vertical shaft Gate: 6.4 m x 6.4 m x 1 set with movable and fixed trash racks
Pressure Tunnel:	Concrete-lined circular tunnel Diameter: 6.4 m Length: 5,650 m
Surge Tank:	Chamber type concrete-lined vertical shaft
Penstock Tunnel & Penstock:	Tunnel length: 430 m Open penstock pipeline: 420 m Diameter: 5.50 m - 2.80 m x 2 Nos.
Power House:	Floor size: 30.5 m x 60.0 m
Turbines:	Vertical shaft Francis turbine, 2 units Elevation of runner centre: EL. 296 m Turbine capacity: 92,700 kW x 2 units Rated speed: 277 rpm Tailwater level: EL. 300 m Max. gross head: 220 m Min. gross head: 180 m
Generators:	Vertical shaft synchronous generator Capacity: 100,000 kVA x 2 units Voltage: 13.8 kV Frequency: 60 Hz Power factor: 0.90
Main Transformer:	Three-phase outdoor type Voltage: 13.8 kV/230 kV Capacity: 100,000 kVA x 2 units
Transmission Line:	Double circuit, single conductor Voltage: 230 kV Conductor: ACSR 795 MCM Length: 2.0 km

Tailrace Conduit: Concrete box culvert
Size: 13.6 m (W) x 7.2 m (H)
Length: 933 m

All the above structures were designed by the hydraulic and stability calculations taking into consideration the economical construction as stated in II-5.

7.2 Construction Method and Time Schedule

All the main works will be carried out by contractors awarded by the international bidding except some special works or minor works.

The many preparatory works, such as access roads, bridges, quarters, power supply system, etc. will be carried out by local contractors as and when so required. The flood forecasting system will be constructed by force account method.

All the construction works will be carried out within five years including the preparatory works and the final running test of the generating facilities. The detailed construction time schedule is shown in the attached Fig. 7-10.

7.3 Construction Cost Estimate

The construction cost of the Project was estimated on the price level of May 1983 using the exchange rates of 10 Pesos and 240 Yen to one US Dollar.

The basic prices of construction materials and labor wages are shown in the attached Table 7-1 for reference.

The major breakdown of the construction cost is shown in the attached Table 7-2. The physical contingencies is estimated to be 10 per cent of the total direct construction cost.

As the result, the total direct construction cost ammounts to 255 million US$ equivalent including the required engineering and administration cost of the Government. It will consist of 170 million US$ equivalent foreign currency and 85 million US$ equivalent local currency, accounting for 67 per cent of foreign currency component. This construction cost was used for the economic evaluation.

The price escalation during the construction period was estimated based on the following assumptions:

1) The annual price escalation rate of local currency portion was assumed to be 8 per cent per annum.

2) The annual price escalation rate of the foreign currency portion was assumed to be 5 per cent per annum.

Then the total construction cost including the price escalation becomes 303.3 million US$ equivalent, consisting of 198 million US$ in foreign currency and 105.3 million US$ equivalent in local currency. This construction cost including price escalation was used for the financial evaluation and annual cash flow analysis.

As for the interest during construction period, the following annual rate was assumed:

1) The annual interest rate for the foreign currency required for the civil works is set at 4 per cent taking into consideration the loan system of OECF of Japan and ADB.

2) The annual interest rate for the foreign currency required for the electro-mechanical works, such as power generating equipment, substation equipment, penstock pipes, gates, etc. is set at 8 per cent taking into consideration the loan system of the Export and Import Bank.

3) The annual interest rate for the local currency is assumed to be 12 per cent per annum.

Then the total investment cost for the Matuno Dam and Hydropower Project will ammount to 370 million US$ equivalent, consisting of 229.2 million US$ equivalent hard currency and 140.8 million US$ equivalent local currency.

7.4 Annual Disbursement Schedule

The above construction cost was distributed in five years of construction period in accordance with the construction work quantities to be completed in each year. The results are shown in the attached Table 7-3 being broken down in both foreign currency and local currency components.

All those cost data were used for the economic and financial evaluation.

Table 7-1 BASIC PRICES OF MATERIALS AND WAGES OF LABORS

1983, May

Item	Price ($)	Price (₱)
		WD
Foreman		41.2
Mechanic		34.0
Electrician Heavy		34.0
Operator Heavy		42.0
Driver dump truck		42.0
ordinary		31.0
Carpenter		34.0
Mason		34.0
Concrete worker		34.0
Reinforcement worker		34.0
Tunnel worker		27.0
Skilled labour		32.0
Common labour		27.0
Fuel		
Gasoline (ℓ)		5.5/ℓ
Light Oil (ℓ)		5.2/ℓ
Heavy Oil (ℓ)		3.36/ℓ
Grease (kg)		20.0/kg
Portland cement		938/ton
Concrete Aggregate (Local hand collected)		
Fine A		40/m^3
Coarse A		50/m^3
Reinforcing Bar		6,000/ton
Deformed Bar		6,250/ton
Structural Steel Channel, H-type		6,500/ton
Explosives		
Dynamite		40.0/kg
AN-FO		14.4/kg
Detonator		8.75/pc
Leading Wire		7.50/m

Table 7-2 Breakdown of Construction Cost

(As of May, 1983)

	Works	Foreign Currency (10^3 US$)	Local Currency (10^3 US$)	Total (10^3 US$)
(1)	Land Acquisition & Other Compensations	0	2,000	2,000
(2)	Preparatory Works	8,400	3,600	12,000
(3)	Diversion Tunnel	7,455	9,765	17,220
(4)	Rockfill Dam	59,000	24,000	83,000
(5)	Scillway	8,710	3,390	12,100
(6)	Spillway Gates	4,648	1,992	6.640
(7)	Intake Structure	1,357	543	1,900
(8)	Pressure Tunnel	8,264	10,736	19,000
(9)	Surge Tank	953	847	1,800
(10)	Penstock Tunnel	2,016	1,984	4,000
(11)	Penstock	8,112	2,088	10,200
(12)	Power House	5,382	1,918	7,300
(13)	Tailrace	7,882	2,818	10,700
(14)	Outlet for Irrigation Water	1,028	432	1,460
(15)	Permanent Buildings	240	360	600
(16)	Flood Forecasting System	560	140	700
(17)	Outdoor Switchyard (Civil)	73	27	100
(18)	Generating Equipment	22,720	5,680	28,400
(19)	Transmission Line	140	78	218
(20)	Substation Equipment	1,230	297	1,527
(21)	Miscellaneous Works	2,298	837	3,135
Total	for Net Direct Const. Cost	150,468	73,532	224,000
(22)	Physical Contingencies	15,047	7,353	22,400
(23)	Engineering & Administration	16,700	9,400	26,100
Total	for Economic Evaluation	182,215	90,285	272,500
(24)	Price Escalation	30,000	21,500	51,500
(25)	Interest During Construction	17,000	29,000	46,000
Grand	Total for Financial Eval.	229,215	140,785	370,000

Table 7-3 Annual Disbursement Schedule for Matuno-Dam & Hydropower Project

(Unit: 10^6 US$)

Fiscal Year	1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
1. Direct Construction Cost Incl. Physical Contingencies & Eng. & Administration						
1-A. Foreign Currency	18.4	25.0	37.2	36.0	64.9	181.5
1-B. Local Currency	19.2	12.9	15.9	17.7	25.3	91.0
Sub-total (Economic Cost)	37.6	37.9	53.1	53.7	90.2	272.5
2. Price Escalation						
2-A. Foreign Currency	0.4	1.9	4.8	6.7	15.8	29.6
2-B. Local Currency	0.8	1.6	3.4	5.5	10.6	21.9
Sub-total	1.2	3.5	8.2	12.2	26.4	51.5
3. Interest During Construction Period						
3-A. Foreign Currency	0.4	1.4	2.8	4.8	7.8	17.2
3-B. Local Currency	1.3	3.2	5.3	7.7	11.3	28.8
Sub-total	1.7	4.6	8.1	12.5	19.1	46.0
4. Grand Total						
4-A. Foreign Currency	19.2	28.3	44.8	47.5	88.5	228.3
4-B. Local Currency	21.3	17.7	24.6	30.9	47.2	141.7
Total (Financial Cost)	40.5	46.0	69.4	78.4	135.7	370.0

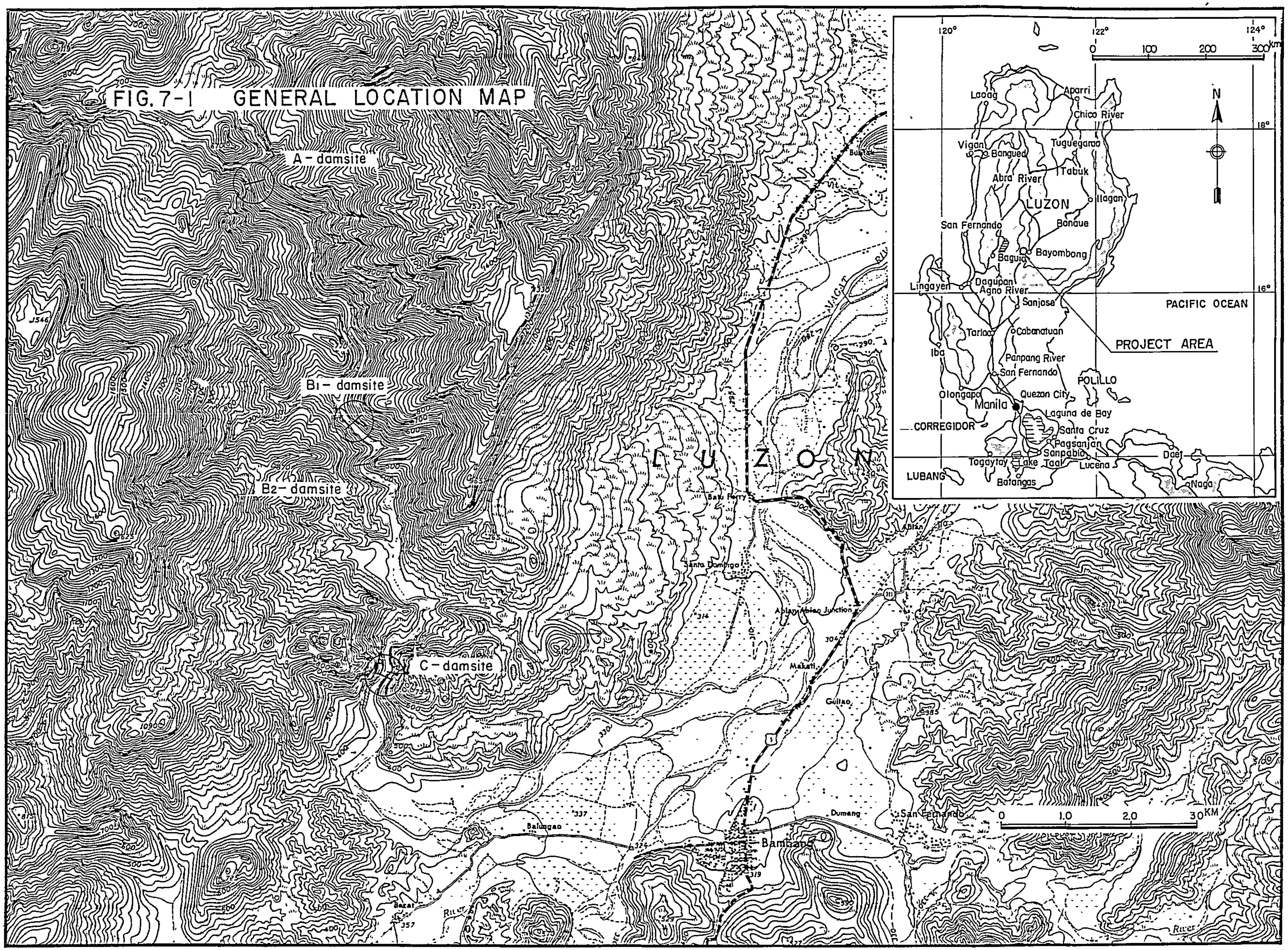


FIG. 7-1 GENERAL LOCATION MAP

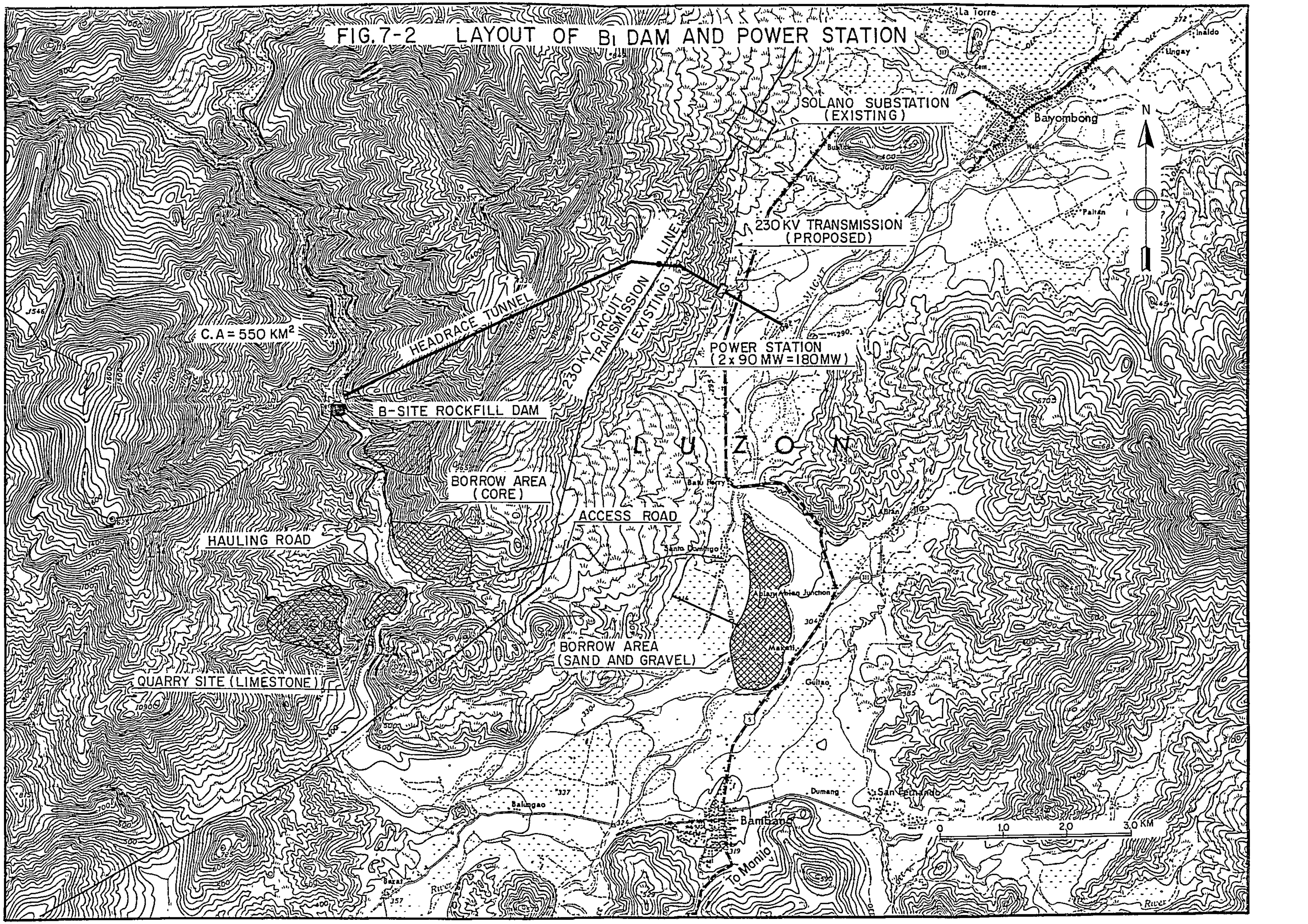


FIG.7-2 LAYOUT OF B1 DAM AND POWER STATION
SOLANO SUBSTATION (EXISTING)
Bayombong
N
230KV TRANSMISSION (PROPOSED)
HEADRACE TUNNEL
230KV CIRCUIT TRANSMISSION LINE (EXISTING)
C.A = 550 KM²
POWER STATION (2 x 90 MW = 180MW)
B-SITE ROCKFILL DAM
L U Z O N
BORROW AREA (CORE)
ACCESS ROAD
HAULING ROAD
BORROW AREA (SAND AND GRAVEL)
QUARRY SITE (LIMESTONE)
Bambang
San Fernando
To Manila
River
0 1.0 2.0 3.0 KM

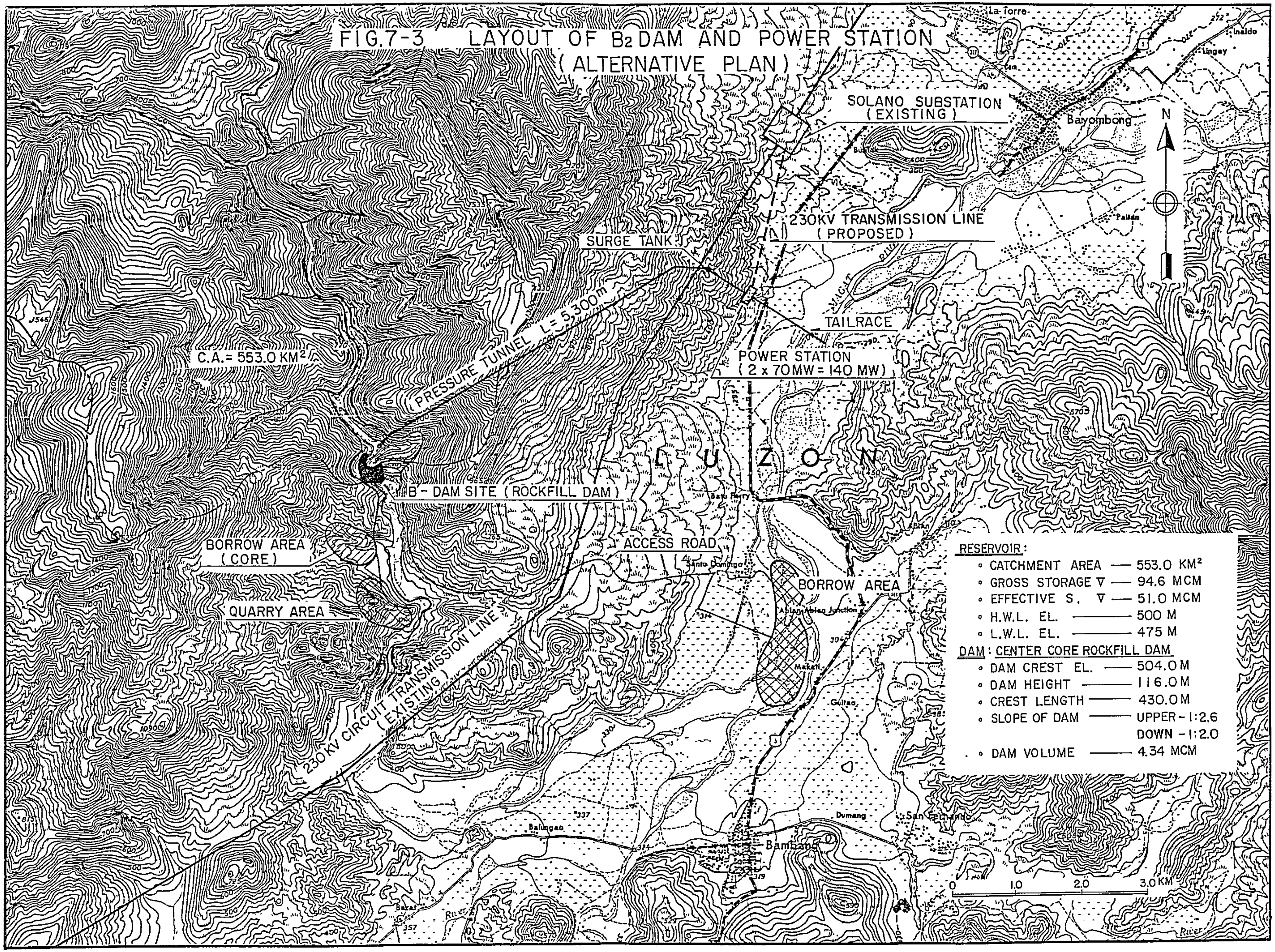


FIG. 7-3 LAYOUT OF B2 DAM AND POWER STATION
(ALTERNATIVE PLAN)

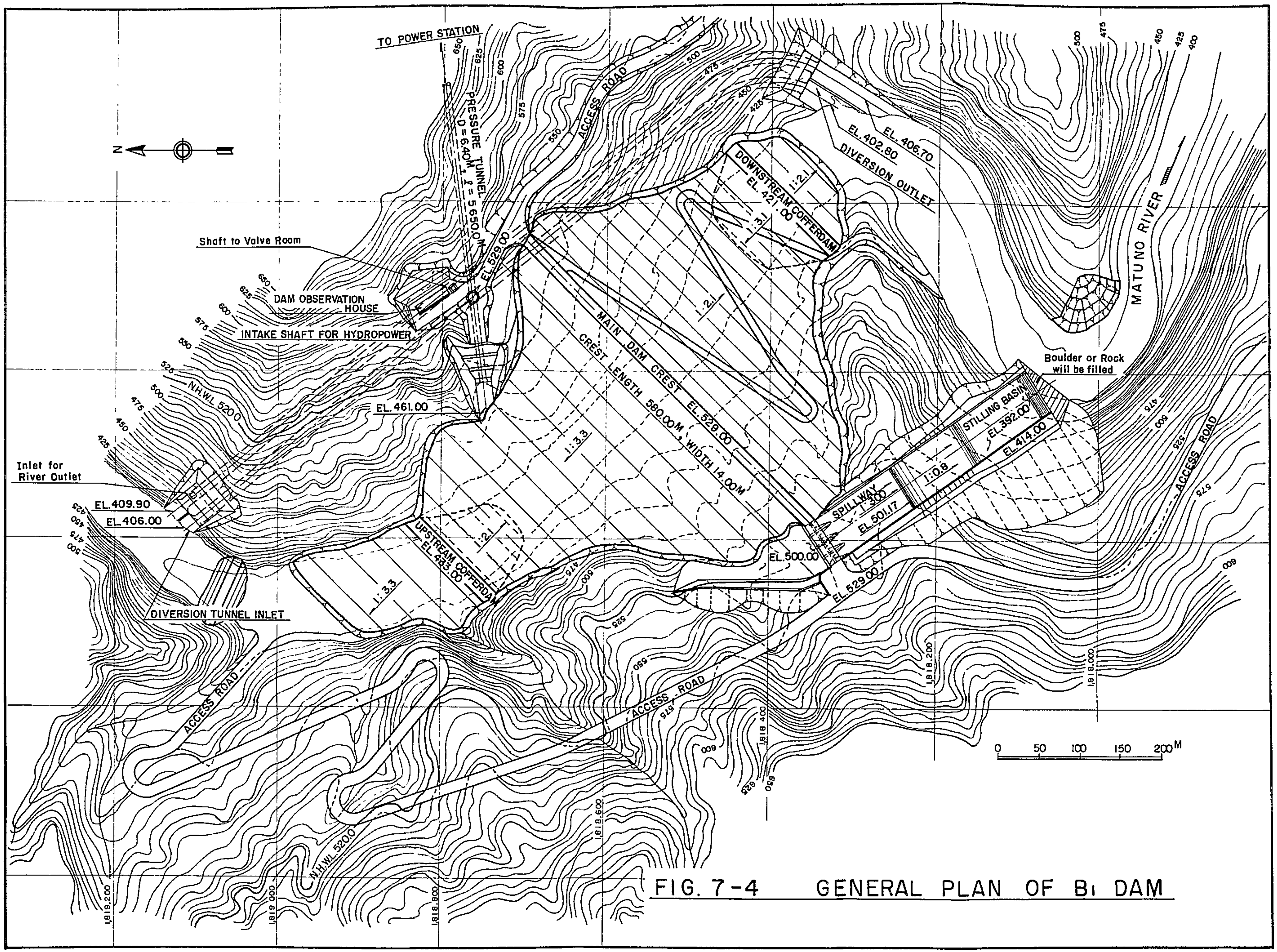
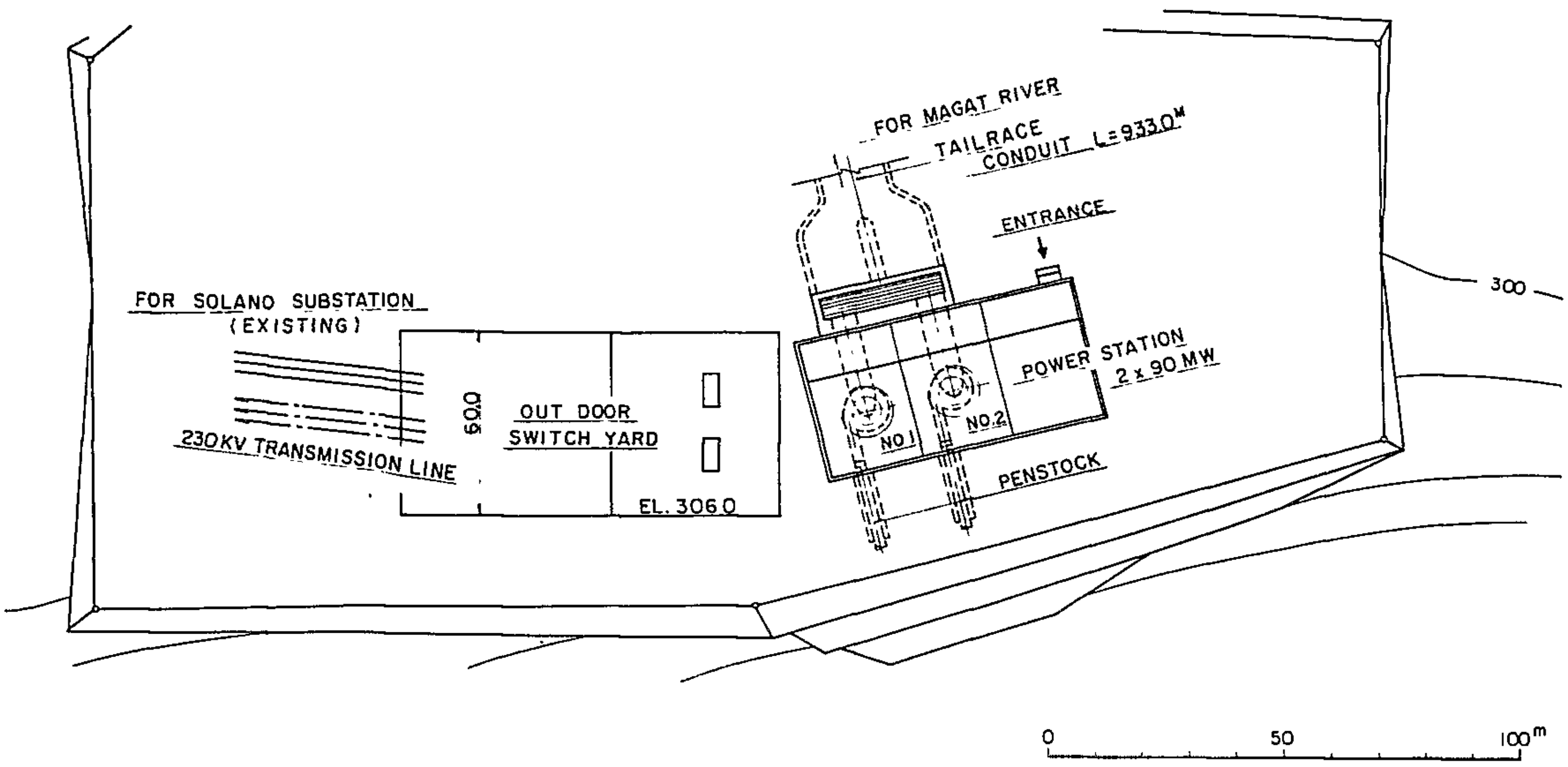


FIG. 7-4 GENERAL PLAN OF B1 DAM



PLAN OF POWERHOUSE AND SWITCHYARD

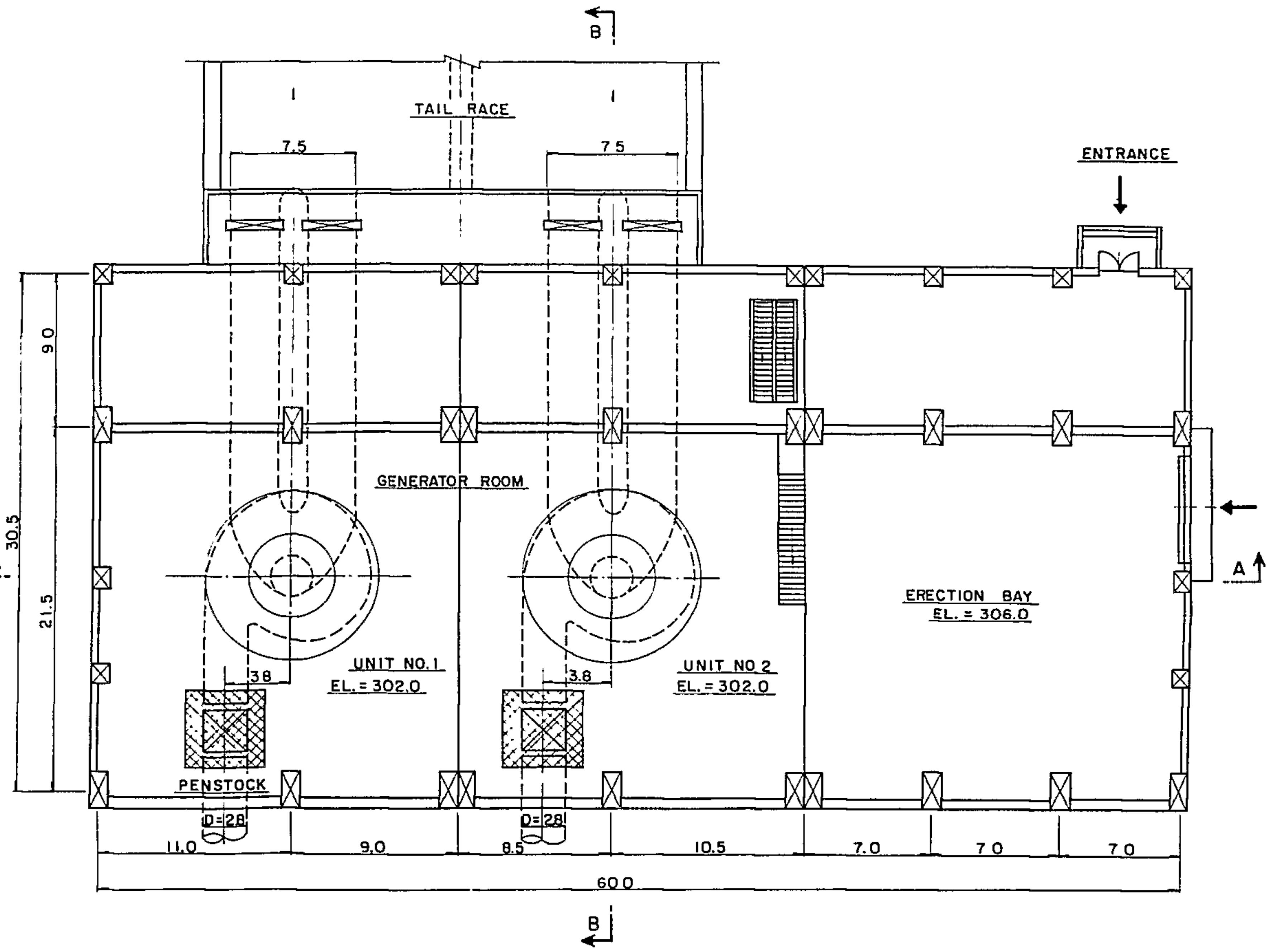
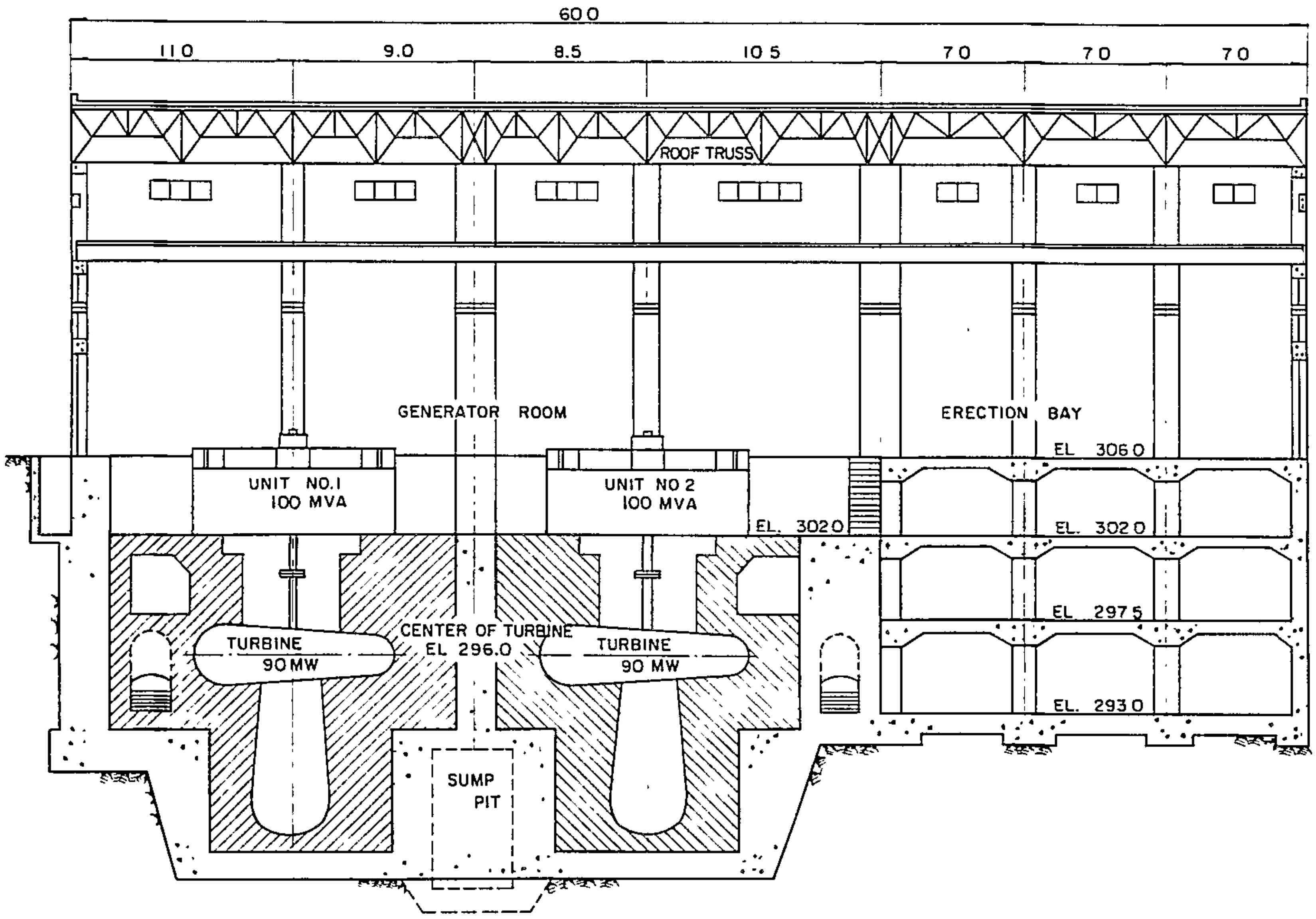
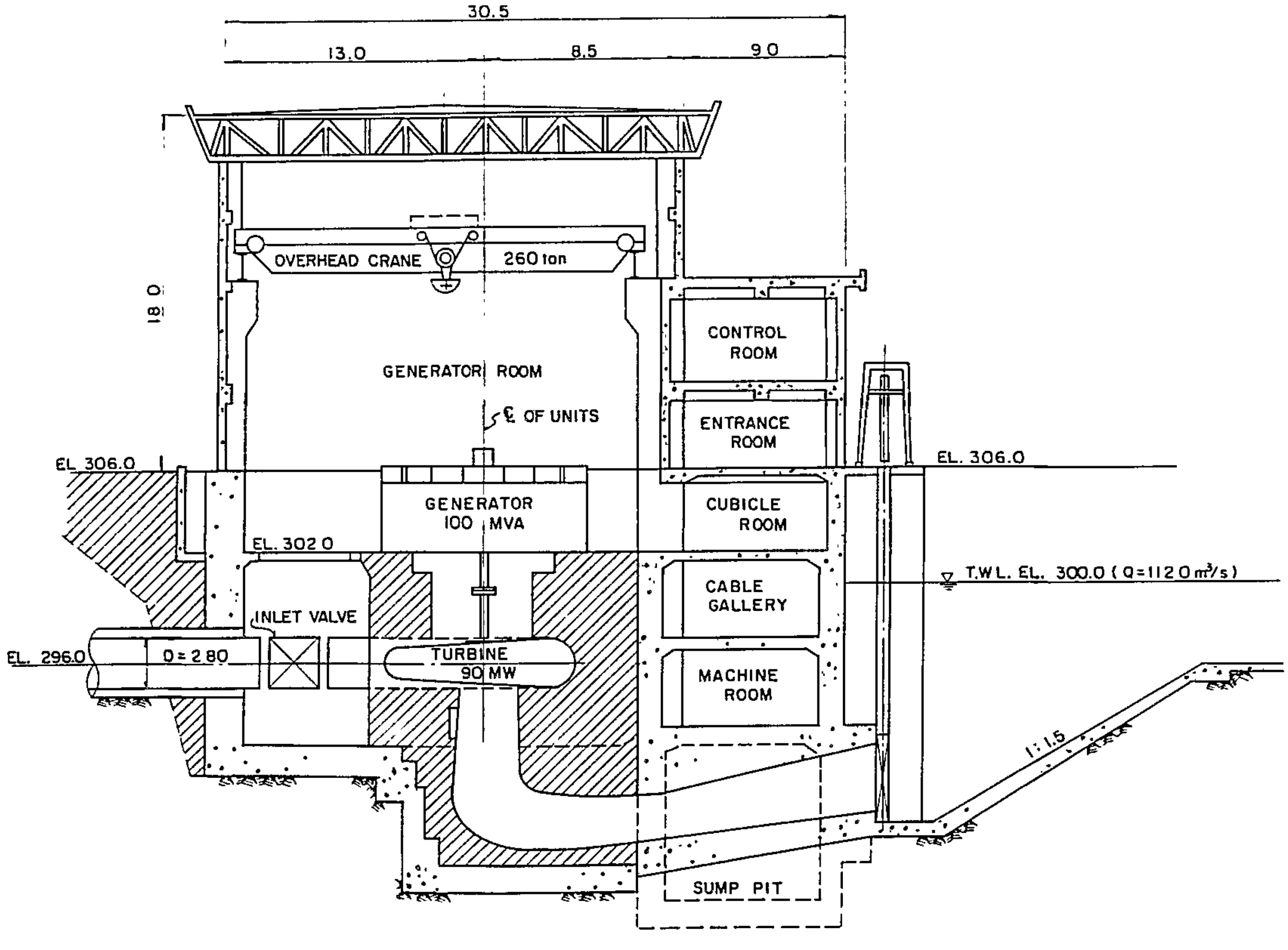


FIG. 7-5 PLAN ON POWERHOUSE AND SWITCHYARD



LONGITUDINAL SECTION (SECTION A–A)



TRANSVERSE SECTION (SECTION B–B)

FIG. 7-6 CROSS SECTION OF POWERHOUSE

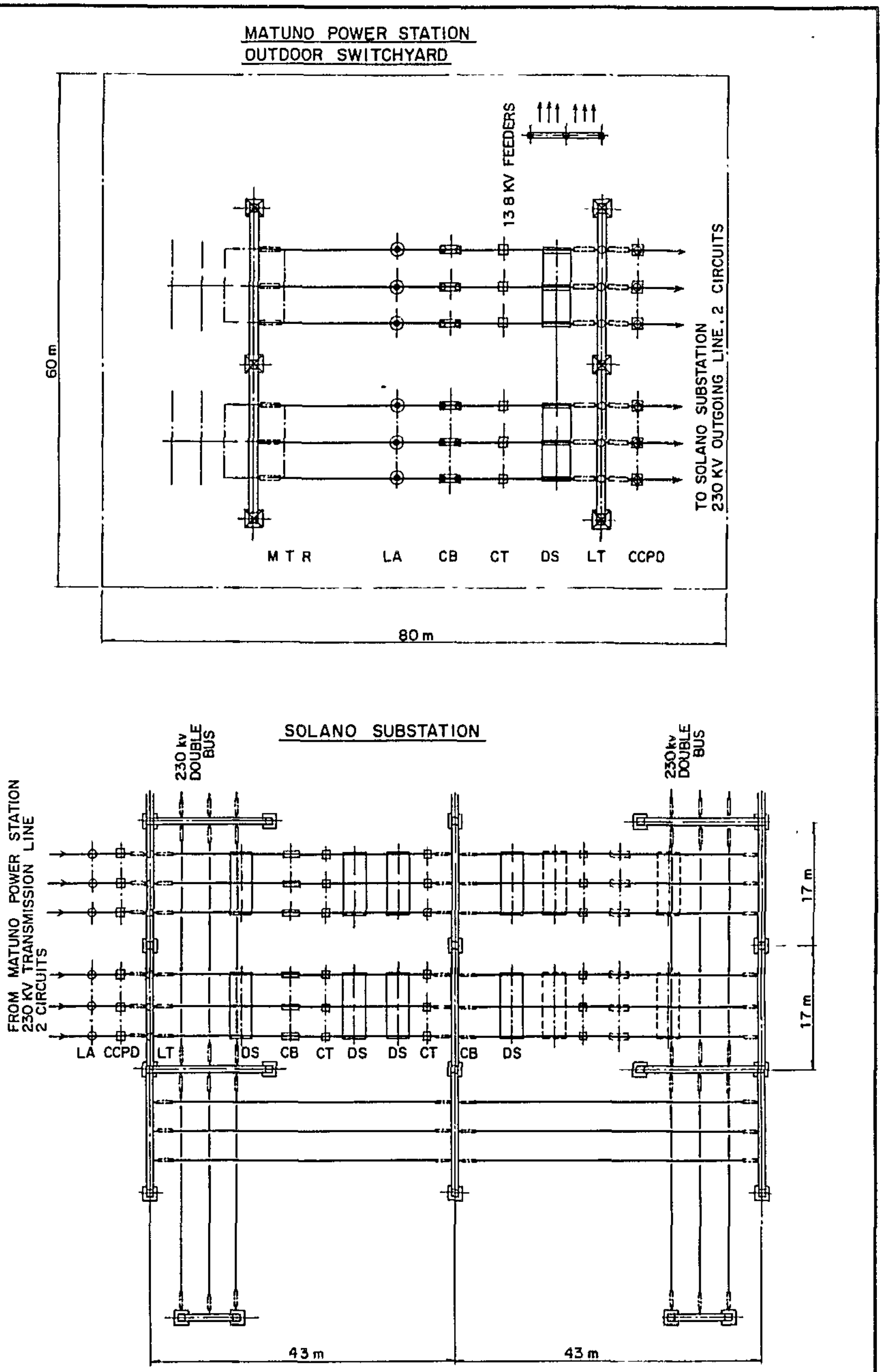


FIG.7-7 ARRANGEMENT OF OUTDOOR SWITCHYARD

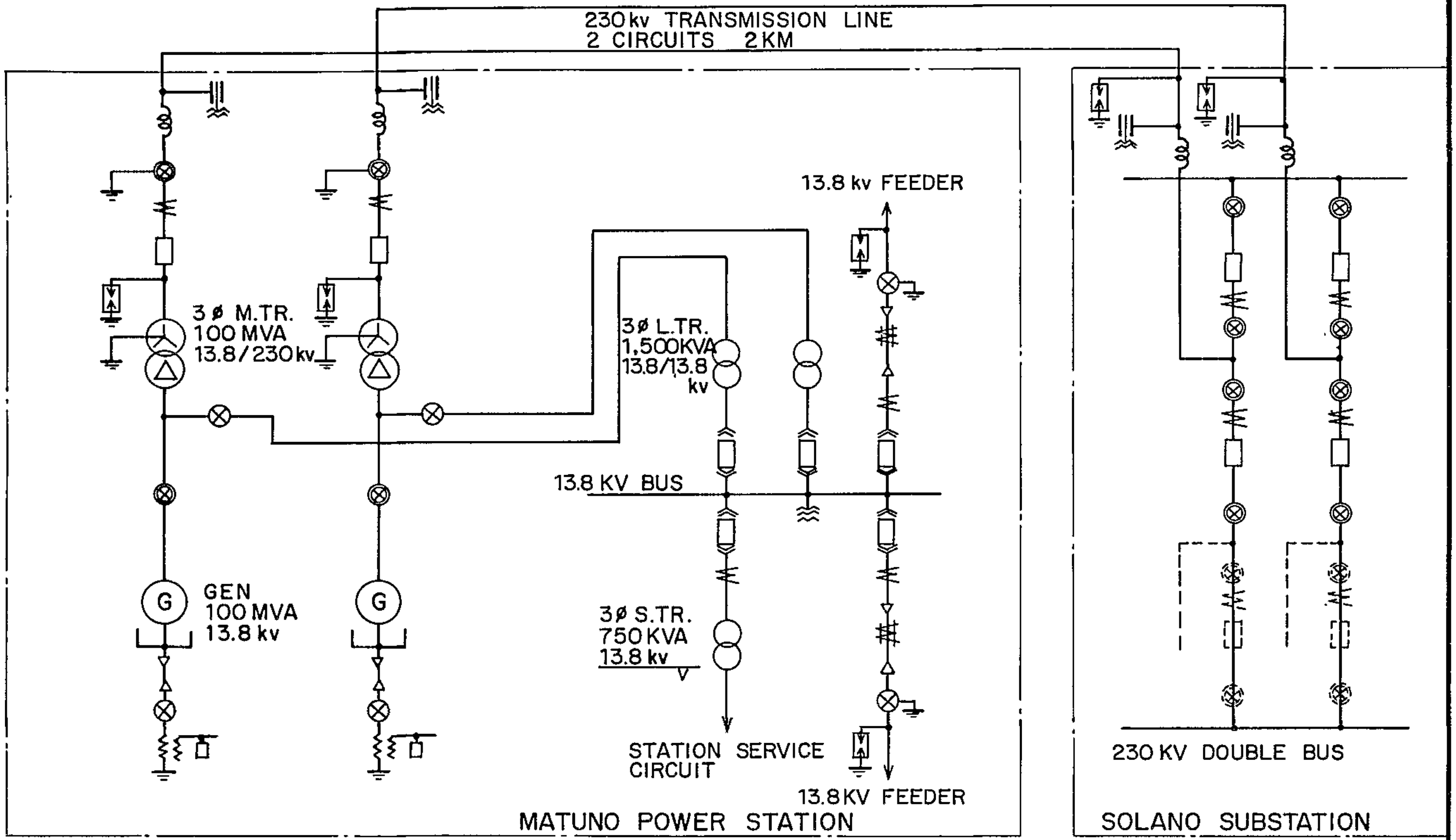


FIG. 7-8 SKELETON CONNECTION DIAGRAM

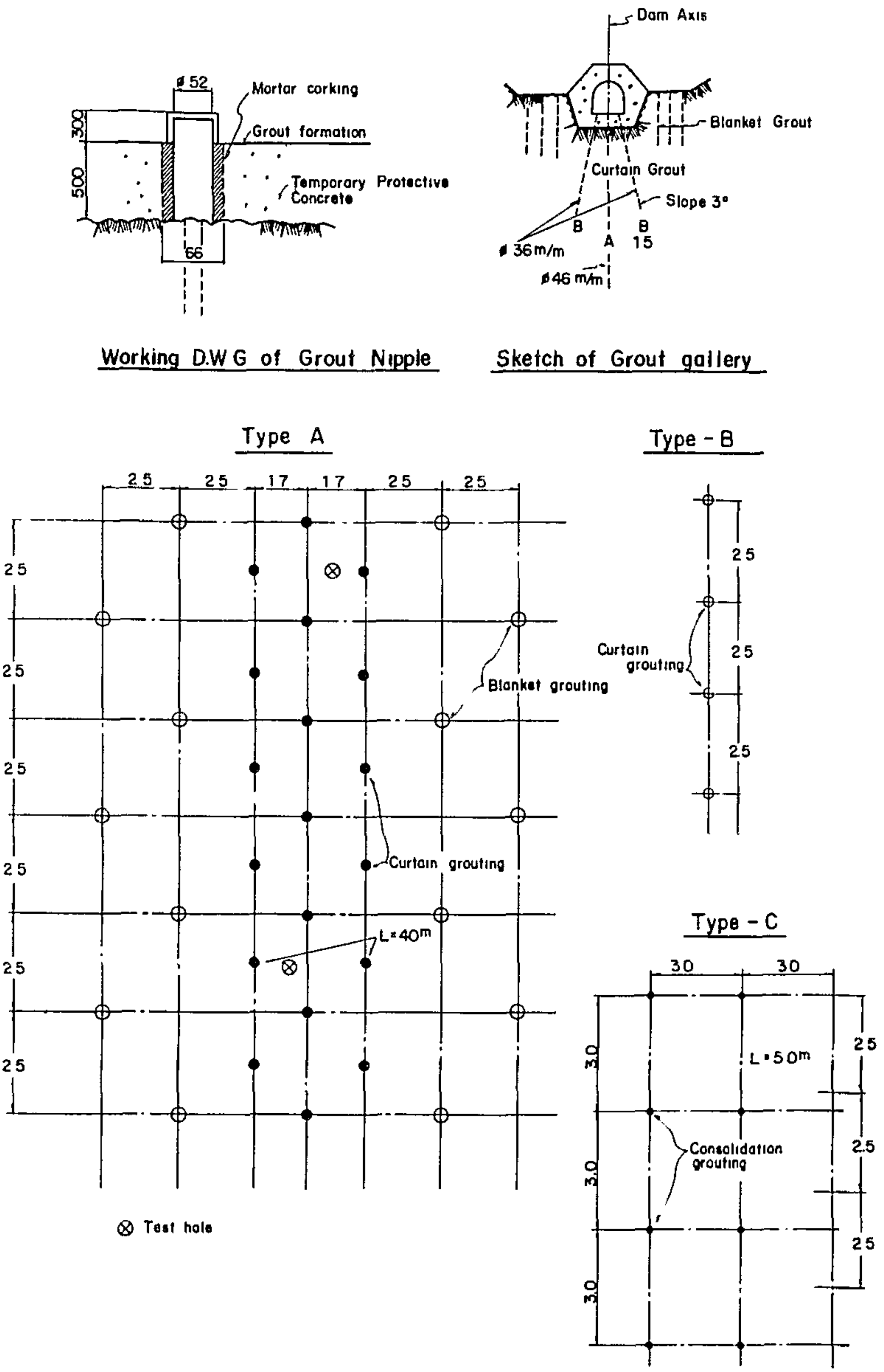
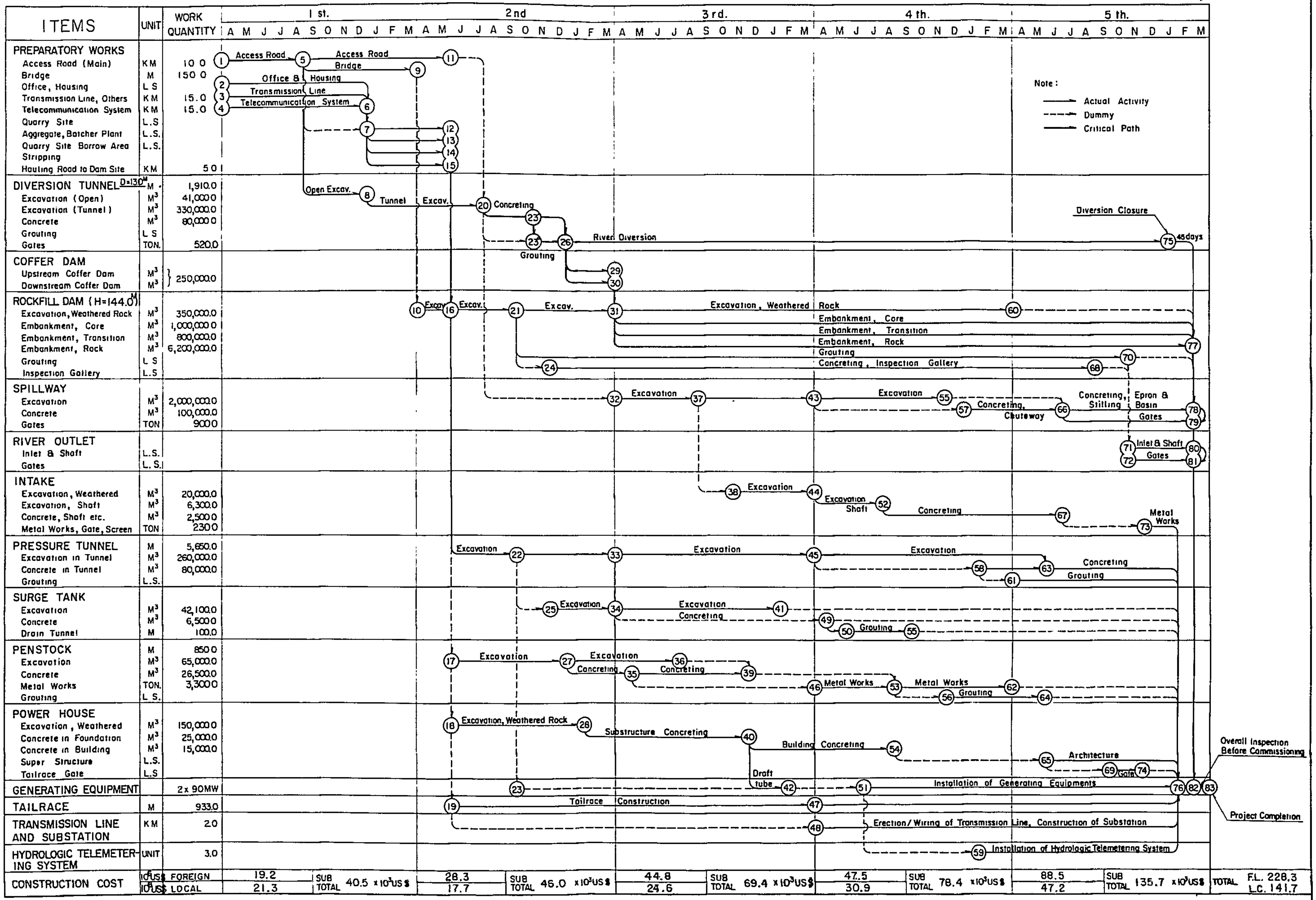


FIG.7-9 GROUT HOLE ARRANGEMENT

FIG.7-10 CONSTRUCTION TIME SCHEDULE OF B1 HIGH DAM AND POWER STATION ON MATUNO PROJECT

(At Price level of May 1983)



JICA