3.5 Power Demand Forecast of East Coast Area

3.5.1 General

According to the 1985 estimation of the total energy sold, the power demand of the east coast areas being 194.8 GWh occupys 34.1 per cent of the total for the whole Sabah, 571.8 GWh. This corresponds to about 71 per cent of the Kota Kinabalu demand. Though the rate of population growth in the Sandakan and Tawau Residencies between the 1970 and 1980 census being 5.4 per cent per annum was much higher than the national average being 3.8 per cent per annum, the power demand growth for the period of 1974 to 1984 was comparatively low; 8.3 per cent per annum for the east coast centers against 12.0 per cent per annum for the whole Sabah.

The major load centers are Sandakan and Tawau. Sandakan was the former capital of Sabah. But, with the shifting of the capital to Kota Kinabalu on the west coast, the roles as the commercial center of the state seem to have also shifted to the west coast. The boom for the logging and timber-based industries in the first half of 1970s has subsided and the related commercial activities are also not so active. These facts seem to have been reflected by the low growth of the power demand.

Tawau is the most active load center in the east coast areas. There are many timber or timber-based industries related to the logging activities in the areas. Industries related to construction and quarrying and other light industries are also in operation. Plantation agriculture for cocoa, oil palm, rubber, coconut, etc. absorbs a lot of labor forces. Reflecting such wide operation of economic activities, the growth of power demand for the period from 1974 to 1984 was largest among the East Coast load centers though slightly below the national average.

3.5.2 Historical Data for Power Demand

The historical power demand data of Sandakan, Tawau, Lahad Datu and Semporna for the period 1974 through 1984 were collected in the similar manner as that for the West Coast Load Centers and are tabulated in Tables 3.27 to 3.30.

1) The annual growth rates of sold energy of each load center are calculated for consumption categories as given below:

Annual Growth Rate of Each Load Center (%/year)

	1974/84	1974/80	1980/84	1982/84
Sandakan				
Domestic	7.0	11.9	7.8	5.6
Commercial	8.9	10.6	6.8	5.2
Industrial	4.8	5.1	4.2	-1.4
Army	6.9	2.0	13.2	24.7
Average	8.0	9.2	6.3	3.1
Tawau				
Domestic	13.3	14.2	11.9	9.1
Commercial	13.2	15.1	10.3	8.6
Industrial	10.1	4.2	19.6	24.7
Army	-4.9	-13.1	6.3	4.6
Average	12.6	10.7	12.7	11.8
Lahad Datu				
Domestic	14.2	15.6	12.1	17.7
Commercial	8.2	10.3	5.3	0.3
Industrial	3.0	4.4	0.9	4.3
Army	-2.3	-6.1	4.3	20.2
Average	8.4	9.6	6.5	7.6
Semporna				
Domestic	9.4	10.4	7.9	6.3
Commercial	8.6	12.1	3.4	1.7
Industrial	9.2	11.4	6.0	16.2
Army	-	-	-	-
Average	9.1	11.1	6.3	6.4

Table 3.27 HISTORICAL POWER DEMAND (1974 - 1984)
(SANDAKAN POWER STATION)

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1. Number of Consumers											
a) Domestic	7,527	8,113	8,766	9,349	10,032	10,600	11,222	12,061	13,036	14,188	14,298
b) Commercial	(1,961)	2,010	2,106	2,261	2,371	2,501	2,660	2,779	2,910	2,588	3,196
c) Industrial	549	398	414	435	462	485	593	563	583	597	662
d) Army	(-)	3	3	3	2	1	1	1	1	1	1
Total	10,037	10,524	11,289	12,048	12,867	13,587	14,476	15,404	16,535	17,374	18,157
2. Sold Energy (MWh)											
a) Domestic	13,634	14,735	16,096	17,934	20,361	23,617	26,720	29,647	32,318	35,465	36,019
b) Commercial	(11,458)	13,292	13,942	15,375	17,491	20,326	22,024	24,218	25,876	27,568	28,618
c) Industrial	19,764	16,631	17,459	18,167	17,622	24,561	26,694	28,037	32,366	32,895	31,459
d) Army	(-)	385	391	377	445	417	426	453	450	509	700
Total	44,856	45,043	47,888	51,853	55,919	63,921	75,864	82,355	91,010	96,437	96,796
3. Generated Energy (MWh)	52,059	52,258	57,171	62,581	68,333	83,148	93,026	104,847	112,800	119,206	123,873
4. Peak Demand (MW)	9.60	10.30	11.35	11.70	13.80	16.20	18.00	19.45	20.77	21.15	22.95
5. Annual Load Factor (%)	61.90	57.92	57.50	61.06	56.53	58.59	59.00	61.54	62.00	64.34	61.61

Table 3.28 HISTORICAL POWER DEMAND (1974 - 1984)
(TAWAU POWER STATION)

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1. Number of Consumers											
a) Domestic	3,948	4,385	4,727	5,154	5,703	6,241	6,893	7,517	8,438	9,544	10,770
b) Commercial	(1,071)	1,073	1,182	1,363	1,534	1,651	1,787	1,911	2,103	2,287	2,436
c) Industrial	270	249	262	284	294	307	335	369	404	440	464
d) Army	-	5	4	5	5	5	5	5	5	5	5
Total	5,289	5,712	6,175	6,806	7,536	8,204	9,010	9,802	10,950	12,276	13,675
2. Sold Energy (MWh)											
a) Domestic	7,666	9,214	8,846	10,845	12,320	14,777	17,019	19,564	22,422	24,321	26,700
b) Commercial	6,961	6,895	7,838	11,197	12,843	14,900	16,222	17,361	20,344	24,554	23,987
c) Industrial	5,707	6,178	5,863	6,551	6,001	6,381	7,302	9,507	9,606	12,419	14,948
d) Army	-	1,615	1,123	1,090	1,107	1,261	800	953	935	1,109	1,023
Total	20,342	23,902	23,670	29,683	32,371	37,319	41,343	47,385	53,307	62,403	66,658
3. Generated Energy (MWh)	23,552	26,830	29,594	35,290	38,237	45,877	50,986	58,943	66,011	75,327	82,839
4. Peak Demand (MW)	4.85	5.05	5.97	6.95	7.45	8.42	9.63	10.20	12.48	13.80	15.00
5. Annual Load Factor (%)	55.43	60.65	56.89	57.96	58.59	62.20	60.44	65.97	60.38	62.31	63.04

Table 3.29 <u>HISTORICAL POWER DEMAND (1974 - 1984)</u>
(LAHAD DATU POWER STATION)

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1. Number of Consumers											
a) Domestic	1,041	1,198	1,321	1,488	1,715	1,910	2,059	2,410	2,610	2,747	3,078
b) Commercial	434	466	492	531	591	636	671	720	757	837	850
c) Industrial	89	70	77	92	107	114	111	120	127	139	145
d) Army	-	1	1	1	1	1	1	1	1	1	1
Total	1,564	1,735	1,891	2,112	2,414	2,661	2,842	3,251	3,495	3,724	4,074
2. Sold Energy (MWh)											
a) Domestic	1,655	1,939	2,206	2,601	2,841	3,370	3,970	4,627	4,532	5,825	6,275
b) Commercial	2,331	2,074	2,301	2,459	2,928	3,622	4,192	4,467	5,116	5,144	5,145
c) Industrial	2,823	3,005	2,961	3,107	2,963	3,253	3,659	3,356	3,480	4,273	3,787
d) Army	-	16	14	13	10	11	11	11	9	11	13
Total	6,809	7,034	7,482	8,180	8,742	10,256	11,832	12,461	13,137	15,253	15,220
3. Generated Energy (MWh)	7,735	8,104	8,973	9,312	10,050	11,778	13,045	14,612	15,467	17,369	17,661
4. Peak Demand (MW)	1.64	1.64	1.85	1.74	1.83	2.12	2.39	2.68	2.99	3.25	-
5. Annual Load Factor (%)	53,84	56.41	55.37	61.09	62.69	63.42	62.31	62.24	59.05	61.01	-

Table 3.30 HISTORICAL POWER DEMAND (1974 - 1984)
(SEMPORNA POWER STATION)

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1. Number of Consumers											
a) Domestic	560	597	661	725	756	857	897	1,074	1,187	1,245	1,330
b) Commercial	136	136	156	161	166	160	211	221	247	235	229
c) Industrial	22	16	28	31	29	33	35	39	37	36	41
d) Army	-	-	-	-	-	-	-	-	-	-	-
Total	718	749	845	917	951	1,050	1,143	1,334	1,471	1,516	1,600
2. Sold Energy (MWh)											
a) Domestic	780	814	918	1,018	1,068	1,200	1,409	1,603	1,693	1,856	1,913
b) Commercial	422	460	519	609	608	703	839	834	929	1,033	960
c) Industrial	249	244	288	409	446	423	476	401	445	525	601
d) Army	-	-	-	-	-	-	-	-	-	-	-
Total	1,451	1,518	1,725	2,036	2,122	2,326	2,724	2,838	3,067	3,414	3,474
3. Generated Energy (MWh)	1,716	2,050	2,287	2,476	2,614	2,830	3,354	3,816	4,248	4,949	5,193
4. Peak Demand (MW)	0.545	0.600	0.620	0.580	0.610	0.650	0.680	0.780	0.950	1.180	1.180
5. Annual Load Factor (%)	35.94	39.00	42.11	48.73	48.13	49.70	56.31	55.85	51.05	47.88	50.24

2) The average growth rate of each load center for the period 1974 through 1984 is lower than the national average being 12.0 per cent per annum. The growth rate of Tawau (12.6%) slightly exceeded the national average and those of the other load centers are lower than 10 per cent per annum (8.0 to 9.1%).

3) It is the same tendency that the west coast growth rates for 1982 to 84 are lower than those for the previous record.

4) The daily load curves of Sandakan, Tawau and Lahad Datu are of day peak pattern and that of Semporna is of evening peak.

3.5.3 Power Demand Forecast

The power demand of each of the four load centers is forecast in the same manner as that for the west coast load centers.

1) The electrification ratios as of 1984 and assumed for 1995 are as given below:

Household Electrification Ratios (%)

		Assumed for 1995	
	1984	High	Low
Sandakan	57.6	75	70
Tawau	37.8	75	70
Lahad Datu	26.8	55	50
Semporna	11.2	20	17

2) The unit energy consumption of domestic demand as of 1984, assumed for 1995 of the consumers already connected in 1984 and of newly connected consumers are given below.:

Unit Consumption per Consumer (kWh)

		Assumed for 1995		New
	1984	High	Low	Connection
Sandakan	2,519	3,600	3,200	1,800
Tawau	2,479	3,600	3,200	1,800
Lahad Datu	2,039	3,000	2,700	1,500
Semporna	1,438	2,300	2,000	1,200

3) The ratios of the commercial demands to the domestic demands as of 1984 and assumed for 1995 are given below:

Ratios of Commercial Demand to Domestic Demand (%)

		Assumed for 1995	
	1984	High	Low
Sandakan	79.5	85	75
Tawau	89.8	100	80
Lahad Datu	82.0	90	80
Semporna	50.2	60	50

4) The growth rates of the industrial demand for the period 1984 through 1995 are assumed as given below:

Growth Rates of Industrial Demand (%)

	High	Low
Sandakan	6	4
Tawau	11	9
Lahad Datu	5	4
Semporna	11	9

5) The results of power demand forecast for the four load centers, Sandakan, Tawau, Lahad Datu and Semporna, are tabulated in Tables 3.31 to 3.34.

3.5.4 Forecast Beyond 1995

The power demand beyond 1995 is forecasted for the two groups, Group-1 for the Sandakan load and Group-2 for the combined load of Tawau, Lahad Datu and Semporna, based on the asssumed sequence for interconnection with the west coast power system. The assumed growth rates are given below:

Annual Growth Rates Beyond 1995 (%/year)

	Group-1		Group-2	
	High	Low	High	Low
1995-2000	7.0	5.3	10.5	8.85
2000-2005	6.0	4.8	8.0	7.1
2005-2010	4.5	3.75	6.0	5.3

3.5.5 System Peak Demand

In obtaining the peak demand which occurs in daytime, a factor of 0.8 is multiplied to the peak demand of Semporna.

The east coast load centers are assumed to be interconnected with the west coast system as given below:

Table 3.31 DEMAND FORECAST (1985 - 1995) FOR TAWAU

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
HIGH ESTIMATE	(ACTUAL)											
1.DOMESTIC DEMAND												
POPULATION (x1,000)	146.8	153.9	160.5	167.4	174.6	182.1	190	197.4	205.1	213.1	221.4	230
NO. OF HOUSEHOLDS	28500	29900	31300	32800	34400	36000	37700	39300	41000	42800	44700	46600
NO. OF CONSUMERS	10770	11912	13174	14570	16115	17823	19712	21801	24112	26667	29494	32620
ELECT. RATIO (%)	37.8	39.8	42.1	44.4	46.8	49.5	52.3	55.5	58.8	62.3	66	70
DOMESTIC DEMAND (MWH)	26700	29852	33337	37199	41163	46180	51396	57158	63544	70591	78391	87027
UNIT CONSUMPTION (KWH)	2479	2506	2531	2553	2573	2591	2607	2622	2635	2647	2658	2668
2.COMMERCIAL DEMAND												
RATIO TO R.D. (%)	89.8	90.7	91.7	92.6	93.5	94.4	95.4	96.3	97.2	98.1	99.1	100
COMMERCIAL DEMAND (MWH)	23987	27084	30555	34440	38772	43611	49013	55038	61776	69282	77667	87027
3.INDUSTRIAL DEMAND (MWH)	14948	16592	18251	20076	22084	24292	26721	29393	32332	35565	39122	43034
4.ARMY DEMAND (MWH)	1023	1074	1128	1184	1243	1305	1370	1439	1511	1587	1666	1749
5.TOTAL POWER DEMAND (MWH)	66658	74602	83271	92899	103562	115388	128500	143028	159163	177025	196849	218837
6.LOSS & STATION USE (%)	17.2	17	16.8	16.6	16.4	16.2	16	15.8	15.6	15.4	15.2	15
7.REQUIRED ENERGY (MWH)	80505	89882	100085	111390	123878	137695	152976	169867	188582	209249	232133	257455
8.ANNUAL LOAD FACTOR (%)	61.3	61	61	61	61	61	61	61	61	61	61	61
9.PEAK DEMAND (MW)	15	16.82	18.73	20.35	23.18	25.77	28.63	31.79	35.29	39.16	43.14	48.18

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
LOW ESTIMATE	(ACTUAL)											
1.DDMESTIC DEMAND												
POPULATION (x1,000)	146.8	153.9	160.5	167.4	174.6	182.1	190	197.4	205.1	213.1	221.4	230
NO. OF HOUSEHOLDS	28500	29900	31300	32800	34400	36000	37700	39300	41000	42800	44700	46600
NO. OF CONSUMERS	10770	11832	12998	14279	15686	17232	18931	20797	22847	25098	27572	30290
ELECT. RATIO (%)	37.8	39.6	41.5	43.5	45.6	47.9	50.2	52.9	55.7	58.6	61.7	65
DOMESTIC DEMAND (MWH)	26700	29316	32194	35354	38823	42634	46820	51416	56463	62004	68090	74803
UNIT CONSUMPTION (KWH)	2479	2478	2477	2476	2475	2474	2473	2472	2471	2470	2470	2470
2.COMMERCIAL DEMAND												
RATIO TO R.D.	89.8	88.9	88	87.1	86.2	85.3	84.5	83.6	82.7	81.8	80.9	80
COMMERCIAL DEMAND (MWH)	23987	26065	28337	30803	33480	36386	39542	42965	46680	50708	55079	59842
3.INDUSTRIAL DEMAND (MWH)	14918	16260	17723	19318	21056	22951	25016	27267	29721	32395	35310	38487
4.ARMY DEMAND (MWH)	1023	1074	1128	1184	1243	1305	1370	1439	1511	1587	1666	1749
5.TOTAL POWER DEMAND (MWH)	66658	72715	79382	86659	94602	103276	112748	123087	134375	146694	160145	174881
6.LOSS & STATION USE (%)	17.2	17	16.8	16.6	16.4	16.2	16	15.8	15.6	15.4	15.2	15
7.REQUIRED ENERGY (MWH)	80505	87608	95411	103908	113160	123241	134224	146184	159212	173397	188850	205742
8.ANNUAL LOAD FACTOR (%)	61.3	61	61	61	61	61	61	61	61	61	61	61
9.PEAK DEMAND (MW)	15	16.39	17.86	19.45	21.18	23.06	25.12	27.36	29.79	32.45	35.34	38.5

Table 3.32 *DEMAND FORECAST (1985 - 1995) FOR SANDAKAN*

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
HIGH ESTIMATE	(ACTUAL)											
1.DOMESTIC DEMAND												
POPULATION (x1,000)	139.0	144.7	150.4	156.2	162.2	168.6	175.1	181.5	188.1	195	202.1	209.5
NO. OF HOUSEHOLDS	24830	25850	27000	28140	29380	30630	31970	33320	34780	36310	37900	39570
NO. OF CONSUMERS	14298	15279	16328	17449	18647	19927	21294	22756	24318	25987	27771	29677
ELECT. RATIO (%)	57.6	59.1	60.5	62	63.5	65.1	66.6	68.3	69.9	71.6	73.3	75
DOMESTIC DEMAND (MWH)	36019	39188	42581	46206	50077	54223	58641	63368	68424	73826	79595	85752
UNIT CONSUMPTION (KWH)	2519	2565	2608	2648	2686	2721	2754	2785	2814	2841	2866	2890
2.COMMERCIAL DEMAND												
RATIO TO R.D. (%)	79.5	80	80.5	81	81.5	82	82.5	83	83.5	84	84.5	85
COMMERCIAL DEMAND (MWH)	28618	31350	34278	37427	40813	44463	48379	52595	57134	62014	67258	72889
3.INDUSTRIAL DEMAND (MWH)	31549	33412	35449	37576	39831	42221	44754	47439	50285	53302	56500	59890
4.ARMY DEMAND (MWH)	700	735	772	811	852	895	940	987	1036	1088	1142	1199
5.TOTAL POWER DEMAND (MWH)	96796	104715	113080	122020	131573	141802	152714	164389	176879	190230	204495	219730
6.LOSS & STATION USE (%)	19.1	18.7	18.4	18	17.6	17.2	16.9	16.5	16.1	15.7	15.4	15
7.REQUIRED ENERGY (MWH)	119649	128844	138501	148772	159694	171334	183691	196852	210867	225780	241642	258506
8.ANNUAL LOAD FACTOR (%)	59.5	60	60	60	60	60	60	60	60	60	60	60
9.PEAK DEMAND (MW)	22.95	24.51	26.35	28.31	30.38	32.6	34.95	37.45	40.12	42.96	45.97	49.18

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
LOW ESTIMATE	(ACTUAL)											
1.DDMESTIC DEMAND												
POPULATION (x1,000)	139	144.7	150.4	156.4	162.2	168.6	175.1	181.5	188.1	195	202.1	209.5
NO. OF HOUSEHOLDS	24830	25850	27000	28140	29380	30630	31970	33320	34780	36310	37900	39570
NO. OF CONSUMERS	14298	15184	16125	17124	18185	19312	20508	21779	23128	24561	26083	27699
ELECT. RATIO (%)	57.6	58.7	59.7	60.9	61.9	63	64.1	65.4	66.5	67.6	68.8	70
DOMESTIC DEMAND (MWH)	36019	38585	41310	44209	47290	50548	54007	57682	61604	65767	70187	74874
UNIT CONSUMPTION (KWH)	2519	2541	2562	2582	2600	2617	2633	2649	2664	2678	2691	2703
2.COMMERCIAL DEMAND												
RATIO TO R.D.	79.5	79.1	78.7	78.3	77.9	77.5	77	76.6	76.2	75.8	75.4	75
COMMERCIAL DEMAND (MWH)	28618	30517	32503	34604	36822	39152	41610	44205	46959	49863	52927	56156
3.INDUSTRIAL DEMAND (MWH)	31549	32811	34123	35488	36908	38384	39919	41516	43177	44904	46700	48568
4.ARMY DEMAND (MWH)	700	735	772	811	852	895	940	987	1036	1088	1142	1199
5.TOTAL POWER DEMAND (MWH)	96796	102648	108708	115112	121872	128979	136476	144390	152776	161622	170956	180797
6.LOSS & STATION USE (%)	19.1	18.7	18.4	18	17.6	17.2	16.9	16.5	16.1	15.7	15.4	15
7.REQUIRED ENERGY (MWH)	119649	126258	133221	140380	147903	155772	164231	172922	182093	191722	202076	212702
8.ANNUAL LOAD FACTOR (%)	59.5	60	60	60	60	60	60	60	60	60	60	60
9.PEAK DEMAND (MW)	22.95	24.02	25.35	26.71	28.14	29.64	31.25	32.9	34.64	36.48	38.45	40.47

Table 3.33 DEMAND FORECAST (1985 - 1995) FOR LAHAD DATU

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
HIGH ESTIMATE												
1.DOMESTIC DEMAND	(ACTUAL)											
POPULATION	64400	66800	69400	72200	75100	78100	81200	84300	87400	90700	94100	97600
NO. OF HOUSEHOLDS	11490	12050	12570	13140	13370	14280	14980	15630	16280	16970	17680	18430
NO. OF CONSUMERS	3078	3430	3823	4260	4748	5291	5897	6572	7324	8162	9096	10136
ELECT. RATIO (%)	26.8	28.5	30.4	32.4	35.5	37.1	39.4	42	45	48.1	51.4	55
DOMESTIC DEMAND (MWH)	6275	7073	7962	8953	10059	11290	12662	14189	15891	17790	19908	22266
UNIT CONSUMPTION (KWH)	2039	2062	2083	2102	2119	2134	2147	2159	2170	2180	2189	2197
2.COMMERCIAL DEMAND												
RATIO TO R.D. (%)	82	82.7	83.5	84.2	84.9	85.6	86.4	87.1	87.8	88.5	89.3	90
COMMERCIAL DEMAND (MWH)	5145	5851	6645	7537	8541	9668	10935	12357	13955	15752	17772	20039
3.INDUSTRIAL DEMAND (MWH)	3787	3976	4175	4384	4603	4833	5075	5329	5595	5875	6169	6477
4.ARMY DEMAND (MWH)	13	14	14	15	16	17	17	18	19	20	21	22
5.TOTAL POWER DEMAND (MWH)	15220	16914	18796	20889	23219	25808	28689	31893	35460	39437	43870	48804
6.LOSS & STATION USE (%)	12.2	12	12	12	12	12	12	12	12	12	12	12
7.REQUIRED ENERGY (MWH)	17335	19220	21359	23738	26385	29327	32601	36242	40295	44815	49852	55159
8.ANNUAL LOAD FACTOR (%)	61	61	61	61	61	61	61	61	61	61	61	61
9.PEAK DEMAND (MW)	3.24	3.6	4	4.44	4.94	5.49	6.1	6.78	7.54	8.39	9.33	10.38

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
LOW ESTIMATE	(ACTUAL)											
1.DOMESTIC DEMAND												
POPULATION	64400	66800	69400	72200	75100	78100	81200	84300	87400	90700	94100	97600
NO. OF HOUSEHOLDS	11490	12050	12570	13140	13730	14280	14980	15630	16280	16970	17680	18430
NO. OF CONSUMERS	3078	3401	3757	4151	4586	5066	5597	6184	6832	7548	8339	9215
ELECT. RATIO (%)	26.8	28.2	29.9	31.6	33.4	35.5	37.4	39.6	42	44.5	47.2	50
DOMESTIC DEMAND (MWH)	6275	6945	7683	8500	9403	10397	11496	12713	14058	15545	17181	18993
UNIT CONSUMPTION (KWH)	2039	2042	2045	2048	2050	2052	2054	2056	2058	2059	2060	2061
2.COMMERCIAL DEMAND												
RATIO TO R.D. (%)	82	81.8	81.6	81.5	81.3	81.1	80.9	80.7	80.5	80.4	80.2	80
COMMERCIAL DEMAND (MWH)	5145	5682	6272	6924	7642	8431	9301	10263	11323	12493	13776	15194
3.INDUSTRIAL DEMAND (MWH)	3787	3938	4096	4260	4430	4607	4791	4983	5182	5389	5605	5829
4.ARMY DEMAND (MWH)	13	14	15	16	17	18	19	20	21	22	23	24
5.TOTAL POWER DEMAND (MWH)	15520	16579	18066	19700	21492	23453	25607	27979	30584	33449	36585	40040
6.LOSS & STATION USE (%)	12.2	12	12	12	12	12	12	12	12	12	12	12
7.REQUIRED ENERGY (MWH)	17335	18840	20530	22386	24423	26651	29099	31794	34755	38010	41574	45500
8.ANNUAL LOAD FACTOR (%)	61	61	61	61	61	61	61	61	61	61	61	61
9.PEAK DEMAND (MW)	3.24	3.58	3.91	4.26	4.65	5.07	5.54	6.05	6.61	7.23	7.91	8.66

Table 3.34 DEMAND FORECAST (1985 - 1995) FOR SEMPORNA

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
HIGH ESTIMATE												
1.DOMESTIC DEMAND	(ACTUAL)											
POPULATION	71310	75590	79370	83340	87500	91880	96470	104340	117370	124300	131630	139400
NO. OF HOUSEHOLDS	11890	12600	13450	14130	14830	15570	16350	17300	17990	18710	19460	20240
NO. OF CONSUMERS	1330	1472	1628	1802	1994	2206	2441	2701	2988	3306	3658	4048
ELECT. RATIO (%)	11.2	11.7	12.1	12.8	13.4	14.2	14.9	15.6	16.6	17.7	18.8	20
DOMESTIC DEMAND (MWH)	1913	2187	2490	2826	3197	3607	4062	4565	5121	5737	6418	7175
UNIT CONSUMPTION (KWH)	1438	1486	1529	1568	1603	1635	1664	1690	1714	1735	1755	1772
2.COMMERCIAL DEMAND												
RATIO TO R.D. (%)	50.2	51.1	52	52.9	53.8	54.7	55.5	56.4	57.3	58.2	59.1	60
COMMERCIAL DEMAND (MWH)	960	1117	1294	1494	1719	1971	2256	2576	2936	3340	3794	4305
3.INDUSTRIAL DEMAND (MWH)	601	667	740	822	912	1013	1124	1248	1385	1537	1706	1894
4.ARMY DEMAND (MWH)	0	0	0	0	0	0	0	0	0	0	0	0
5.TOTAL POWER DEMAND (MWH)	3474	3971	4524	5142	5828	6591	7442	8389	9442	10614	11918	13374
6.LOSS & STATION USE (%)	33.1	31.5	29.8	28.2	26.5	24.9	23.2	21.6	19.9	18.3	16.6	15
7.REQUIRED ENERGY (MWH)	5035	5797	6444	7162	7929	8776	9690	10700	11788	12991	14290	15734
8.ANNUAL LOAD FACTOR (%)	48.7	49.3	49.8	50.4	51	51.6	52.1	52.7	53.3	53.9	54.4	55
9.PEAK DEMAND (MW)	1.18	1.34	1.48	1.62	1.77	1.94	2.12	2.32	2.52	2.75	3	3.27

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
LOW ESTIMATE	(ACTUAL)											
1.DOMESTIC DEMAND												
POPULATION	71310	75590	79370	83340	87500	91880	96470	100330	117370	12430	131630	139400
NO. OF HOUSEHOLDS	11890	12600	13450	14130	14830	15570	16350	17300	17990	18710	19460	20240
NO. OF CONSUMERS	1330	1450	1581	1724	1879	2049	2234	2435	2655	2895	3156	3441
ELECT. RATIO (%)	11.2	11.5	11.8	12.2	12.7	13.2	13.7	14.1	14.8	15.5	16.2	17
DOMESTIC DEMAND (MWH)	1913	2124	2356	2608	2882	3182	3509	3865	4253	4677	5139	5641
UNIT CONSUMPTION (KWH)	1438	1465	1490	1513	1534	1553	1571	1587	1602	1616	1628	1639
2.COMMERCIAL DEMAND												
RATIO TO R.D. (%)	50.2	50.2	50.2	50.1	50.1	50.1	50.1	50.1	50.1	50	50	50
COMMERCIAL DEMAND (MWH)	960	1066	1182	1308	1445	1594	1758	1935	2129	2340	2570	2821
3.INDUSTRIAL DEMAND (MWH)	601	655	714	778	848	924	1007	1098	1197	1305	1422	1550
4.ARMY DEMAND (MWH)	0	0	0	0	0	0	0	0	0	0	0	0
5.TOTAL POWER DEMAND (MWH)	3474	3845	4252	4694	5175	5700	6274	6898	7579	8322	9131	10012
6.LOSS & STATION USE (%)	33.1	31.5	29.8	28.2	26.5	24.9	23.2	21.6	19.9	18.3	16.6	15
7.REQUIRED ENERGY (MWH)	5035	5613	6057	6538	7041	7590	8169	8798	9462	10186	10918	11779
8.ANNUAL LOAD FACTOR (%)	48.7	49.3	49.8	50.4	51	51.6	52.1	52.7	53.3	53.9	54.4	55
9.PEAK DEMAND (MW)	1.18	1.3	1.39	1.48	1.58	1.68	1.79	1.91	2.03	2.16	2.3	2.44

1995 : Sandakan

2000 : Tawau,Lahad Datu and Semporna

The interconnected peak demand of the East Coast system is tabulated in Table 3.35 and the peak demand of the non-interconnected system in the state of Sabah is tabulated in Table 3.36. The peak demands of the non-interconnected and interconnected system in the state of Sabah are shown in Figures 3.4 and 3.5 respectively.

3.6 Power Development Plan

3.6.1 Strategy for Power Development

In planning the development strategy for the power generation, SEB takes into account the following policies set out by the Malaysian Government:

1) Reduce reliance on fossil fuel for power generation

2) Improved efficiency of the existing system of power generation

3) Development of other sources of energy generation, e.g. hydro, gas, coal,etc.

During the period of Fourth Malaysian Plan (1981 - 1985), SEB has accomplished the followings:

1) Successful implementation of the Tenom Pangi Power Project, Phases I and II.

2) Implementation of one mini hydro project at Mesilau.

3) Assisting the development of gas resources in the west coast of Sabah leading to the establishment of the Sabah Energy Corporation in 1981.

Table 3.35 FORECAST OF SYSTEM PEAK DEMAND (SEB EAST COAST AREA)

(Unit: MW)

Demand centers	1985	1986	1987	1988	1989	1990	1991	1992	1995	2000	2005	2010
(High Forecast)												
Group 1												
Sandakan	24.5	26.3	28.3	30.4	32.6	34.9	37.4	40.1	49.2	69.0	92.3	115.1
Group 2												
Tawau	16.8	18.7	20.9	23.2	25.8	28.6	31.8	35.3	48.2			
Lahad Datu	3.6	4.0	4.4	4.9	5.5	6.1	6.8	7.5	10.4			
Semporna	1.1	1.2	1.3	1.4	1.5	1.7	1.8	2.0	2.6			
Total	21.5	23.9	26.6	29.5	32.8	36.4	40.4	44.8	61.2	100.8	162.3	217.3
Grand Total	(46.0)	(50.2)	(54.9)	(59.9)	(65.4)	(71.3)	(77.8)	(84.9)	(110.4)	169.8	254.6	332.4
(Low Forecast)												
Group 1												
Sandakan	24.0	25.4	26.7	28.1	29.6	31.3	32.9	34.6	40.5	52.4	66.3	79.7
Group 2												
Tawau	16.4	17.9	19.4	21.2	23.1	25.1	27.4	29.8	38.5			
Lahad Datu	3.6	3.9	4.3	4.6	5.1	5.6	6.0	6.6	8.7			
Semprna	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.9			
Total	21.0	22.9	24.9	27.1	29.5	32.1	34.9	38.0	49.1	75.0	105.7	136.9
Grand Total	(45.0)	(48.3)	(51.6)	(55.2)	(59.1)	(63.4)	(67.8)	(72.6)	(89.6)	127.4	172.0	216.6

Note: 1. The interconnection with the west coast is assumed to be made with Sandakan at first and with Tawau, Lahad Datu and Semporna at a later date.

2. For Semporna, assumed day peak values are entered.

3. Figures in parentheses are non-interconnected peak demand.

Table 3.36 SUMMARY OF PEAK POWER DEMAND FORECAST IN SABAH

(Unit: MW)

Year	West coast area		East coast area		Total	
	High forecast	Low forecast	High forecast	Low forecast	High forecast	Low forecast
1985	82.0	80.0	46.0	45.0	128.0	125.0
	(10.8%)	(7.8%)	(9.2%)	(7.1%)	(10.3%)	(7.6%)
1990	137.2	116.5	71.3	63.4	208.5	179.9
	(9.9%)	(7.1%)	(9.1%)	(7.2%)	(9.7%)	(7.1%)
1995	220.1	164.2	110.4	89.6	330.5	253.8
	(9.9%)	(7.1%)	(9.0%)	(7.3%)	(9.6%)	(7.1%)
2000	353.5	230.9	169.8	127.4	523.3	358.3
	(8.0%)	(5.7%)	(8.4%)	(6.2%)	(8.1%)	(5.8%)
2005	519.4	304.0	254.6	172.0	774.0	476.0
	(6.0%)	(4.2%)	(5.5%)	(4.7%)	(5.8%)	(4.4%)
2010	695.1	374.3	332.4	216.6	1,027.5	590.9

Note: Figures in parenthses are annual average growth rate of forecasted peak power demand.

4) Execution of the Master Plan Development Study for an overview of power requirement throughout Sabah up to the year 2010.

5) Increased generation and transmission capacity to meet power demand for the existing systems throughout the State of Sabah.

In order to meet the increasing power demand of Sabah, which is forecasted by SEB to reach 208.8 MW in 1990, 521 MW in 2000 and 1,023.6 MW in 2010 for peak demand, SEB set out a long term power development plan, which envisages the development of two hydro power projects; the Tenom Pangi Power Project, Phase III, and Liwagu No. 2 or Padas No. 5 (both rated at about 100 MW) and a gas-fired combined cycle plant of about 200 MW in installed capacity utilizing natural gas available at Labuan.

Several alternatives have been considered based upon the price of gas to be supplied from the Sabah Gas Industries. Construction of a coal-fired thermal plant is also considered in the case that gas is not available on economically competitive basis.

In order to fully utilize electric power generated at major power stations and to shut down money-consuming small scale diesel power stations, the existing transmission system will be extended within the reasonable transmission and distribution distance from the existing and proposed power system. Mini hydro power projects will be implemented for pursuing the rural electrification programme.

3.6.2 Generation Expansion Plan

During the period of Fifth Malaysian Plan (1986-90), the following generating capacity expansion plans are scheduled to be implemented in the power supply area of the Tenom Pangi Power Project, Phase III.

1) Power receiving from SGI

A combined cycle generating set of SGI, consisting of two gas turbine generators with 32 MW capacity and a 15 MW steam turbine set, is now operating for their own power supply. Normal operation output of this generating set is 47 MW with one set each of gas turbine generator and the steam turbine generator, out of which about 30 MW is scheduled to be available for SEB's use.

The 33 kV tie line between SGI and SEB has been completed and the power receiving from SGI started in July 1986.

2) Major hydro power projects

A feasibility study of the Tenom Pangi Power Project, Phase III, has been commenced with target completion of the project by the end of 1993.

A feasibility study of the Liwagu No. 2 Hydro Power Project with expected capacity of 100 MW is planned to be commenced in 1986. This power station is scheduled to start actual construction in 1989 for completion of the project during the first half of 1990s. Depending on further study, the Upper Padas Project may be selected.

3) New diesel power plant at Sepangar Bay

This power station is planned to have four sets of 12 MW diesel generator and is located in the Sepangar Bay area, about 20 km north of Kota Kinabalu.

It is planned to construct this power plant by a private party. In such case, 200 GWH of energy is to be supplied to the SEB system annually.

4) Standby generating sets in Kota Kinabalu

Taking into account power supply under emergency cases, it is planned to install two sets of 20 MW class gas turbine or diesel engine generator in the Tanjung Aru power station or any other appropriate location.

5) Mini hydro power projects

Mini hydro power projects are planned for electrification of rural areas which are far from the main power grid and are not within the reasonable power sending distance.

6) Addition of conventional diesel generators as required

In isolated power stations such as Lahad Datu, Kudat and other minor stations outside the power supply area of the power grid, diesel generators are required in order to satisfy power demand before the interconnection with the major grid.

3.6.3 Power Transmission System Expansion

For the existing power system, the average per unit generation cost of the minor stations is substantially higher than that of major stations. According to available information the generation cost of minor stations is 50 to 60 Malaysian cents per kWh against that of major stations being 20 to 30 Malaysian cents per kWh. By exploiting major hydro projects and gas-fired combined cycle plants cheaper energy less than 20 Malaysian cents per kWh can be expected.

Under such situation, SEB is planning to develop large scale generating plants and to interconnect various load centres in order to shutdown the existing small scale diesel plants as much as possible. During the period of Fifth Malaysian Plan, the following transmission extension plans are envisaged:

1) <u>33 kV sub-transmission lines from Beaufort substation</u>

At the Beaufort substation there is a provision for taking out two 33 kV lines for power supply to many minor and rural load centres. One is the Bongawan feeder which is for Membakut, Bongawan, Gadong, Pimping, Binsulok and Kuala Penyu and the other is Sipitang feeder for Kerukan, Weston, Sipitang and Sindumin. These lines are scheduled to be completed in 1986.

2) <u>66 kV power system reinforcement in Kota Kinabalu area</u>

The 66 kV power system reinforcement plan in the Kota Kinabalu area consists of the following two parts:

- 14.7 km 66 kV overhead transmission line, double circuits with 250 mm^2 ACSR (Bear) between the Inanam Substation and the Sepangar Bay power station and the 4.4 km 66 kV extension, single circuit with 250 mm^2 ACSR on DC towers from the Sepangar Bay power station to the Sepangar Bay substation. The Sepangar Bay substation will be of indoor installation which contains gas-insulated switchgear and provided with two 20 MVA main transformers.

- 13.9 km 66 kV XLPE underground cables comprising three single-core cables of 630 mm^2 per circuit from the Inanam substation to the Tanjung Aru substation. Two substations are planned at Tanjung Lipat and Karamunsing for supply to the city centre loads of Kota Kinabalu. Both substations are of indoor installations with gas-insulated switchgear, each provided with two sets of 20 MVA main transformer.

These 66 kV lines and substations are scheduled to be completed by 1987.

3) <u>132 kV transmission line construction between Pangi power station and Keningau</u>

A 132 kV double circuit transmission line is planned to be constructed between the Pangi power station and the Keningau substation. The conductor size is 350 mm^2 (Bison) which is same as that of the 132 kV line under the Tenom Pangi Power Project and route length is approximately 40 km.

Two 132/11 kV stepdown substations are planned to be constructed. One is the Tenom Town substation with single bus arrangement having two sets of 7.5 MVA main transformer and the other is the Keningau substation with two 15 MVA main transformers. The Keningau substation is of double busbar arrangement and extendable for connection of 132 kV lines to Kota Kinabalu and to the Sook power station.

This transmission plan is scheduled to be completed by 1987.

4) <u>132 kV interconnection with Labuan system</u>

As mentioned in the foregoing paragraph, surplus power is available in Labuan after the 33 kV interconnection with the SGI's combined cycle power plant. There is also a possibility that SEB will construct another combined cycle power plant with installed capacity within 200 MW. The Beaufort substation has a provision for connection of a 132 kV transmission line to Labuan. This interconnection include submarine cable section of approximately 8 km and is considered to become cost effective after 1989. Feasibility and technical studies are in plan.

5) <u>132 kV extension to Kota Belud and Kudat</u>

There is a plan to extend the 132 kV transmission system from Kota Kinabalu to Kota Belud and Kudat. This transmission plan will become economically feasible with increase in power demand in Kota Belud and Kudat. The implementation of this project is scheduled to be completed in 1990.

6) <u>Other transmission projects</u>

The following three schemes will be implemented in the period of Fifth MalaysianPlan up to 1990:

- 66 kV transmission to Lok Kawi

  The construction of a 66 kV transmission line from the Penampang substation to the Lok Kawi Industrial Estate will be required before this industrial complex become fully operational.

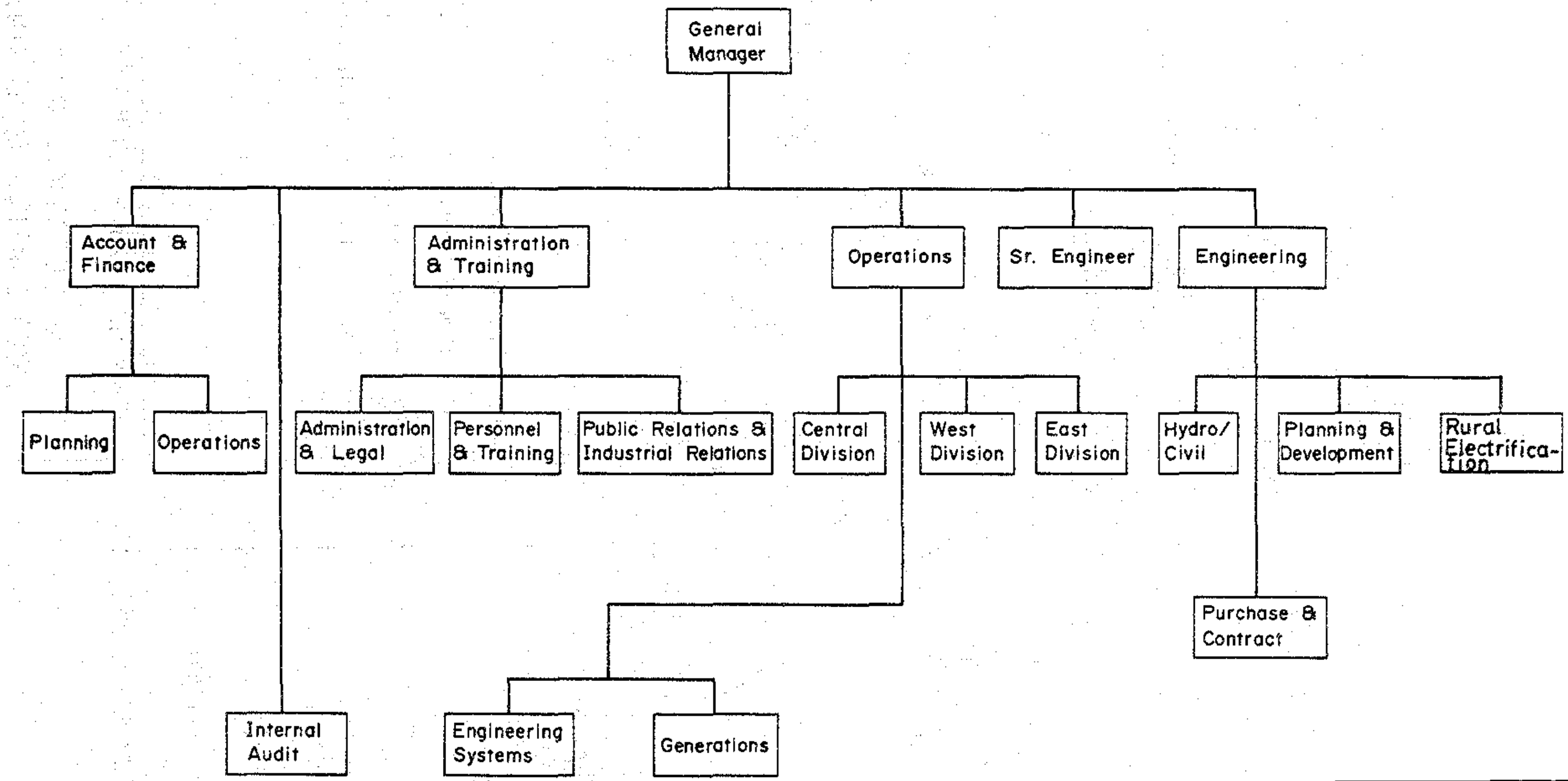
- Construction of Papar substation

  The power supply to the Papar area is currently performed through a 22 kV line from the Tanjung Aru power station. Construction of a 132/33/11 kV substation is planned near the existing 132 kV transmission line between the Beaufort substation and the Penampang substation. This substation will be required before the Papar demand exceeds the transmission capacity of 22 kV line probably by 1990.

- Construction of Tuaran substation

  The power to Tuaran is currently supplied from the Inanam substation through a 22 kV line. Construction of a new substation with 2 x 20 MVA capacity will be required and is to be constructed at Kampong Berugis or somewhere at the centre of the power supply area in Tuaran and Tamparuli in the period of Fifth Malaysian Plan by extending the 66 kV power system in Kota Kinabalu or by utilizing a part of the 132 kV transmission line to Kota Belud and Kudat.

FIGURE NO. : 3.1

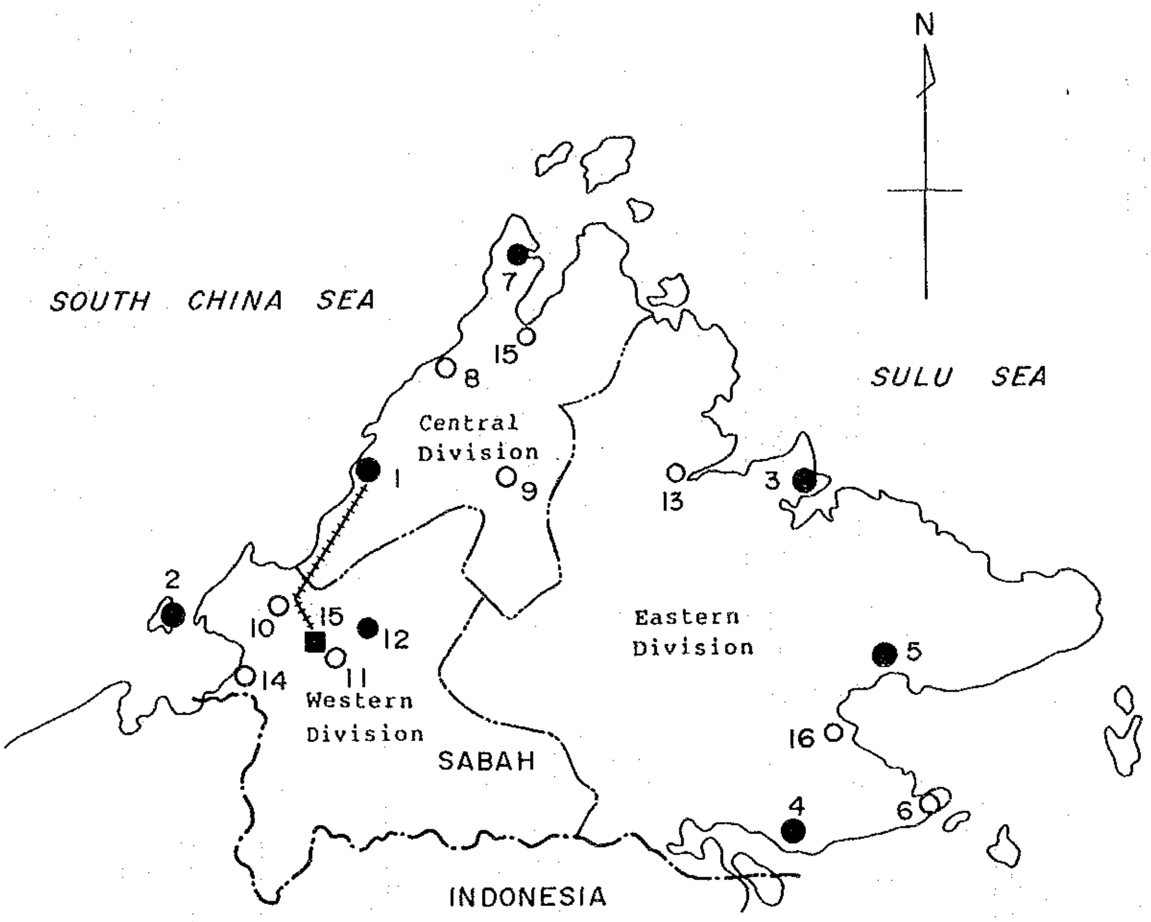


TENOM PANGI PHASE III

SIMPLIFIED SEB ORGANIZATION (OCTOBER 1985)

SEB / JICA

FIGURE NO. : 3.2



No.	NAME OF STATION
1	KOTA KINABALU
2	LABUAN
3	SANDAKAN
4	TAWAU
5	LAHAD DATU
6	SEMPORNA
7	KUDAT
8	KOTA BELUD
9	RANAU
10	BEAUFORT
11	TENOM
12	KENINGAU
13	BELURAN
14	SIPITANG
15	KOTA MARUDU
16	KUNAK
17	TENOMPANGI HYDRO

0 50 100 km

● MAJOR STATION

○ MINOR STATION

■ HYDRO STATION

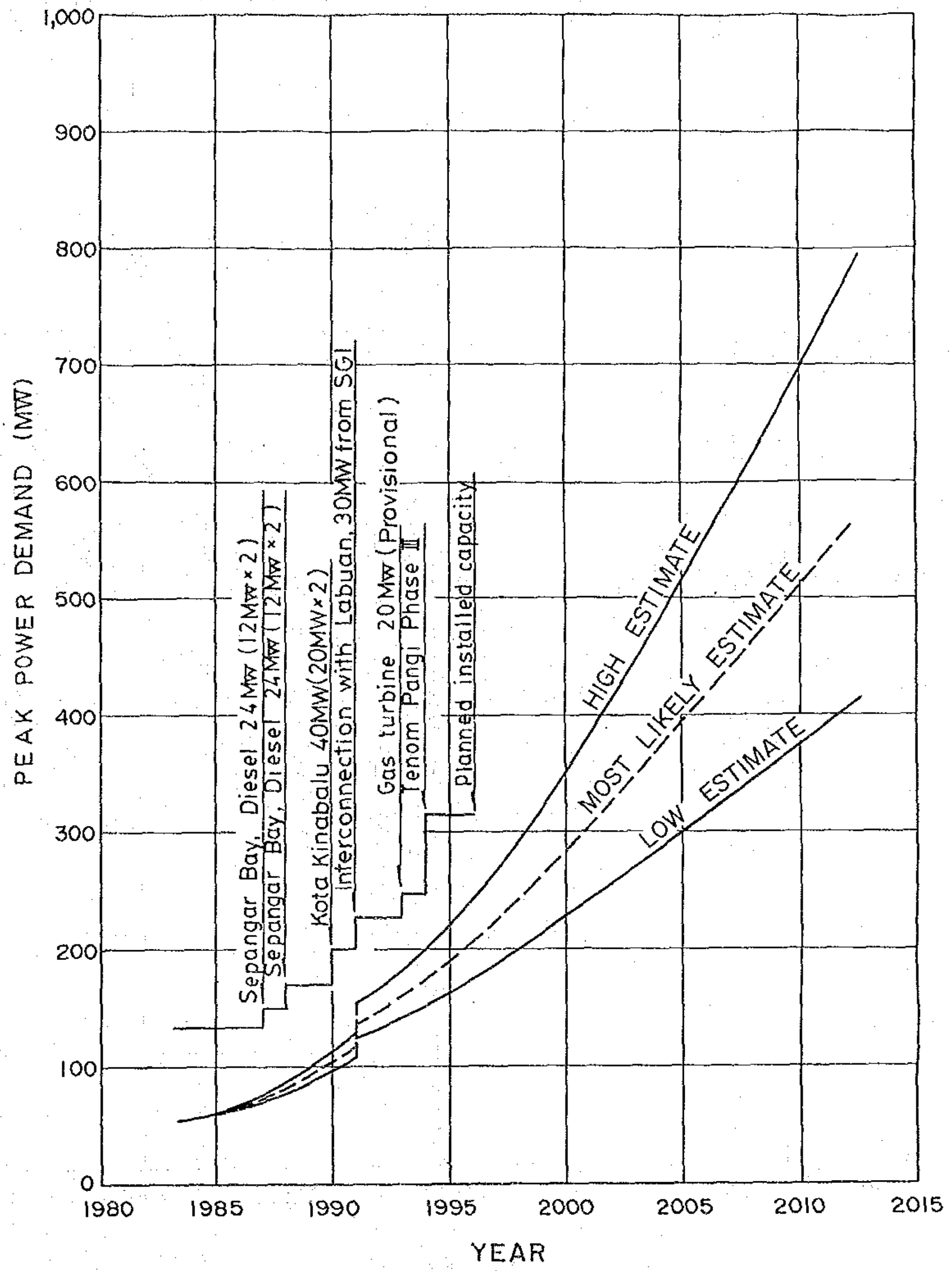
+++++++ 132 KV TRANSMISSION LINE

TENOM PANGI PHASE III

LOCATION OF
GENERATING STATIONS

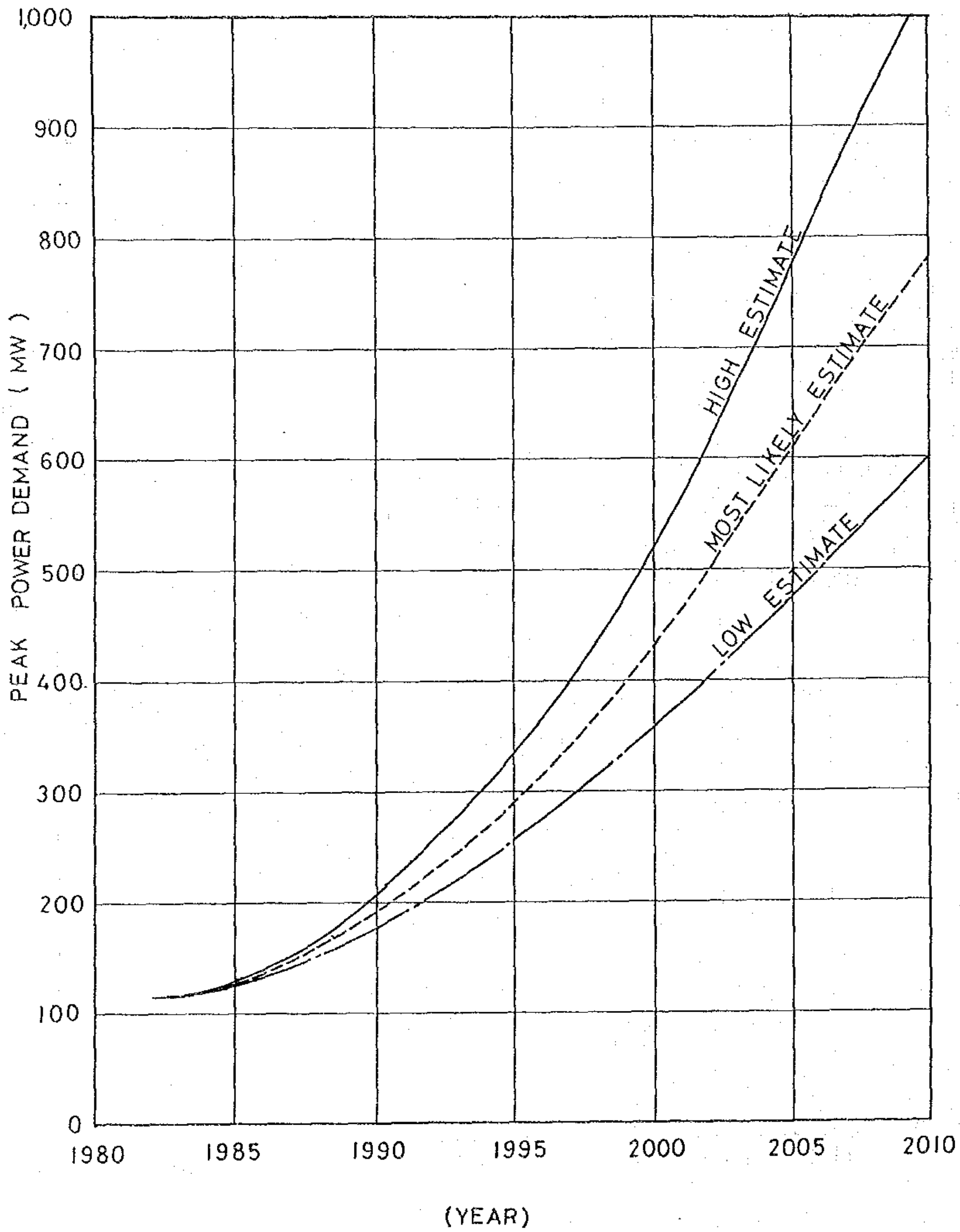
SEB / JICA

FIGURE NO. : 3.3



TENOM PANGI PHASE III
INTERCONNECTED PEAK POWER DEMAND FOR WEST COAST AREA
SEB / JICA

FIGURE NO. : 3.4

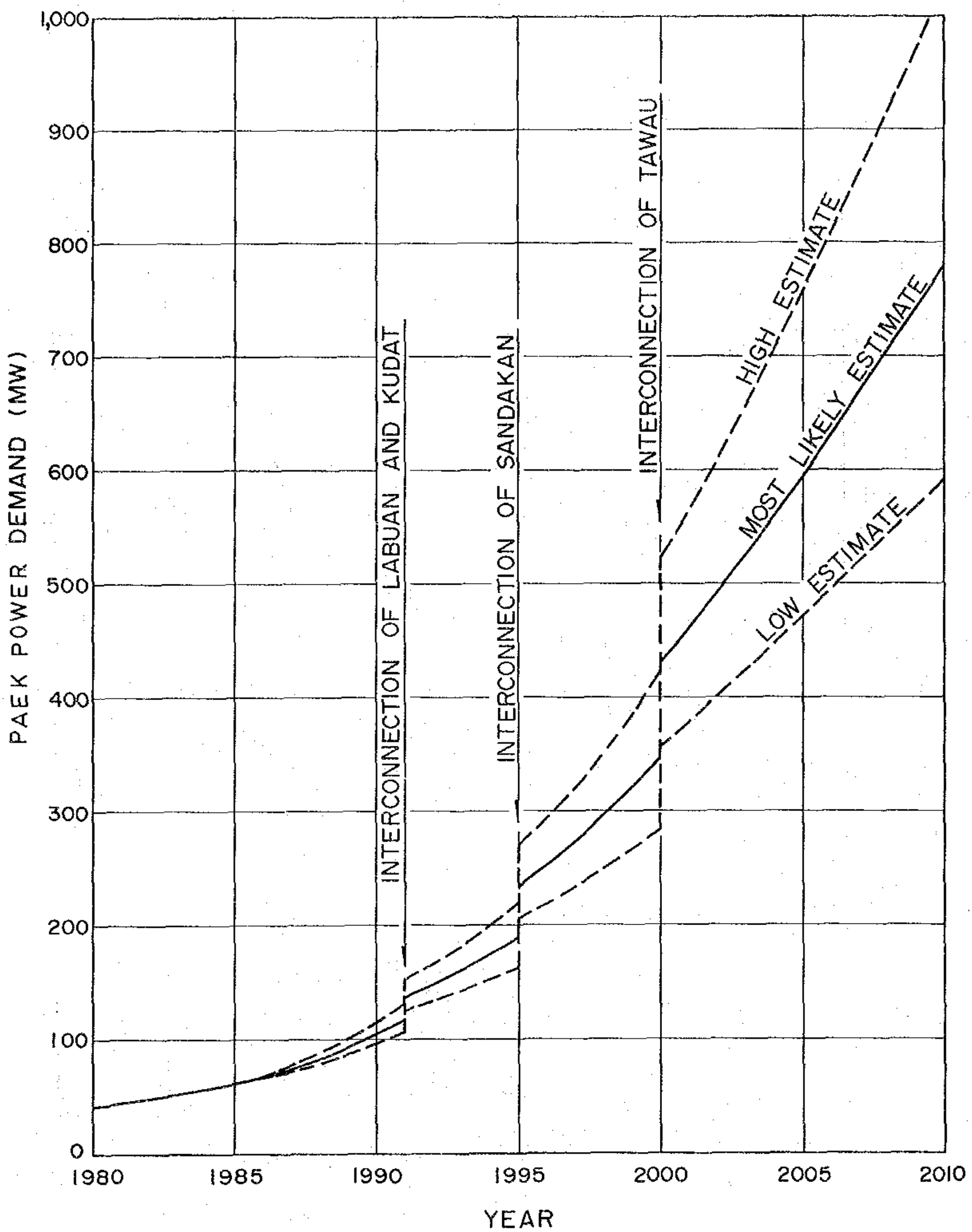


TENOM PANGI PHASE III

NON-INTERCONNECTED
PEAK POWER DEMAND
IN SABAH

SEB / JICA

FIGURE NO. : 3.5

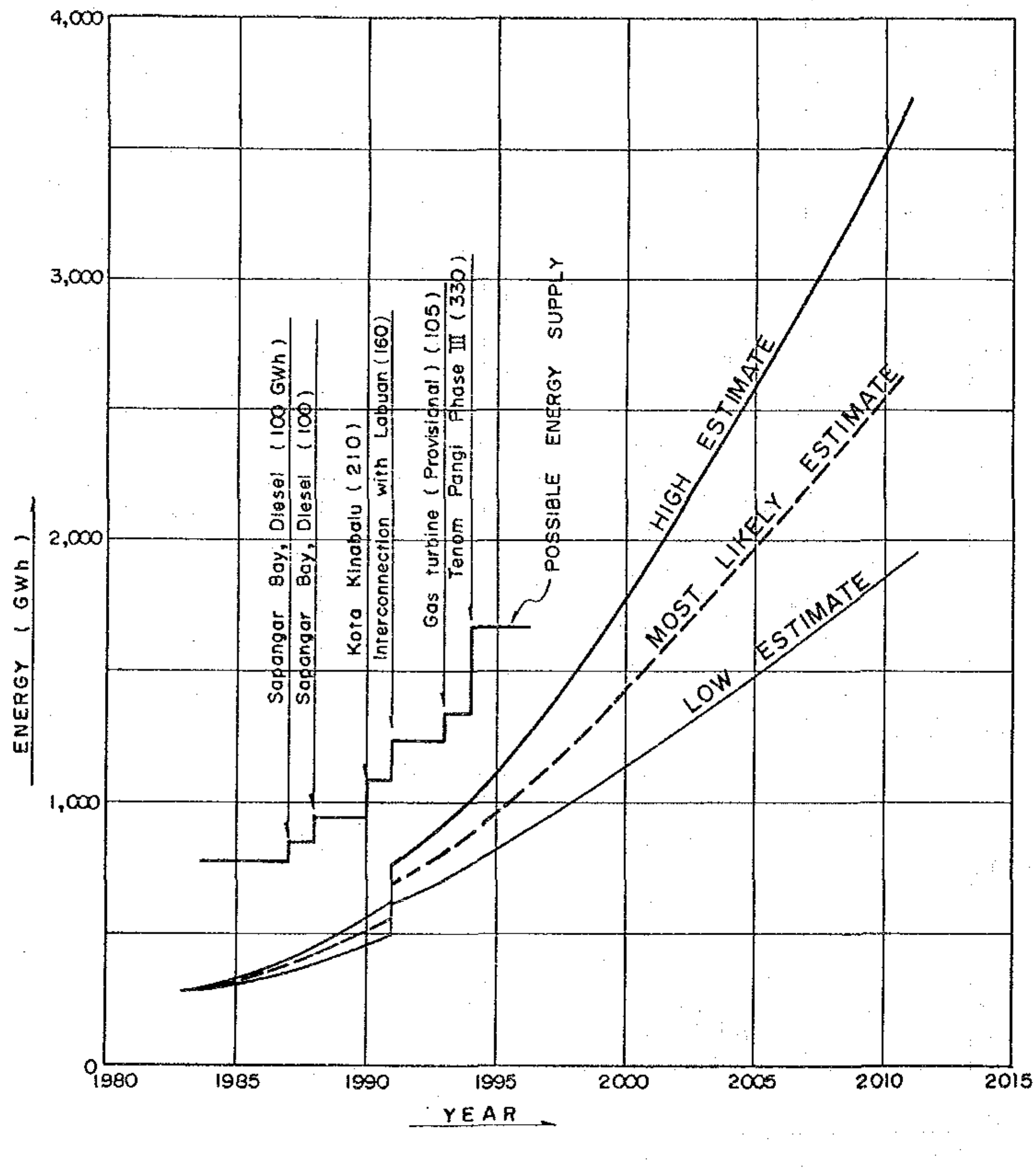


TENOM PANGI PHASE III

INTERCONNECTED
PEAK POWER DEMAND
IN SABAH

SEB / JICA

FIGURE NO. : 3.6



TENOM PANGI PHASE III

ENERGY DEMAND FOR WEST COAST AREA

SEB / JICA

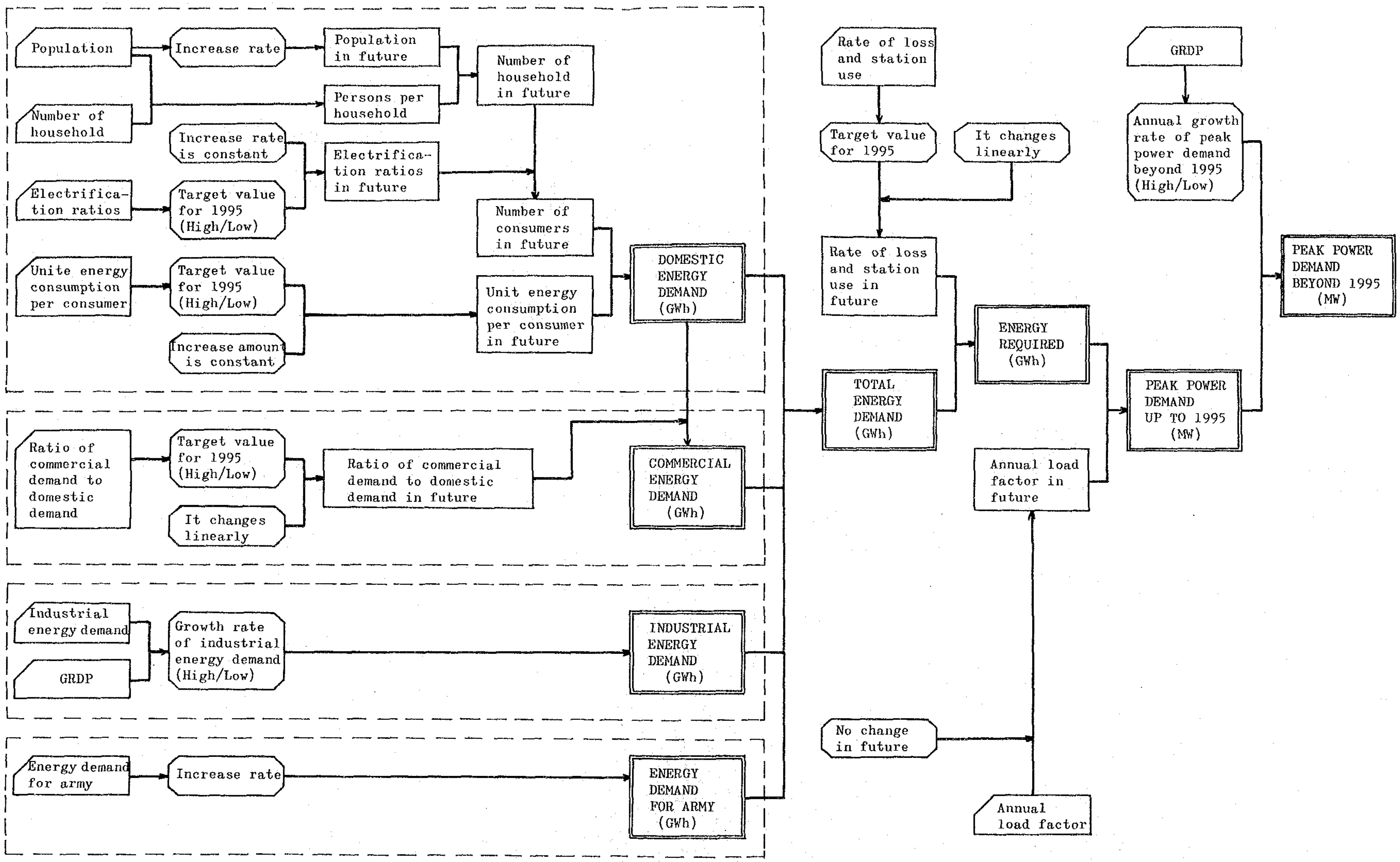


FIG. 3.7 FLOW CHART OF POWER DEMAND FORECAST

4. PROJECT PLAN FORMULATION

4.1 Existing Tenom Pangi Project

As was explained in the preceding chapter, the existing Tenom Pangi Project, Phases I and II, was completed as the first major hydropower project in Sabah to meet increasing power demand and to corroborate the save-energy-policy of Malaysia. It becomes the central of SEB's west coast power system.

With the limited storage capacity of 4.7 million cubic meters at the head water, the Tenom Pangi Project is designed to be a run-of-river type hydropower plant having an installed capacity of 66 MW. Principal features of the existing Tenom Pangi Project are as summarized below:

1.	Catchment area:	7,815 km^2
2.	Annual rainfall (1960-1984):	1,856 mm
3.	Mean annual runoff (1969-1984):	210 m^3/s
4.	Normal high water level:	El. 173.9 m
5.	Low water level:	El. 170.7m
6.	Tail water level:	El. 99.2 m
7.	Effective storage capacity:	4.7×10^6 m^6
8.	Gross head:	74.7-71.5m
9.	Net head:	63.1-59.9 m (average 61.5 m)
10	Maximum plant discharge:	127.3 m^3/s
11.	Intake weir:	Gated weir 4 nos - 15 m wide x 9 m high roller gates 1 no - 6 m wide x 12 m high roller gate

12.	Headrace tunnel:	6.3 m dia.x 4,352 m long
13.	Penstock:	3 lines x 3.0 m dia.x 145 m long
14.	Power station:	26.5 m wide x 53.5 m long
15.	Installation:	3 nos x 22 MW = 66 MW
16.	Transmission line:	132 kV - 120 km (Tenom Pangi-Kota Kinabalu)
17.	Dependable power:	45.0 MW
18.	Energy outpout	516.2 GWh
	•Firm energy	(331.6 GWh)
	•Dump (secondary) energy	(184.6 GWh)

According to the feasibility study for the Tenom Pangi Project 1/ in 1974, it is reported that:

(1) Tenom Pangi Project is optimized to have a 66 MW installation under average annual stream flow of 196 m^3/s and 95% dependable flow of 40.1 m^3/s.

(2) The development of the project is made favourably by step-wise basis to install 44 MW in total by 1979 and 66 MW in total by 1985 as the power demand increases in the power market.

(3) The power plant is recommended to be operated as a base power station during the high flow season and as a peaking power station during the low flow season.

(4) The Diesel power plants then operated is recommended to be retired or used as the stand-by in the power system.

1/ "Sabah Power Development Project", prepared by Nippon Koei Co., Ltd. for SEB/ADB, February 1974

So, to clarify the former planning, the scale of the existing Tenom Pangi Project is reviewed and rechecked under the changed conditions, adding up-to-date hydrological and economical data and information collected for about ten years since then. As the result, the optimum scale of the existing Tenom Pangi Project is proved to have more or less 66 MW installation on the assumption that approximately 60 per cent capacity factor of the power station is secured almost all the year round, which is as same as the annual average load factor in the power market. Result of calculation is as shown in Table A-4.1 and A-4.2 in Annex. Thus, the installed capacity of 66 MW for the existing Tenom Pangi power station seems to be a reasonable figure.

4.2 Expansion of Tenom Pangi Project (Sook Reservoir and Power Station)

The existing Tenom Pangi Project is located at the downstream reaches of the Pegalan-Padas basin. Its catchment area is 7,815 km^2 at the weir site, and mean annual streamflow is 210 m^3/s. According to the feasibility study of the Tenom Pangi Project in 1974, it was recommended to firm up the Tenom Pangi power station in future when the power demand is increased. For this purpose then study suggested to construct the Sook reservoir on the upstream tributary. Together with the construction of the Sook reservoir, installed capacity of the existing Tenom Pangi power station was recommended to be increased by adding some 100 MW to meet peaking power demand. At the first stage, additional 50 MW extension was recommended but was revised to be 44 MW extension in the study of the detailed design for the project in 1977.

The scales of the Sook reservoir and the related power stations such as the Sook and extending Tenom Pangi power stations are reviewed and rechecked under the changed hydrological and economic conditions.

In order to firm up the existing Tenom Pangi Project of 66 MW installation, two different schemes are conceivable:

Scheme I : Sook reservoir plus extending Tenom Pangi power station (Sook Reservoir Only)

Scheme II : Sook reservoir and power station plus extending Tenom Pangi power station (Sook Reservoir and Power Station)

For these two schemes, several groups of the study cases for the project scale are compared with respect to the combination of the following major parameters:

1. <u>For Sook reservoir</u>

   1) High water level (HWL)

   2) Effective storage capacity (V)

2. <u>For Sook and Tenom Pangi (extension) power stations</u>

   1) Installed capacity (Ps for Sook/Pt for Tenom Pangi)

Due to topographical and hydrological characteristics, Sook reservoir is favorably operated as a peaking power station and the extending Tenom Pangi power station as a base load power station in the SEB's power system. In this case, extending installation for the existing Tenom Pangi power station is first fixed at 44 MW. Then, several cases of smaller (22 MW) and bigger (66 MW) installations are checked around the apparently optimum case. As the result, all the cases of the extending installed capacity for the Tenom Pangi power station other than 44 MW show lower net benefit as shown in Tables 4.1, A-4.3 and A-4.4 and depicted in Figure 4.1. Therefore, the extending installed capacity is finally fixed to be 44 MW.

Comparative study cases for the optimization of the Sook reservoir, Sook power station and extension of Tenom Pangi power station are as summarized below:

Case	HWL (Eℓ.-m)	Effective storage capacity (V) ($10^6 m^3$)	Installed capacity (MW) Sook (Ps)	Pangi (Pt)	Total
I. Sook Reservoir Only					
1	290	141	0	44	44
2	300	336	0	44	44
3	310	632	0	44	44
4	315	820	0	44	44
II. Sook Reservoir and Power Station					
5	300	300	10	44	54
6	300	300	20	44	64
7	300	300	30	44	74
8	300	300	40	44	84
9	305	300	10	44	54
10	305	300	20	44	64
11	305	300	30	44	74
12	305	300	40	44	84
13	305	400	10	44	54
14	305	400	20	44	64
15	305	400	30	44	74
16	305	400	40	44	84
17	310	400	10	44	54
18	310	400	20	44	64
19	310	400	30	44	74
20	310	400	40	44	84
21	310	500	10	44	54
22	310	500	20	44	64
23	310	500	30	44	74
24	310	500	40	44	84
25	310	550	10	44	54
26	310	550	20	44	64
27	310	550	30	44	74
28	310	550	40	44	84
29	315	500	10	44	54
30	315	500	20	44	64
31	315	500	30	44	74
32	315	500	40	44	84
33	315	600	10	44	54
34	315	600	20	44	64
35	315	600	30	44	74
36	315	600	40	44	84

Case	HWL (Eℓ.-m)	Effective storage capacity (V) ($10^6 m^3$)	Installed capacity (MW) Sook (Ps)	Pangi (Pt)	Total
37	315	700	10	44	54
38	315	700	20	44	64
39	315	700	30	44	74
40	315	700	40	44	84

Other conditions, assumptions and considerations taken into account for the comparative study are as summarized below:

1. Estimation of the cost for comparative study is made referring to the construction cost data for the similar type of the projects in Sabah or in the neighbouring areas which have been completed recently. They are expressed in 1985/86 prices after making an inflation adjustment.

2. Estimation of the benefit is made by means of the least cost alternative method. As an alternative facility, development cost of the coal-fired thermal plant which seems to be most likely constructed in future to supply peak and base loads of the system is selected. Its capacity is considered to be 50 MW class taking into account the scale of the Sook-Tenom Pangi hydro system. The estimated unit power benefit is as below:

1) Alternative facility : Coal-fired thermal plant
2) Capacity : 50 MW class
3) Unit construction cost : 1,350 US$/kW (1985/86 price)
4) Service life : 25 years
5) Annual OMR costs : 3.0%
6) Adjustment factor :

		Thermal	Hydro
Forced outage	:	0.03	0.005
Auxiliary power use	:	0.07	0.005
Overhaul	:	0.15	0.01
Transmission losses	:	0.02	0.04

Capacity adjustment factor =

$$\frac{(1-0.005)(1-0.005)(1-0.01)(1-0.04)}{(1-0.03)(1-0.07)(1-0.15)(1-0.02)} = 1.252$$

Energy adjustment factor =

$$\frac{(1-0.005)(1-0.04)}{(1-0.07)(1-0.02)} = 1.048$$

7) Capacity value

Discount rate : 10%

Capital recovery factor : 0.1102

Capacity value = 1,350 x(0.1102 + 0.03) x 1.252

= <u>237.0</u> (US$/kW)

8) Energy value

Price of coal : 0.055 US$/kg

Fuel consumption rate : 0.45 kg/kWh

Energy value = 0.055 x 0.45 x 1.048

= <u>0.026</u> (US$/kWh)

3. Development scale of the project is determined to maximize annual equivalent net benefit (B-C). It is calculated:

[Annual equivalent net benefit (B-C)] = [Annual equivalent benefit (B)] − [Annual eqivalent cost (C)]

4. Annual equivalent cost is calculated on the assumption that economic life of the project is 50 years; discount rate, 10 per cent per annum; operation, maintenance and replacement costs (OMR costs), 1.5 per cent of the total construction cost.

5. Estimation of the annual equivalent benefit is made based on the unit power benefit mentioned-above and 95 per cent dependable power as power generation and firm and dump (secondary) energy as energy output, which are calculated based on the results of the reservoir operation study for the

proposed Sook dam in combination with the existing Tenom Pangi power station. In this report, dump energy is defined as the energy produced by surplus water over the firm discharge during high flow period. It is also assumed that 50 per cent of total dump energy is used to save fuel consumption for other thermal power plant in the power system of SEB.

6. Maximum plant discharge for the Sook and Tenom Pangi power stations is calculated from the installed capacity as shown below:

$$Qp = \frac{P}{9.8 \times (Hg - Hl) \times Eo}$$

Where,

Qp	:	Maximum plant discharge (m^3/s)
P	:	Installed capacity (kW)
Hg	:	Gross rated head which is determined at 20% of drawdown for Tenom Pangi reservoir and at 50% of drawdown for Tenom Pangi reservoir (m)
Hl	:	Loss of head which is estimated at 4 m for Sook power station and at 11.5 m for Tenom Pangi power station (m)
Eo	:	Overall efficiency of turbine and generator which is estimated at 0.85 for Sook power station and at 0.86 for Tenom Pangi Power Station.

Firm and dump plant discharges are defined as average discharge for power plants throughout the years from January 1969 to December 1984. Firm discharge is used to generate power as far as discharge is available within the capacity factor of 60 per cent for the combined Sook-Tenom Pangi hydro system. Dump discharge is used to generate power whenever surplus discharge over firm discharge is available.

7. Energy output for firm and dump is calculated by:

$$E = 24 \times 30 \times 12 \times 9.8 \times Q \times H \times Eo$$

Where,

E	:	Annual energy output (GWh)
Q	:	Average discharge (m^3/s)
H	:	Average net head (m)
Eo	:	Overall efficiency of turbine and generator which is estimated at 0.85 for Sook power station and at 0.86 for Tenom Pangi power station.

Results of cost-benefit comparison to determine HWL and storage capacity of the reservoir as well as the installed capacity of the Sook power station are as shown in Table 4.1 and as depicted in Figure 4.2. The cost data for the comparative study are as shown in Tables A-4.6(1) to (40) in Annex.

4.3 Scale of the Project

As the result of the comparative study on the scale of the project, the case without the Sook power station (Scheme I) seems to be less favourable than that of the case with the Sook power station (Scheme II). Thus, the Tenom Pangi Project, Phase III, is recommended to consist of the Sook reservoir, Sook power station and the extending Tenom Pangi Project, and the most optimum scale of the project is determined to be as summarized below:

1. Sook Reservoir and Power Station

1)	NHWL:	El. 310 m
2)	LWL:	El. 285 m
3)	TWL:	El. 250 m
4)	Gross storage capacity:	$732 \times 10^6 m^3$
5)	Effective storage capacity:	$550 \times 10^6 m^3$
6)	Drawdown:	25 m
7)	Gross head:	60-35 m
8)	Net head:	51 m
9)	Plant discharge, max.:	47.1 m^3/s
10)	Installed capacity:	20 MW

2. <u>Tenom Pangi Power Station</u>

1) NHWL:	El. 173.9 m
2) LWL:	El. 170.7 m
3) TWL:	El. 99.2 m
4) Effective storage capacity:	4.7 x 10^6m^3
5) Gross head:	74.7-71.5 m
6) Net head:	61.5 m, average
7) Plant discharge, max.:	
Extension:	84.9 m^3/s
Existing:	127.3 m^3/s
Total:	<u>212.2</u> m^3/s
8) Installed capacity:	
Extension:	44 MW
Existing:	66 MW
Total:	<u>110</u> MW

4.4 <u>Operation Study on Sook-Tenom Pangi Hydro System</u>

Based on the determined project scale of the Sook reservoir as well as the Sook and Tenom Pangi power stations (Sook-Tenom Pangi Hydro System), operation study is carried out. It is made on the assumption that the proposed Sook power station is operated to secure the peaking power portion and the Tenom Pangi power station, the base power portion of the hydro system with the overall capacity factor of 60 per cent. During the low flow season when sufficient water can not be used for power generation, the hydro system is assumed to be operated to produce the peaking power as much as possible, and the base power is assumed to be secured by operating the supporting diesel or gas turbine plants.

Results of the simulation operation of the hydro system are shown by using the month-to-month reservoir water level, plant discharges, power generation and energy output in Figures 4.3 and 4.4.

Table 4.1(1) COMPARATIVE STUDY FOR SOOK - TENOM PANGI POWER SYSTEM

Case	Sook reservoir		Installed capacity (MW)			Dependable power	Energy output (GWh)			Power benefit (10^6US$)			Construction cost (10^6US$)			Annual cost	Annual net benefit
	HWL (El.-m)	Storage capacity (10^6m^3)	Sook	Pangi ext.	Total	(MW)	Firm	Dump	Total	Capacity	Energy	Total	Sook	Pangi ext.	Total	(10^6US$)	(10^6US$)
I. Sook Reservoir Only																	
1	290	141	-	44	44	11.6	208.1	27.2	235.3	2.7	5.8	8.5	57.4	72.6	130.0	15.1	-6.6
2	300	336	-	44	44	41.0	222.7	23.1	245.8	9.7	6.1	15.8	65.8	72.6	138.4	16.0	-0.2
3	310	632	-	44	44	60.0	231.0	21.1	252.1	14.2	6.3	20.5	79.9	72.6	152.5	17.7	2.8
4	315	820	-	44	44	65.0	235.7	19.5	255.2	15.4	6.4	21.8	100.0	72.6	169.3	19.6	2.2
II. Sook Reservoir and Power Station																	
5	300	300	10	44	54	51.4	271.5	22.3	293.8	12.2	7.3	19.5	80.0	72.6	152.6	17.7	1.8
6	300	300	20	44	64	51.2	316.0	5.7	321.7	12.1	8.3	20.4	88.6	72.6	161.2	18.7	1.7
7	300	300	30	44	74	41.4	340.2	0	340.2	9.8	8.8	18.6	94.8	72.6	167.4	19.4	-0.8
8	300	300	40	44	84	41.5	355.3	0	355.3	9.8	9.2	19.0	101.6	72.6	174.2	20.2	-1.2
9	305	300	10	44	54	52.4	272.2	22.9	295.1	12.4	7.4	19.8	85.3	72.6	157.9	18.3	1.5
10	305	300	20	44	64	53.2	319.0	8.9	327.9	12.6	8.4	21.0	93.0	72.6	165.6	19.2	1.8
11	305	300	30	44	74	41.8	347.3	0	347.3	9.9	9.0	18.9	99.6	72.6	172.2	20.0	-1.1
12	305	300	40	44	84	44.5	363.6	0	363.6	10.5	9.5	20.0	106.0	72.6	178.6	20.7	-0.7
13	305	400	10	44	54	51.3	275.3	21.9	297.2	12.2	7.4	19.6	85.4	72.6	158.0	18.3	1.3
14	305	400	20	44	64	51.3	322.7	6.6	329.3	12.2	8.5	20.7	93.5	72.6	166.1	19.3	1.4
15	305	400	30	44	74	45.5	350.7	0	350.7	10.8	9.1	19.9	99.7	72.6	172.3	20.0	-0.1
16	305	400	40	44	84	44.5	367.3	0	367.3	10.5	9.5	20.0	106.3	72.6	178.9	20.7	-0.7
17	310	400	10	44	54	52.2	275.7	22.2	297.9	12.4	7.5	19.9	92.7	72.6	165.3	19.2	0.7
18	310	400	20	44	64	53.2	324.3	9.6	333.9	12.6	8.6	21.2	100.5	72.6	173.1	20.1	1.1
19	310	400	30	44	64	52.3	357.1	0	357.1	12.4	9.3	21.7	106.5	72.6	179.1	20.8	0.9
20	310	400	40	44	84	45.0	375.4	0	375.4	10.7	9.8	20.5	112.8	72.6	185.4	21.5	-1.0
21	310	500	10	44	54	55.7	278.7	20.6	299.3	13.2	7.5	20.7	93.2	72.6	165.8	19.2	1.5
22	310	500	20	44	64	63.9	327.6	7.2	334.8	15.1	8.6	23.7	101.0	72.6	173.6	20.1	3.6
23	310	500	30	44	74	60.0	359.5	0	359.5	14.2	9.3	23.5	107.4	72.6	180.0	20.9	2.6
24	310	500	40	44	84	48.8	378.3	0	378.3	11.6	9.8	21.4	113.4	72.6	186.0	21.6	-0.2

Table 4.1(2) COMPARATIVE STUDY FOR SOOK - TENOM PANGI POWER SYSTEM

Case	Sook reservoir HWL (El.-m)	Sook reservoir Storage capacity (10^6m^3)	Installed capacity (MW) Sook	Installed capacity (MW) Pangi ext.	Installed capacity (MW) Total	Dependable power (MW)	Energy output (GWh) Firm	Energy output (GWh) Dump	Energy output (GWh) Total	Power benefit (10^6US$) Capacity	Power benefit (10^6US$) Energy	Power benefit (10^6US$) Total	Construction cost (10^6US$) Sook	Construction cost (10^6US$) Pangi ext.	Construction cost (10^6US$) Total	Annual cost (10^6US$)	Annual net benefit (10^6US$)
25	310	550	10	44	54	62.4	280.1	19.6	299.7	14.8	7.5	22.3	93.5	72.6	166.1	19.3	3.0
26	310	550	20	44	64	71.0	329.2	6.3	335.5	16.8	8.6	25.4	101.5	72.6	174.1	20.2	5.2
27	310	550	30	44	74	67.9	360.3	0	360.3	16.1	9.4	25.5	107.9	72.6	180.5	20.9	4.6
28	310	550	40	44	84	48.7	379.6	0	379.6	11.5	9.9	21.4	114.4	72.6	187.0	21.7	-0.3
29	315	500	10	44	54	56.2	278.9	20.6	299.5	13.3	7.5	20.8	116.4	72.6	189.0	21.9	-1.1
30	315	500	20	44	64	68.4	328.7	9.7	338.4	16.2	8.7	24.9	123.9	72.6	196.5	22.8	2.1
31	315	500	30	44	74	65.6	364.7	0	364.7	15.5	9.5	25.0	129.7	72.6	202.3	23.4	1.6
32	315	500	40	44	84	49.6	385.4	0	385.4	11.8	10.0	21.8	135.7	72.6	208.3	24.1	-2.3
33	315	600	10	44	54	70.2	282.0	19.2	301.2	16.6	7.6	24.2	116.6	72.6	189.2	21.9	2.3
34	315	600	20	44	64	77.0	332.4	7.8	340.2	18.2	8.7	26.9	123.9	72.6	196.5	22.8	4.1
35	315	600	30	44	74	75.2	367.2	0	367.2	17.8	9.5	27.3	129.9	72.6	202.5	23.5	3.8
36	315	600	40	44	84	63.6	388.9	0	388.9	15.1	10.1	25.2	136.0	72.6	208.6	24.2	1.0
37	315	700	10	44	54	70.0	285.2	17.7	302.9	16.6	7.6	24.2	116.6	72.6	189.2	21.9	2.3
38	315	700	20	44	64	74.9	335.8	5.3	341.1	17.8	8.8	26.6	124.1	72.6	196.7	22.8	3.8
39	315	700	30	44	74	79.8	369.2	0	369.2	18.9	9.6	28.5	130.0	72.6	202.6	23.5	5.0
40	315	700	40	44	84	63.6	391.3	0	391.3	15.1	10.2	25.3	136.3	72.6	208.9	24.2	1.1

4.5 Study on Power Development Scheme

In order to find out the most favourable electric power development scheme to cope with the increasing power demand in Sabah, a comparative study is made to the development of the power sources for the following three basic scheme.

1. All thermal scheme
2. Combined thermal and hydro scheme
3. All hydro scheme

Of the above schemes, all thermal scheme and combined thermal and hydro scheme are further classified into 8 cases since, in the case of the thermal scheme, peak load will apparently be supplied by diesel or gas turbine plant and base load by oil or coal-fired thermal plant. The respective cases are expressed by the combination of the plants as shown below:

1. In case of all thermal schemes:
    1) Diesel (peak) + Oil-fired thermal (base)
    2) Gas turbine (peak) + Oil-fired thermal (base)
    3) Diesel (peak) + Coal-fired thermal (base)
    4) Gas turbine (peak) + Coal-fired thermal (base)

2. In case of combined thermal and hydro scheme:
    5) Diesel (peak) + Hydro (base)
    6) Gas turbine (peak) + Hydro (base)
    7) Hydro (peak) + Oil-fired thermal (base)
    8) Hydro (peak) + Coal-fired thermal (base)

In the case of the hydro power scheme, all of the power demand in the system, peak and base loads, are assumed to be supplied by the hydro plants. So the case may be:

3. In case of all hydro scheme:
    9) Hydro (peak) + Hydro (base)

As for the installation capacity of the base load plant, the same capacity of the extended Tenom Pangi hydro power station (Existing + Extending), i.e. 110 MW, is adopted because the Tenom Pangi power station is one of the biggest installation of the SEB's west coast network system at present and still in near future, by which the demand centres of the west coast area will be integrated into one system. Installed capacity of the peak load plant is assumed to be 20 MW, which is the most optimum scale for the proposed Sook hydropower station.

In the case of the combined thermal and hydro schemes where the hydro plant is assumed to be operated as the base load power station, backup plant to firm up the hydro plant will be indispensable when the river flow runs dry during the low flow periods. For comparison, therefore, such a backup plant is introduced. It is assumed to be a gas turbine plant for its low installation cost.

In the case of the all hydro scheme, operational characteristics of the power plant varies largely with its location, topography, geology, hydrology, development scale, etc. Therefore, the extended Tenom Pangi and the proposed Sook power station are selected as the typical hydro power plant for the comparative study. In this case also a backup plant to firm up the base load hydro plant will be necessary.

Conceivable comparative cases for the power development scheme are as follows:

Case	Schemes	Plant[1/]	Capacity (MW)
1	All thermal	Diesel (P)	20
		Oil-fired (B)	110
		Total	130
2	All thermal	Gas turbine (P)	20
		Oil-fired (B)	110
		Total	130
3	All thermal	Diesel (P)	20
		Coal-fired (B)	110
		Total	130
4	All thermal	Gas turbine (P)	20
		Coal-fired (B)	110
		Total	130
5	Combined	Diesel (P)	20
		Gas turbine (S)	6
		Hydro (B)	110
		Total	130
6	Combined	Gas turbine (P)	20
		Gas turbine (S)	6
		Hydro (B)	110
		Total	130
7	Combined	Hydro (P)	20
		Oil-fired (B)	110
		Total	130
8	Combined	Hydro (P)	20
		Coal-fired (B)	110
		Total	130
9	Hydro	Hydro (P)	20
		Gas turbine (S)	14
		Hydro (B)	110
		Total	130

1/: P = peak power
B = base power
S = backup power

Other conditions, assumptions and consideration taken into account for the comparative study of the power development scheme are as summarized below:

1. Power market used for the comparative study is the demand centres, which are integrated into the west coast network system including Kota Kinabalu and its surrounding areas. For simplicity, it is assumed that all the produced power and energy output is used up at one time in these demand centers.

2. Both peak and base loads are assumed to be supplied at the same time by the respective peak load and base load plants so as to keep the system load factor as being 60 per cent as a whole.

3. Pertinent data used for each type of power plant are as summarized below:

Table 4.2 PERTINENT DATA OF EACH TYPE OF POWER PLANT

Item	Diesel	Gas Turbine	Oil-fired thermal	Coal-fired thermal	Hydro
	Type of power plant				
1. Project life(yr)	17	20	25	25	50
2. Installation cost (US$/kW)	550	300	850	1,350	-
3. Annual OMR costs in % of installation cost	4.0	2.0	2.5	3.0	1.5
4. Fuel consumption rate(kg/kWh)	0.24	0.42	0.27	0.45	-
5. Fuel price(US$/kg)	0.21	0.29	0.21	0.055	-
6. Fuel cost(US$/kWh)	0.05	0.122	0.057	0.025	-
7. Lubricant cost (US$/kWh)	0.002	-	-	-	-
8. Adjustment factor to hydro 1/					
1) For capacity	1.251	1.220	1.226	1.252	1.000
2) For energy	0.990	1.000	1.026	1.048	1.000
9. Adjusted installation cost(US$/kW)	688	366	1,042	1,690	-
10. Adjusted fuel cost (US$/kWh)	0.051 2/	0.122	0.058	0.026	-

1/: Adjustment factor to hydro is calculated using the following data:

Item	Diesel	Gas turbine	Oil-fired thermal	Coal-fired thermal	Hydro
1. Forced outage(%)	5.0	5.0	3.0	3.0	0.5
2. Auxiliary power use (%)	2.0	3.0	5.0	7.0	0.5
3. Overhaul (%)	18.0	15.0	15.0	15.0	1.0
4. Transmission loss (%)	1.5	1.5	2.0	2.0	4.0

2/: Including lubricant cost

4. Estimation of the cost of the development scheme is made by referring to the cost data for the similar type of the projects in Sabah or in the neighbouring areas which have been completed recently or those for international tenders in the recent years. They are expressed by 1985/86 prices after making inflation adjustments.

5. Comparison of the development scheme is made by using the unit cost of the energy output.

6. Inherent data of the installation cost, annual capital cost, annual fuel cost and annual OMR costs for the respective cases are tabulated in Tables A-4.7(1) to (9), and its summary is as shown in Table 4.3. In this case discount rate of 10% is used.

Table 4.3 COMPARISON OF UNIT COST PER ENERGY OUTPUT

Case	Installation cost (10^3US$)	Annual capital cost (10^3US$)	Annual fuel cost (10^3US$)	Annual OMR costs (10^3US$)	Total annual cost (10^3US$)	Energy output (GWh)	Unit cost (US$/kWh)
1	128,380	14,350	39,510	3,420	57,280	683.3	0.084
2	125,600	13,490	40,710	3,020	57,220	683.3	0.084
3	199,660	22,210	17,520	6,130	45,860	683.3	0.067
4	193,220	21,350	18,720	5,730	45,800	683.3	0.067
5	299,060	30,540	7,090	4,840	42,470	683.3	0.062
6	292,620	29,680	8,290	4,440	42,410	683.3	0.062
7	216,120	22,870	38,650	4,390	65,910	683.3	0.096
8	287,400	30,730	16,660	7,100	54,490	683.3	0.080
9	309,820	31,340	2,750	4,670	38,760	683.3	0.057

As the result of the comparative study on several alternatives of the power supply scheme, the most recommendable scheme is proved to be the all hydro scheme, (case 9), namely the combination of the Sook and Tenom Pangi power stations.

This scheme is slightly better than the combination of diesel or gas turbine with coal-fired thermal (case 3 or 4). However coal price is now depressed at somewhat unreasonably low level compared with oil price, and its price increase is quite probable in near future. In such case may be, the hydro scheme will become more favourable than the coal-fired thermal scheme.

As the supporting facility of the hydro scheme, there is a possibility to use the retired plants. In this case, installation cost of the supporting facility is much decreased, and only the sunk cost of the retired plants is taken into calculation. It will reduce the total scheme cost considerably, and make the hydro scheme more favourable.

Above all, the hydro power is the clean and indigenous energy, and its development meets the nation's save-energy policy. If the situation permitted, every efforts should be concentrated to develop the hydro power.

For these reasons, the all hydro scheme (case 9), (the Sook and Tenom Pangi power stations) is said to be the most recommendable development scheme among others.

4.6 Development of Hydropower Project

In the energy policy of the Fourth Malaysia Plan (1981 - 1985), emphasis is placed regarding power generation on:

- Reducing the dependence on oil for power generation

- Diversifying energy resources

Malaysia has reserves of petroleum. But petroleum is one of the important source for earning foreign exchange for Malaysia, being nearly 40 per cent of the total exports of Sabah in 1983. Naturally, it is preferable to reduce domestic consumption of petroleum and export it in order to earn foreign exchange.

It is considered that the most promising sources of indigenous energy for power generation is hydro and gas. Gas is of fossil source of energy with limited quantity. Gas is one of the most promising sources of energy for power generation but this can be utilized for other purposes such as raw materials for industrial production. Hydro power is clean energy with indigenous nature and is renewable resources.

Coal for coal-fired thermal power plants is another source of relatively cheap energy. But, there are no identified source of coal that is commercially obtained in Malaysia. By construction of a coal-fired thermal plant, large scale power can be obtained easily but the source of supply must rely on import.

Under these situation, hydro resources would be the most preferable sources of energy for power generation.

Up to the beginning of the 1980s in Sabah, power supply had been entirely depending on the Diesel power which was operated at each load center. Such power plants had been operated individually without being interconnected each other.

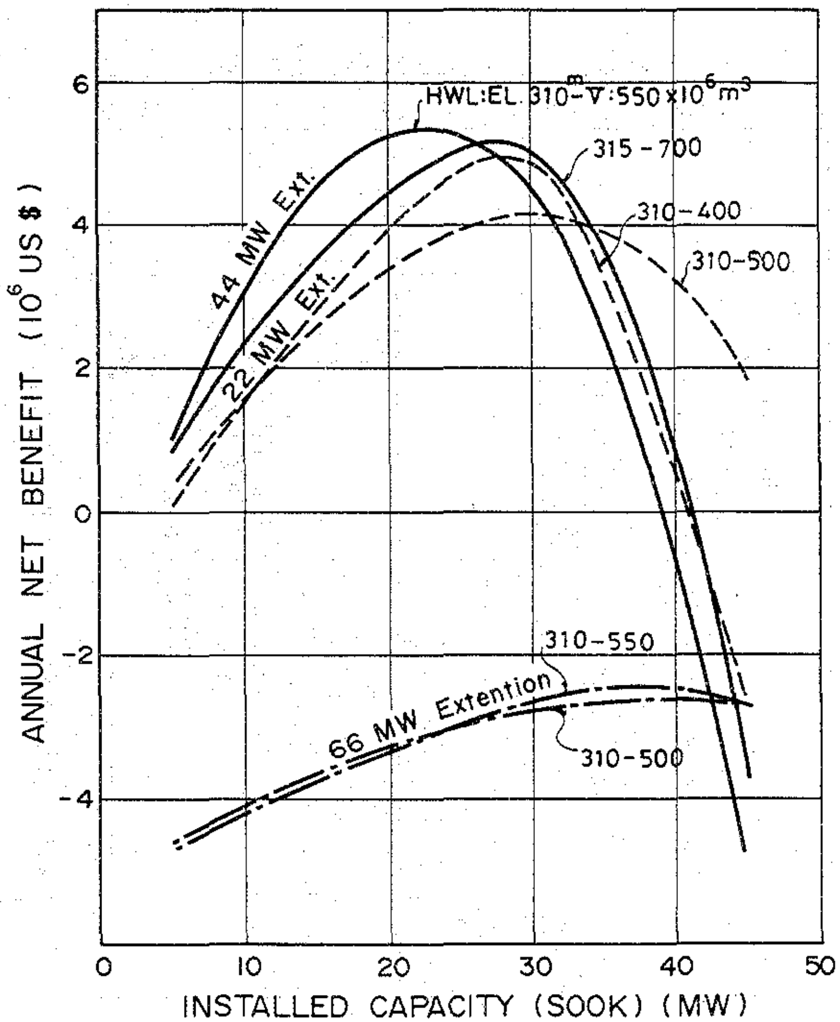
The 66 MW Tenom Pangi Hydroelectric Power Development Project commenced its commercial operation in 1984. The supply of hydropower from this power plant has been much contributing to save oil consumption. The power supply to Tenom and Beaufort through the associated transmission and distribution systems enabled the retirement of high cost minor Diesel stations. By the completion of the 132 kV transmission line to Keningau and the 33 kV subtransmission lines from the Beaufort substation to Sipitang, Membakut, Bongawan and other towns, which are now under construction, further retirement of minor and rural stations will be possible.

Saving oil consumption and retirement of minor stations has resulted in the substantial saving of the operating expenditure of SEB.

In Sabah it would be proper to design an adequate mix of power generating sources putting the hydro as a core. In the Master Plan Study, the adequate mix is envisaged by hydro and gas-fired combined cycle and/or coal thermal being supported by diesel and gas turbine plants. Among others, favorable hydropower potential sites are identified in the upper Padas basin, which are named PD05, PD07 and PD14. The anticipated power development scales are 180 MW, 80 MW and 86 MW in the installed capacity for the respective sites. Due to the adverse condition of remote access in the jungle area, no field investigation for these sites has been carried out until now. Feasibility study for these sites is expected to be commenced as early as possible.

Thus, it is recommended to implement an economically justifiable middle scale hydropower project such as the Tenom Pangi Project, Phase III, at an earliest possible time to meet the power demand of the 1990s.

The Sook and Tenom Pangi projects are formulated, each other to make an integral part of the Sook-Tenom hydro system. The Sook project can augment 95 per cent dependable flow at Tenom Pangi from 52 m^3/sec to 121 m^3/sec, and the Tenom Pangi can catch up such regulated streamflow by the extension of 44 MW installation together with the existing 66 MW installation. Individual project of Sook is needless to say financially infeasible for its high cost and small energy output. Thus, no such project formulation was studied.



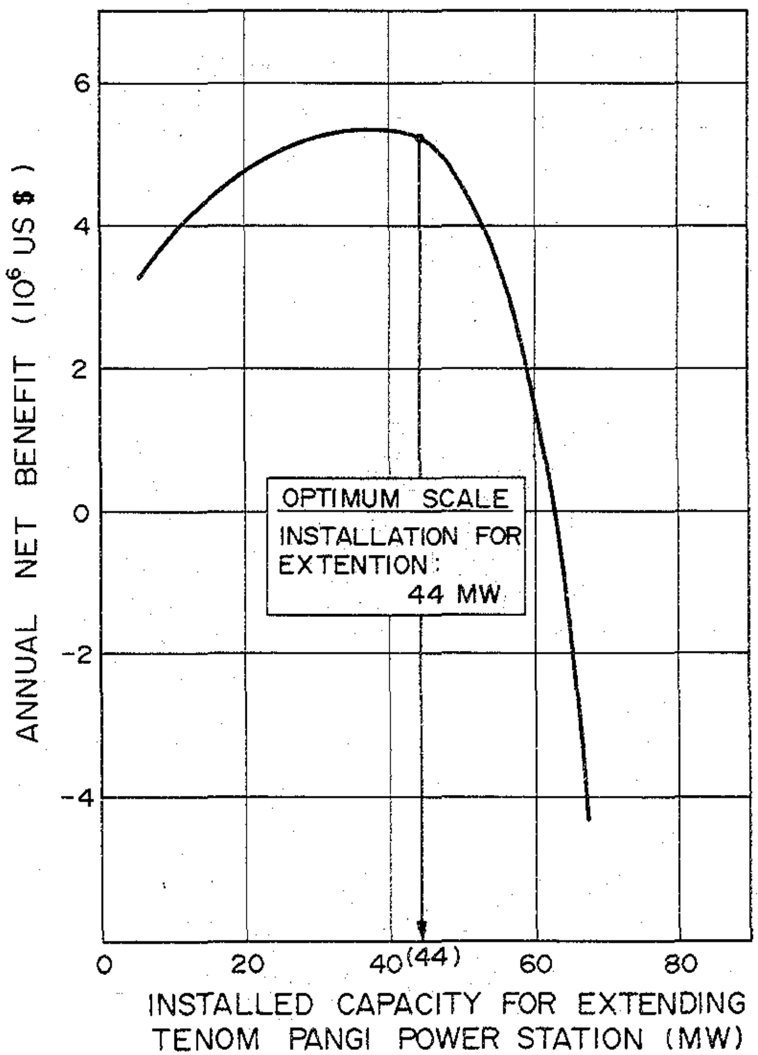


Fig. 4.1 OPTIMUM SCALE OF EXTENDING TENOM PANGI POWER STATION

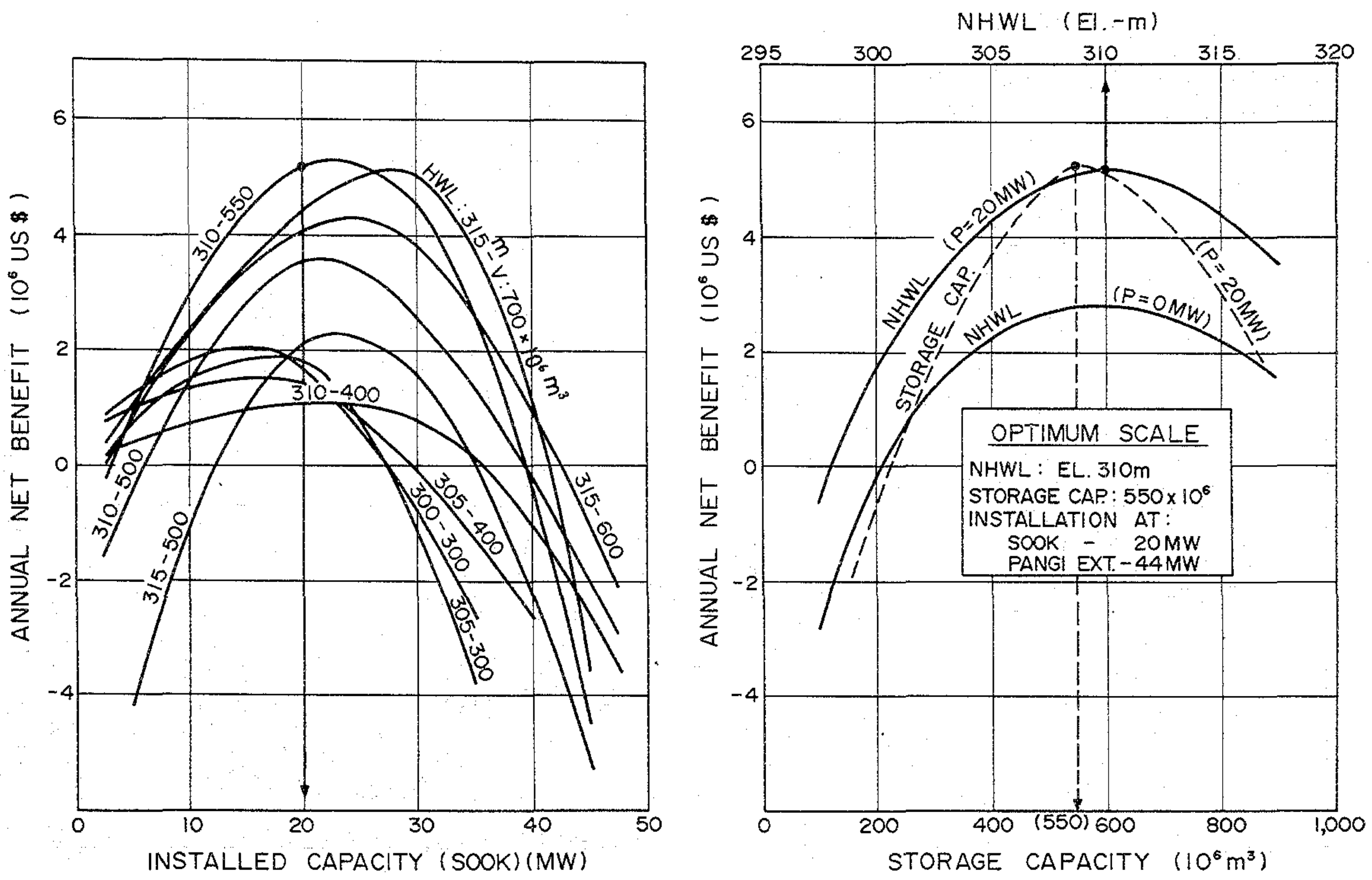
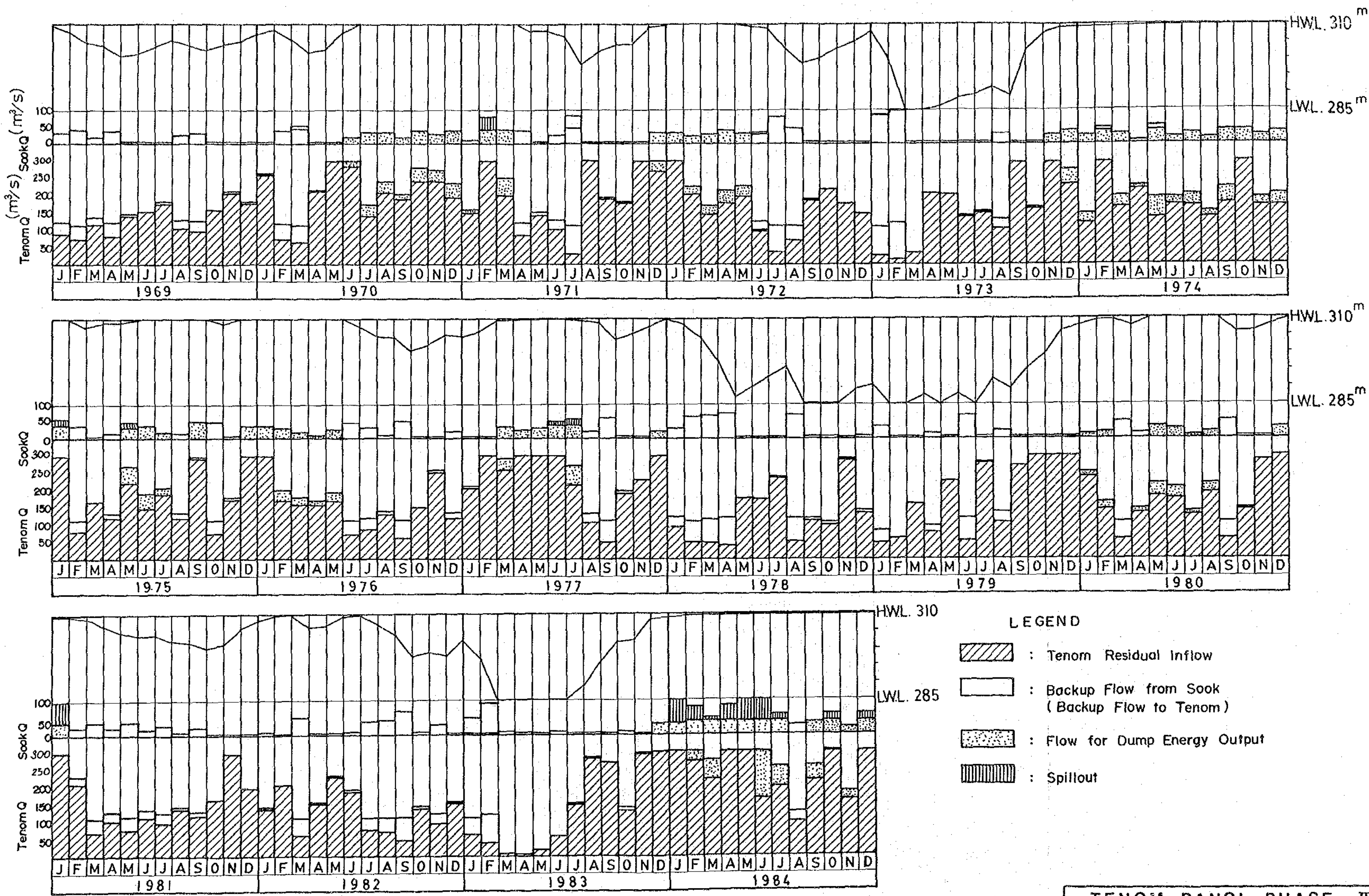


Fig. 4.2 OPTIMUM SCALE OF SOOK DAM AND POWER STATION

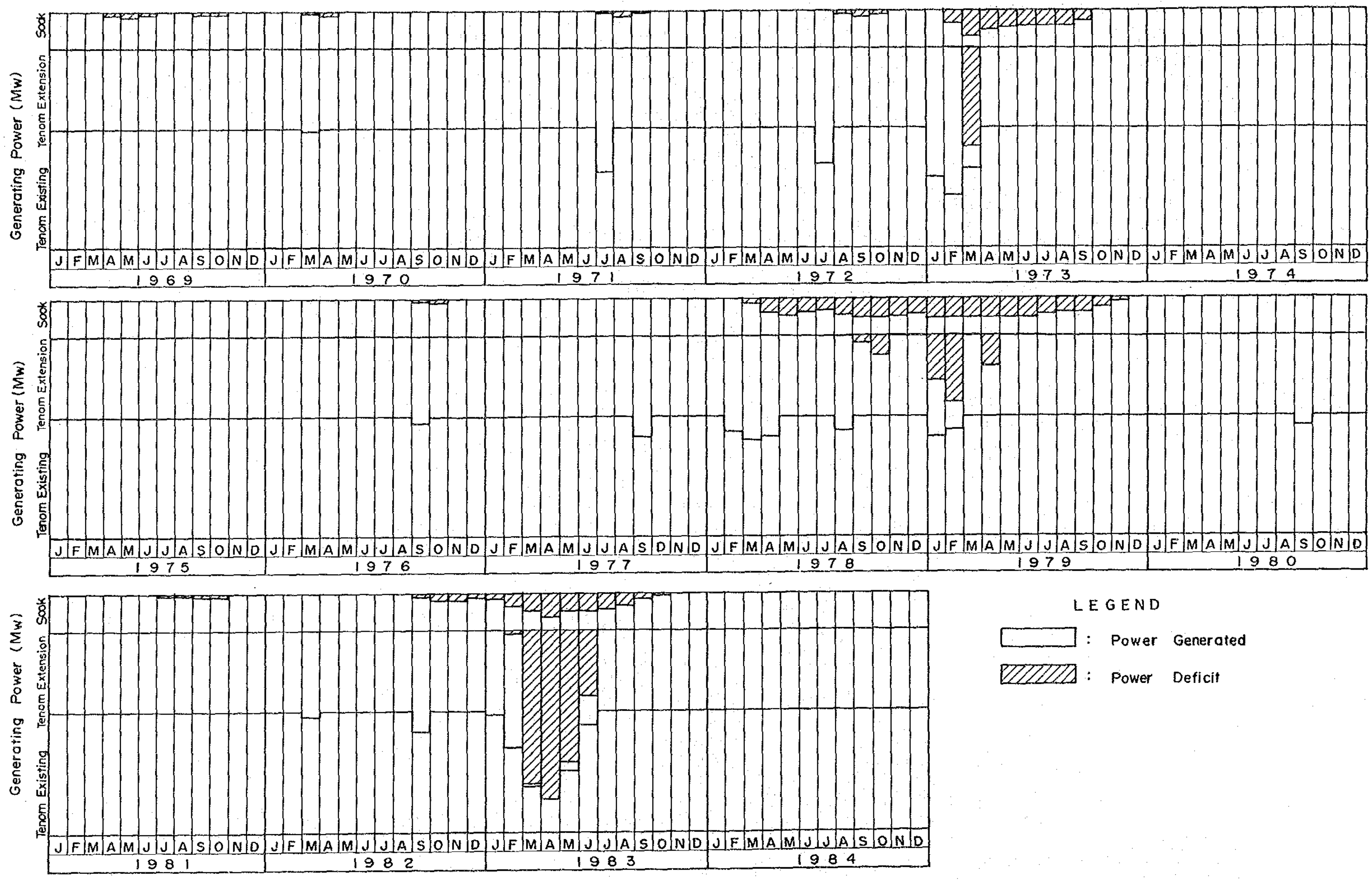
FIGURE NO. 4.3



TENOM PANGI PHASE III

RESERVOIR OPARATION RESULT

SEB / JICA



LEGEND

: Power Generated

: Power Deficit

TENOM PANGI PHASE III

MONTHLY GENERATED POWER

(SIMULATION RESULTS)

SEB / JICA

5. PRELIMINARY DESIGN

5.1 General

This chapter explains the preliminary designs of major structural components for the Tenom Pangi Hydroelectric Power Development Project, Phase III.

As the result of plan formulation study mentioned in the previous chapter, the Tenom Pangi Phase III project includes construction of the Sook dam and power station and extension of the Tenom Pangi power station.

The major structural components for the Sook dam and power station are the main and saddle dams, river diversion facility, spillway, waterway consisting of intake, headrace tunnel, surge tank and penstock line, power house and outdoor switchyard.

For extension of the Tenom Pangi power station, the major components are the waterway consisting of headrace tunnel, surge tank and penstock line, power house and outdoor switchyard. The intake structure for the extension scheme has already been constructed during the implementation of Phases I and II.

The preliminary design for the above major structural components has been carried out to confirm the technical feasibility and to estimate the project cost on the feasibility study level based on the results of the field investigation conducted in this stage.

The results of preliminary design are summarized in the following sections.

5.2 Sook Reservoir

5.2.1 Main Dam

1) Selection of Damsite

Two alternative damsites had been investigated on the Sook River for comparison. One is located in the Sook gorge where the Sook River breaks through the rocky hill at the upper reaches of the confluence with the Pegalan River. It is about 8 km south-southeast of Keningau. The other is located at about 18 km upstream of the Sook gorge along the Sook River.

As the results of the comparison, it is finally decided to select the damsite in the Sook gorge due to the following reasons:

(1) The upstream alternative damsite requires bigger inundation area to make a reservoir with the same storage capacity as the one in the Sook gorge. The land to be inundated is calculated to be about 2.5 times of the Sook gorge damsite case. This will result in higher compensation cost, and also reduction of precious flat land in this district.

(2) The dam volume is estimated to be bigger at the upstream damsite than that of the Sook gorge damsite by more than 10 per cent. This will also result in higher dam construction cost.

As for the selected damsite in the Sook gorge, field reconnaissance had been carried out to seek the promising dam axis. As the results of field reconnaissance, two alternative dam axes were selected. The selected alternative dam axes are as shown in Figure 5.1. Along these dam axes, core drilling and seismic exploration had been conducted to investigate the geological condition. The topographical survey had also been carried out over the area covering the two alternative dam sites .

It is concluded that the upstream dam axis is more viable than the downstream one due to the following reasons;

(1) There is high permeability zone showing more than 100 in Lugeon unit up to 50 m in depth on the right bank of the downstream dam axis. On the left bank of the downstream dam axis, the same high permeability zone is ranging from 7 m to 20 m in depth from the ground surface.

(2) On the contrary, it is ranging from 5 m to 12 m in depth from the ground surface on both banks of the upstream dam axis.

(3) Such high permeability zone is needed to be properly improved by means of the curtain grouting and rim grouting for dam foundation.

(4) Foundation treatment for the downstream axis is technically unviable and cost of foundation treatment for the downstream dam axis is higher than that for the upstream dam axis.

Judging from the geological conditions mentioned above, the upstream dam axis is selected for layout study of dam.

2) Selection of Dam Type

In order to select the most suitable dam type for the Sook damsite, comparative study was carried out for the most popular three kinds of dam types which are rockfill dam with impervious earth core, concrete gravity dam and concrete facing rockfill dam as shown in Figures 5.2 and 5.3.

The spillway of gravity dam can be provided on the center of river course so that better flow direction of water released from the spillway can be realized. In the case of rockfill dam with impervious earth core or concrete facing, spillway structure must be located on the firm rock foundation so that location of spillway is restricted on the abutment of dam. Therefore, there is such case that the river bank at the opposite side of spillway structure can not avoid the attack of water flow released from the dam.

The bottom width in a cross section of gravity dam is usually much narrower than one of rockfill dam with impervious earth core or facing concrete. This means that bigger bearing capacity of foundation is needed for gravity dam than for rockfill type dams.

Construction materials of rockfill type dam will be obtained in the vicinity of damsite. Otherwise this type is not economically justified because dam volume of rockfill type dam is much bigger than that of gravity dam. According to the results of the materials survey, embankment materials for rockfill type dam are available around the project site.

Construction costs of alternative dam types are compared as shown in Table 5.1.

Table 5.1 COMPARISON OF CONSTRUCTION COST

	Item	Concrete gravity dam	Rockfill dam with facing concrete	Rockfill dam with earth core
1)	Upstream slope	Vertical	1:1.5	1:2.5
2)	Downstream slope	1:0.8	1:1.9	1:1.9
3)	Volume ($10^6 m^3$)	0.5	1.8	1.2
4)	Cost (10^6 US$)			
	Main dam	60.0	28.0	24.0
	Spill way	1.5	10.0	11.0
	Diversion tunnal	3.5	9.0	10.0
	Waterway	3.5	9.0	9.0
	Total	68.5	56.0	54.0
	Percentage	(127%)	(104%)	(100%)

According to the results of geological survey for the selected damsite, shearing strength of fresh foundation rock is presumed at 10 kg/cm^2 or less.

In the case of gravity dam having a typical section shown in Figure 5.2, foundation rock should be more than 15 kg/cm^2 in shearing strength. Therefore bottom of dam should be widened to decrease the dam pressure acting on the foundation rock if a gravity dam is adopted for the Sook damsite. This will be more costly compared with the estimates as shown in Table 5.1.

Moreover a rockfill dam with facing concrete is not recommendable unless rock of dam foundation is strong and stable enough not to cause any harmful settlement or deformation which may result in occurrence of cracks in facing concrete.

Considering the geological conditions of the proposed Sook damsite, it is concluded that a rockfill dam with impervious earth core is the most recommendable type of dam for the Sook scheme from economical and technical view points.

3) Crest Elevation of Dam

Crest elevation of the dam should be determined taking into account freeboad which is defined as the vertical distance between the maximum water level and the top of the dam.

To determine a value of freeboard, the following should be considered:

(1) Wave uprush
(2) Unexpected accidents in operation of spillway gate

Wave uprush can be determined from fetch of reservoir, wind velocity, slope of upstream face and slope condition as shown in Figure 5.4. It is estimated at 1.3m for the Sook reservoir under the following conditions:

- Fetch of reservoir : 10 km
- Wind velocity : 20 m/sec
- Slope of upstream face : 1:2.5
- Slope condition : Riprap

Allowance for unexpected accidents in operation of spillway gates is usually taken at 1.5m for rockfill dam.

The freeboad of the Sook dam is determined to be 2.8 m adding the above two values.

As mentioned later, the maximum water level of the Sook reservoir is determined at EL. 311.1 m adding 1.1 m of rise in the reservoir surface due to routing of the probable maximum flood to EL. 310.0 m of the reservoir normal high water level. It is determined from the optimization study of the spillway capacity.

Crest elevation of the Sook dam is designed at EL. 314.0 m rounding up the total of the freeboard and the maximum reservoir water level.

4) Reservoir Sedimentation

After construction of the Sook dam, the sediment carried by the Sook River will be trapped by the dam. Thus, silt storage capacity should be provided in the reservoir.

Specific sediment inflow into the Sook reservoir is estimated at 170 m^3/km^2/year from the sediment study. Assuming that all of the transported sediment is trapped by the reservoir, annual sediment deposit volume is estimated at 290,000 m^3 for 1,705 km^2 of catchment area at the Sook damsite.

The required capacity for sediment desposit, therefore, is estimated at 29,000,000 m^3 for 100 years.

The normal high water level and low water level of the Sook reservoir is determined at Eℓ.310.0 m and Eℓ.285.0 m respectively by the optimization study for developoment scale of the project.

Taking into account the space needed to arrange the intake structure below the low water level, the dead water surface is set at Eℓ.277.0 m in this study. The space below Eℓ.277.0 m is estimated at 100,000,000 m^3. This space will be sufficient to store the anticipated sediment transport to the reservoir.

5) Foundation Treatment

(1) Excavation of dam foundation

Judging from the results of geological investigation, impervious core portion is determined to be placed on the zone having seismic velocity higher than 2.8 km/sec and the permeability less than 50 in Lugeon unit. Rock embankment portion is to be placed on the foundation surface created by removing the top soil, detritus zone and the completely weathered zone. Therefore, excavation line for core zone is about 25 m deep below the ground surface at the left abutment, about 5 m deep at the riverbed portion and about 10 to 25 m deep at the right abutment. Excavation line for rock zone is about 5 m deep ranging from 2 m to 8 m below the ground surface.

(2) Improvement of dam foundation

In order to reduce water leakage through the foundation rock and its velocity, dam foundation is designed to be improved by curtain grouting and blanket grouting.

Curtain grouting is planned to make impermeable curtains in the foundation rock under the impervious core zone. It is performed through main and supporting grout holes. The main grout holes are to be arranged at 2 m interval and staggered positions on two lines which are 2 m away from each other. The supporting grout holes are to be arranged at 3 m interval and staggered positions on 4 lines sandwiched two lines of the main grout holes. The inside and outside lines of supporting grout holes for one side are to be at 2 m and 4 m respectively away from the main grout hole line.

In this feasibility study stage, the depth of the curtain grouting is determined by the following empirical equation:

$$D = H/3 + C$$

where, D : Depth of grout hole (m)

H : Dam height (m)

C : Constant ranging 8 to 25

Blanket grouting is planned to reduce the permeability of foundation rock near the surface contacted with the impervious core where hydraulic gradient of seepage water shows the highest value in the foundation rock. The grout holes are arranged to cover the whole area contacted with the impervious core except the curtain grouting zone. They are placed at 3 m interval and staggered positions on lines which are 2 m away from each other. The depth of blanket grouting is 5 m.

6) Stability of Dam

Stability analysis of dam embankment is preliminarily carried out by the slip circular method to determine the upstream and downstream slopes of dam embankment. It is made for the condition of steady seepage from normal high water level and pseudo-static earthquake loading condition. The minimum factors of safety acceptable for the above conditions are determined at 1.5 for the former condition and 1.15 for the later condition respectively following the current international recommendations.

Material properties used for the preliminarily stability analysis are indicated in Table 5.2.

Table 5.2 PARAMETERS FOR PRELIMINARY STABILITY ANALYSIS

Zone	Specific gravity	Unit weight(t/m^3)			Stress Parameters	
		Dry	Wet	Saturated	C(t/m^2)	φ(°)
Core	2.85	1.60	2.00	2.04	0.95	24
Filter	2.62	2.00	2.10	2.26	0	37
Rock	2.70	1.90	1.95	2.20	0	42

The seismic coefficient for preliminary stability analysis is determined at 0.12 as the result of statistic analysis of earthquake records.

The flow net used for the stability analysis is shown in Figure 5.5.

Assuming the upstream and downstream slopes of dam embankment, stability analysis had been repeated to determine the stable and economic dam section.

As the results of stability analysis, the section of dam is preliminarily designed as below:

Crest elevation of dam	:	El. 314.00 m
Flood water level	:	El. 311.10 m
Normal high water level	:	El. 310.00 m
Low water level	:	El. 285.00 m
Sedimentation surface level	:	El. 277.00 m
Bottom elevation of dam	:	El. 244.00 m
Dam height	:	70 m
Width of dam crest	:	10 m
Upstream slope	:	1:2.5
Downstream slope	:	1:1.9

The results of the preliminary stability analyses are summarized in Table 5.3 and shown in Figures 5.6 and 5.7.

Table 5.3 MINIMUM FACTORS OF SAFETY

Condition	Upstream slope	Downstream slope
Normal	2.26	1.75
Seismic	1.34	1.33

7) Earthquake-resistant Design

It is reported from the Geological Survey Department of Malaysia that according to the aerial photograph interpretation and the satellite images interpretation, a major tectonic lineation is detected in the vicinity of the Sook reservoir area. It indicates a possibility that a major fault may exist in the Sook area.

In order to clarify this possibility, aerial photographs were studied and geological investigation including the trench excavation was carried out by geologists. As the result, it is concluded that existence of major fault is not confirmed clearly at the site. However, for the safety of the dam, the emphasis is put on to conduct the design of the dam taking with full consideration of the earthquake resistant design.

The design of the dam is made taking into account the following major causes of the failure case:

(1) Disruption of dam body by major fault movement in foundation.

(2) Loss of freeboard due to differential tectonic ground movements.

(3) Slope failures induced by ground motions.

(4) Loss of freeboard due to slope failures or soil compaction.

(5) Sliding of dam on weak foundation materials.

(6) Piping failure through cracks induced by ground motions.

(7) Overtopping of dam due to slides or rockfalls into reservoir.

(8) Failure of spillway or outlet works.

Moreover, the following defensive measures for earthquake-resistant dam design are included:

(1) Allow ample freeboard to allow for settlement, slumping or fault movements.

(2) Use wide transition zones of material not vulnerable to cracking.

(3) Use chimney drains near the central portion of embankment.

(4) Provide ample drainage zones to allow for possible flow of water through cracks.

(5) Use wide core zones of plastic materials not vulnerable to cracking.

(6) Use a well-graded filter zone upstream of the core to serve as a crack stopper.

(7) Provide crest details which will prevent erosion in the event of overtopping.

(8) Flare the embankment core at abutment contacts.

(9) Locate the core to minimize the degree of saturation of materials.

(10) Stabilize slopes around the reservoir rim to slides into the reservoir.

(11) Provide special details if danger of fault movement in foundation.

5.2.2 Spillway

The slopes of river bank at the selected damsite are about vertical 1 to horizontal 2 at the right bank and about vertical 1 to horizontal 5 at the left bank. The depths of top soil, detritus, completely and highly weathered zones are about 7m at the right bank and about 10m at the left bank. Taking into consideration these topographical and geological conditions, the spillway is located on the left abutment and founded on the moderately weathered zone.

The spillway is designed to pass the probable maximum flood (PMF) taking into account the surcharge effect of the reservoir. The peak inflow of PMF for the Sook dam is estimated at 1,940 m^3/sec by the hydrological analysis.

The spillway capacity is optimized by cost comparative study assuming the maximum discharge to be released form the spillway. The rise in reservoir surface due to flood routing is calculated and the elevation of dam crest is determined for each case. Construction cost of dam is roughly estimated using the determined elevation of dam crest. Construction cost of spillway is also estimated from the maximum discharge to be spilled out.

The results of comparative study are summarized in Table 5.4.

As the results of optimization study on spillway capacity, the capacity of the spillway is determined safety to pass the outflow discharge of 1,000 m^3/sec. The highest reservoir water level is calculated at El. 311.1 m adding 1.1m of the rise in reservoir surface due to flood routing above El. 310.0 m of normal high water level.

Table 5.4 OPTIMIZATION OF SPILLWAY CAPACITY

	Item	Alternatives I	II	III	IV
1)	Maximum spillway discharge(m^3/sec)	1,940	1,500	1,000	500
2)	Surcharge volume of reservoir($10^6 m^3$)	0	8.7	42.6	142.9
3)	Surcharge water depth (m)	0	0.3	1.1	3.7
4)	Flood water level of reservoir (El-m)	310.0	310.3	311.1	313.7
5)	Elevation of dam crest (El-m)	312.9	313.2	314.0	316.5
6)	Construction cost of dam (10^6US$)	23.0	23.4	24.0	27.5
7)	Construction cost of spillway (10^6US$)	10.6	9.7	8.5	7.1
8)	Total cost (10^6US$)	33.6	33.1	32.5	34.6
9)	Percentage (%)	103	102	100	106

The spillway comprise a curved intake channel, an ogee crest with two roller gates, a concrete lined chute and a stilling basin. The intake channel is excavated to El. 300.0 m to limit the velocity over the weathered rock bed to less than 1.5 m/sec during the 100 year flood. The ogee crest is provided with two roller gates having the dimensions of 11.5 m wide and 7.0 m high. To prevent cavitation damage due to high velocity flow, flow aeration will be taken into consideration for design of the concrete lined chute. The stilling basin is preliminary designed at the end of the chute to kill the excess energy of released water. The slope excavated on the left abutment should be properly protected against land slide.

5.2.3 River Diversion During Construction

The river flow should be safely diverted during construction of the main dam. In the case of rockfill type dam, overtopping will cause serious damages to the construction works. Therefore river diversion system should be properly provided.

The construction period of main dam is preliminarily estimated for two years and a half. On the other hand, the river flow at damsite has been recorded for more than 17 years since 1968.

Taking into consideration a risk of cofferdam overtopping and construction cost, the diversion flood is preliminarily determined at the recorded maximum flood. The peak flow of the recorded maximum flood is 410 m^3/sec and equivalent to about the 30-year probable flood as shown in Table 2.7. To select a final design flood for river diversion scheme, the followings should be taken into consideration:

1) Accepted practice

2) The reliability and period of recorded catchment rainfall and river flows at the damsite.

3) Duration of the construction period.

4) Cost of repairs required at the site and of delayed completion if the cofferdam fails

5) Loss of life and cost of the damage associated with the flood wave if the cofferdam fails

6) Cost of insurance

The river diversion works preliminarily adopted for the construction of Sook dam include twin 5 m diameter conduits, a main cofferdam contained within the main dam and two temporary cofferdams. The two diversion tunnels are located on the left river bank. The elevation of No.1 diversion tunnel inlet sill is determined at

El.253.0 m almost same as the riverbed elevation. However it is selected at El.259.0 m for No.2 diversion tunnel taking into account of easy closure of diversion tunnel and combined use of No.2 diversion tunnel for river outlet works.

The crest of the main cofferdam is designed at El.270.0 m taking into consideration the required construction period of main cofferdam. The diameter of twin diversion tunnel should be big enough not to cause overtopping of main cofferdam. The flood routing calculations are made to determine a relation between the diameter of twin tunnel and the highest flood water level. The calculation results are shown in Figure 5.8. Referring to these flood routing calculations and the selected crest elevation of main cofferdam, the diameter of twin diversion tunnel is preliminary determined at 5.0 m.

5.2.4 River Outlet Works

The river outlet works are planned to be provided in the diversion tunnel No.2. The inlet structure with trashrack for river outlet is designed at the inlet portion of diversion tunnel No.2. The bottom elevation of inlet sill is set at El.279.0 m above the design sedimentation surface level of El.277.0 m.

A jet flow gate is planned to control outlet discharge. The valve chamber is designed at the just downstream of plug concrete to install the jet flow gate.

The capacity of jet flow gate is preliminary determined at 60m^3/sec taking into consideration requirement of water supply for the Pangi power station during dry periods under the condition that one unit of two generators for the Sook power station is out of operation. In this case the diameter of jet flow gate is 2.0 m. However optimum capacity and details of facility will be determined during the detailed design stage.

5.2.5 Saddle Dam

Saddle dams are needed to be constructed on the portions lower than the highest water level of reservoir. These lower portions are located on the terrace laying between the Sook plain and the Keningau valley plain where is about 5 km northeast of the Sook damsite. The axis of saddle dams was selected at site for the detailed topographical and geological investigations. The lowest ground elevation is about El.303 m. Therefore, the maximum height of the saddle dam is about 11 m. The crest length of saddle dams is about 1,500 m in total. According to the geological investigation results, the foundation of saddle dam consists of about 50 m thick terrace deposits which are mainly sandy soils at upper half and clay at the lower half. The terrace deposits can be used for the impervious earth embankment material with some treatment.

Taking into account of the geological condition of dam foundation and availability of embankment materials, the homogeneous earthfill dam is selected for the saddle dams. The upstream and downstream slopes of saddle dams should be protected against erosion due to wave action of reservoir water and heavy rainfall.

5.2.6 Waterway

The waterway for power generation comprises an intake, a headrace tunnel, a surge tank and a penstock line. The preliminary designs of these structures are summarized below;

1) Intake

The intake structure is located on the right bank about 120 m upstream of the main dam axis from the topographical condition. It is preliminary designed as an intake with inclined gate shaft laid on the excavated slope.

The entrance sill is set at El.278.0 m taking into consideration the design sediment surface level of El.277.0 m and the reservoir low water level of El.285.0 m.

2) Headrace tunnel

The headrace tunnel is located on the right bank. The tunnel route is selected so as to keep sufficient depth from the ground surface and to shorten its length as short as possible. The tunnel has a circular section. The concrete lining is provided to improve roughness coefficient of tunnel surface. The length of tunnel is about 450 m. The diameter of tunnel is determined at 3.9 m.

3) Surge tank

The surge tank is located on a small ridge about 250 m downstream of the main dam axis.

According to the preliminary study about surge tank type, fluctuation of water level in the simple type surge tanks is much bigger than that in the restricted orifice type surge tank.

Taking into consideration the topographical and geological conditions at the selected surge tank site, the restricted orifice type is selected for the Sook power scheme. The diameter of surge tank is determined at 12.0 m. The surging curve for the selected case is shown in Figure 5.9. The surging analysis was conducted under the following conditions:

(1)	Discharge	:	46.6 m^3/sec
(2)	Normal high water level	:	El.310m
(3)	Low water level	:	El.285m
(4)	Tail water level	:	El.250m
(5)	Tunnel length	:	449m
(6)	Tunnel diamter	:	3.9m
(7)	Closing time of guide vane	:	6 sec
(8)	Opening time of guide vane	:	10 sec
(9)	Roughness coefficient for upsurging	:	0.012

(10) Roughness coefficient for downsurging : 0.015

(11) Port area for restricted orifice type : $4.8m^2$

(12) Discharge coefficient of port(in) : 0.900

(13) Discharge coefficient of port(out) : 0.628

4) Penstock Line

The penstock line comprises tunnel and open portions. The tunnel penstock portion is horizontal and 56 m long. The open penstock portion is laid on the excavated slope and 83 m long. The inside diameter of steel penstock is determined at 3.1 m on an average.

5.2.7 Power Station

The Sook power station is located just downstream of the main dam taking into account of the space for the outdoor switchyard. The power house is founded on the stable sand stone layer. It is a surface type power house.

5.3 Extension of Tenom Pangi Power Station

5.3.1 Waterway

The waterway for extension of the Tenom Pangi power station comprises the intake, headrace tunnel, surge tank and penstock line.

1) Intake

The intake structure for Phase III development is located just downstream of the intake structure for Phases I and II on the left bank of the Tenom gorge. It has been constructed during the Phases I and II stages.

The intake weir is equipped with 3 roller gates which are 9.0 m high and 6.0 m wide respectively. As the open space at the intake site is not enough, the sand settling basin is located underground. It is 56 m long, 10 m wide and about 15 m high.

In the Phase III development, gates and trashracks are to be installed.

2) Headrace Tunnel

The headraced tunnel is to be aligned parallel to the existing headrace tunnel for 66 MW installation at the river side. The center lines of both tunnels are away by about 35 m each other. The inside diameter of tunnel is optimized at 5.2 m and the tunnel length is about 4,200 m.

3) Surge Tank

The surge tank is located near the existing surge tank for Phases I and II development. The surge tank shaft is wholly laid in the firm rock and its crest is opened at El.200 m of the excavated surface.

As the result of preliminary study on surge tank type, the restricted orifice type is selected for extension of the Tenom Pangi power station. The diameter of surge tank is determined at 14.0 m. The surging curve for the selected case is shown in Figure 5.10. The surging analysis was carried out under the following condition:

(1)	Discharge	: 85 m^3/sec
(2)	Normal high water level	: El.173.9 m
(3)	Low water level	: El.170.7 m
(4)	Tail water level	: El.99.2 m
(5)	Tunnel length	: 4,140 m
(6)	Tunnel diameter	: 5.2 m
(7)	Closing time of guide vane	: 6 sec
(8)	Opening time of guide vane	: 10 sec
(9)	Roughness coefficient for upsurging	: 0.012

(10) Roughness coefficient for downsurging : 0.015

(11) Port area for restricted orifice type : 4.56 m^2

(12) Discharge coefficient of port (in) : 0.900

(13) Discharge coefficient of port (out) : 0.636

4) Penstock Line

Taking into consideration the topographical conditions and the existing penstock line, an underground penstock line is designed for the extension scheme. It is alined parallel to the existing penstock line at the upstream side along the Padas River. It is 220 m long including both horizontal and inclined portions. The inside diameter of the penstock is determined at 4.0 m on an average.

5.3.2 Powerhouse

The space for extension of powerhouse has been reserved at the upstream side adjacent to the existing powerhouse. Therefore, the powerhouse is extended towards the upstream side so that the existing overhead crane can be used for the extended portion. The existing assembly bay and overhead crane will be used for erection of additional turbines and generators. Control of the newly installed units can be made in the existing control room.

5.4 Generating Equipment

Water turbines for the Sook power station are of vertical shaft Kaplan type coupled directly with synchronous generators. The water turbine generators have output of 2x10 MW under the rated head of 51 m and rated speed of 429 rpm. One set of 23 MVA step-up transformer will be provided for stepping up the generator voltage to 132 kV for power transmission to the Keningau substation.

Additional water turbine generators for the extension of the Tenom Pangi power station, 2x22 MW, will be installed in the extended portion of the powerhouse. The basic features of the water turbine generators will be the same as those of the existing three sets of 22 MW unit. The water turbines will be of vertical shaft Francis type with rated head of 59.9 m and rated speed of 300 rpm. The generator output will be stepped up to the transmission voltage of 132 kV with two sets of 25 MVA transformer to be installed adjacent to the power house and will be connected to the 132 kV outdoor switchyard through 132 kV power cables. Two bay extension of the outdoor switchyard is required toward the opposite side of the powerhouse, the upstream side of the Padas river.

5.5 Transmission Line

The generated power at the Sook power station will be sent to Keningau with a single circuit transmission line with ACSR conductors of 175 mm^2 (Lynx). The distance of the transmission line will be about 10 km and the line will be terminated at the 132 KV bus of the Keningau substation which is now under execution with target completion in 1987. This substation has a provision to extend the 132 kV double bus for receiving the power from the Sook power station.

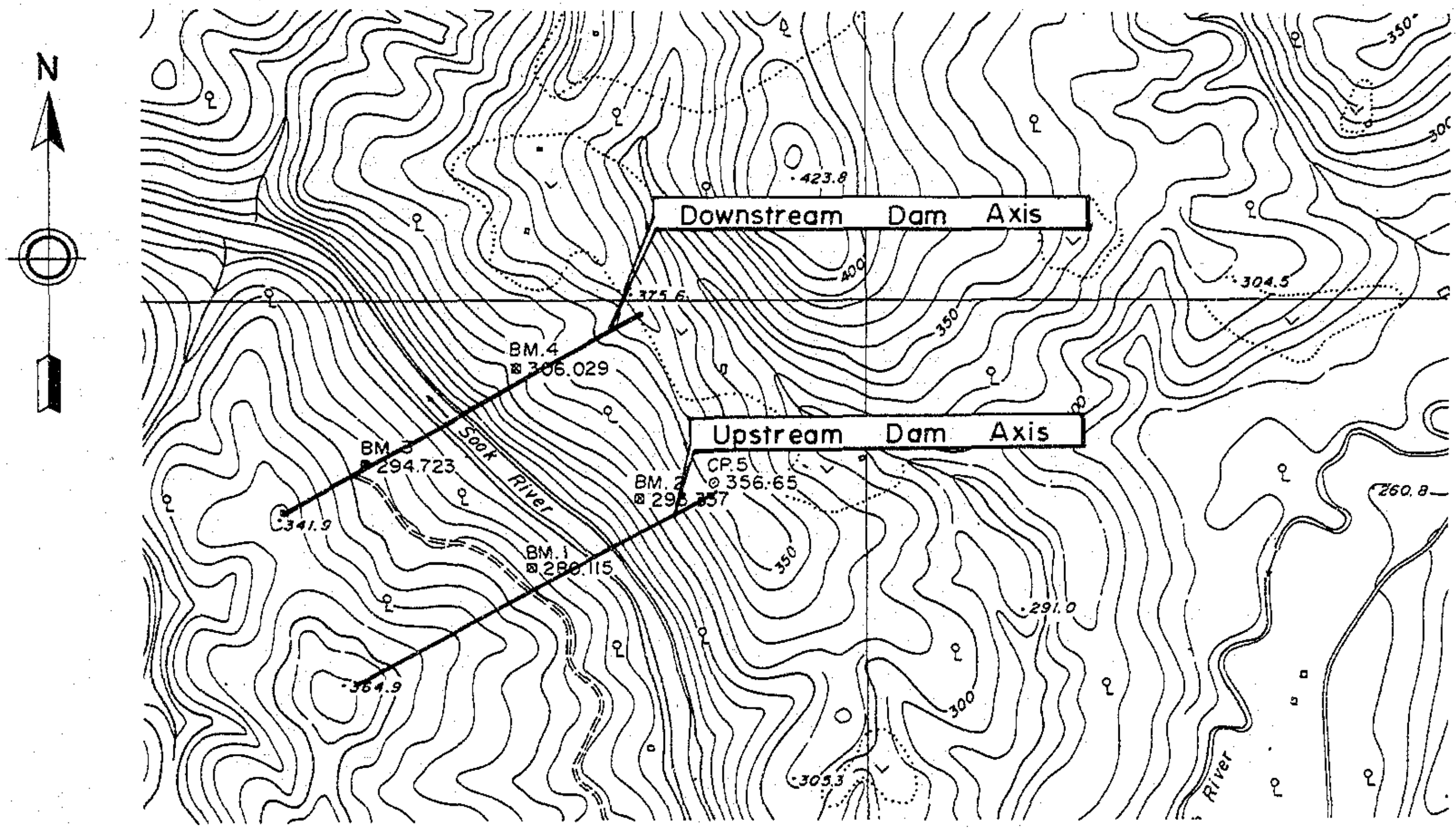
In addition to the existing 132 KV double circuit transmission line to Kota Kinabaru provided with ACSR conductors with sectional area of 350 mm^2 (Bison) which was constructed under Phases I and II of the Tenom Pangi Power Project, a 132 KV double circuit transmission line is under construction between the Tenom Pangi power station and Keningau substation. The conductors of this line is also ACSR, 350 mm^2 (Bison), same as the Pangi-Kota Kinabaklu line, which takes into account future extension of the transmission system from Keningau to Kota Kinabalu.

The power demand for load centers at Tenom, Keningau, Beaufort is not much, about 20 MW in total in 1995 and the major portion of the generated power at the Tenom Pangi power station and the Sook power station, being 130 MW in total, must be sent to Kota Kinabalu and its surrouding area. For transmission of the 110 MW power over the distance of 120 km, transmission capacity of the existing line from the Tenom Pangi power station to the Penampang substation will not be enough. In principle, an important transmission system shall be planned so as to be operated without serious trouble even when any one circuit of the component line in the system is out of service. Between the Beaufort substation and the Panampang substation, the power flow from Labuan to Kota Kinabalu shall also be taken into account. The transmission capacity of single circuit line when the other circuit is out of service is obviously not enough to send all the generated power.

In order to increase transmission capacity, there is no doubt about necessity for construction of another double circuit line with at least the same particulars as those of the existing Tenom Pangi-Penampang line between Keningau and Kota Kinabalu. Particulars of facilities for this new transmission line shall be decided taking into account the power transmission from Labuan. This transmission is recommended to be planned and constructed under a separate power transmission project which is to be realized when the Labuan interconnection is to be executed or as the case may require.

With regard to electrification around the project area, public power is available up to Ansip village by the extension of an 11 kV line from Keningau at present. In order to facilitate power supply to the affected area, provision will be made for 11 kV outgoing facilities from the power station. When construction plan of 11 kV power distribution line around the project area is worked out, the power distribution lines can easily be connected to these facilities.

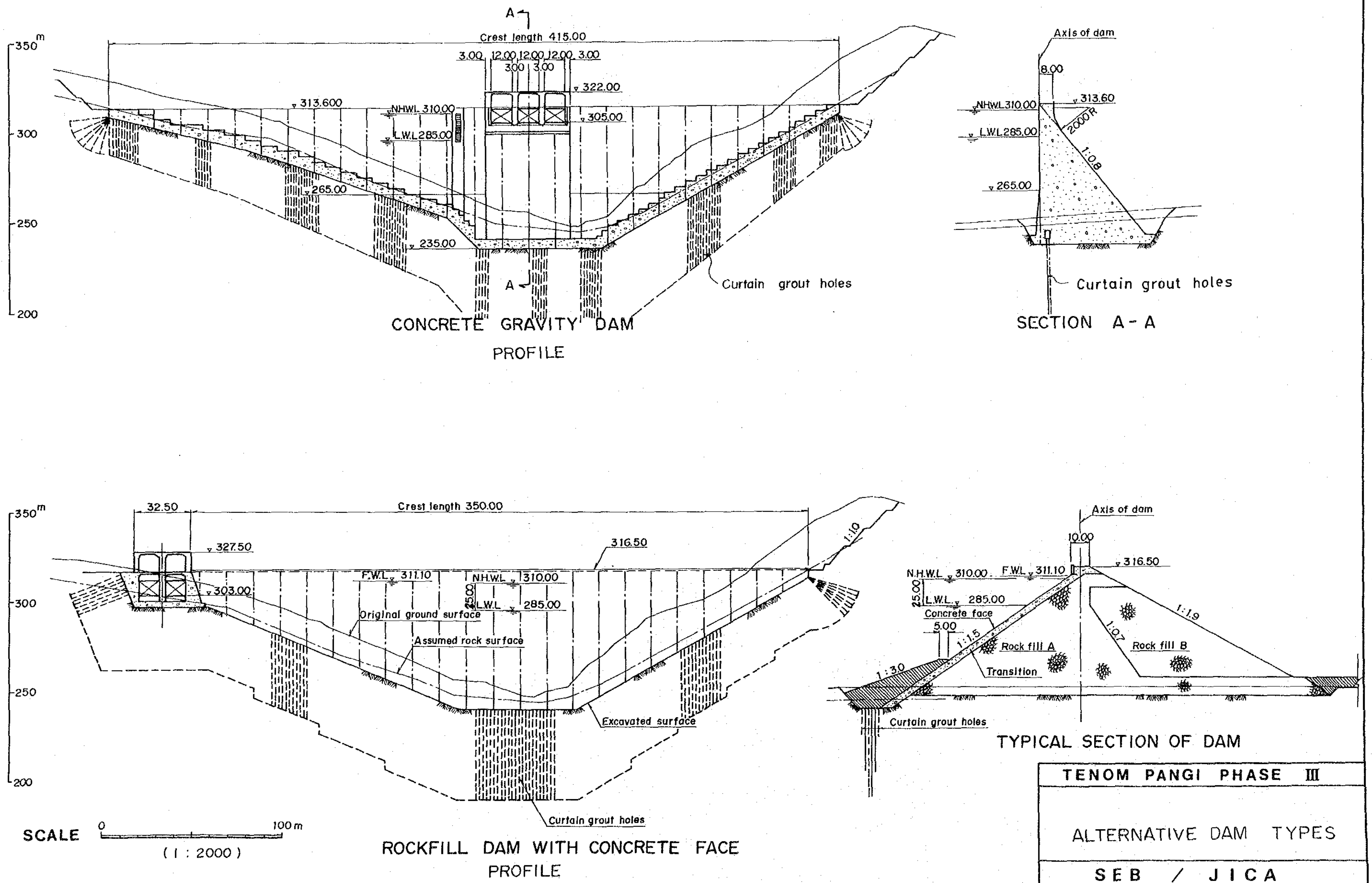
FIGURE NO. : 5.1



SCALE 0 500m
(1 : 10,000)

TENOM PANGI PHASE III
ALTERNATIVE DAM AXES
SEB / JICA

FIGURE NO. : 5.2



TENOM PANGI PHASE III

ALTERNATIVE DAM TYPES

SEB / JICA

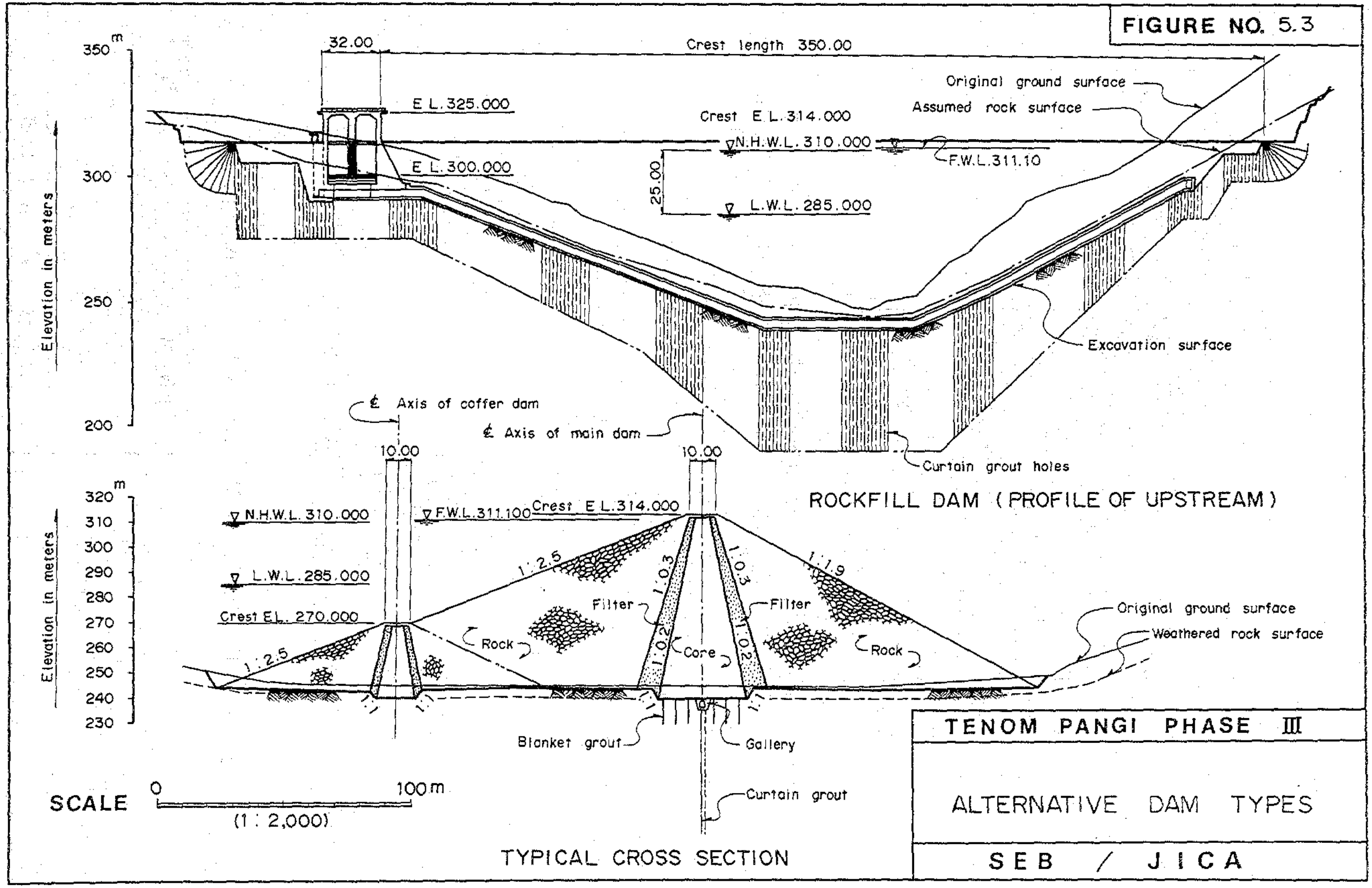


FIGURE NO. 5.3
Crest length 350.00
32.00
E.L.325.000
E.L.300.000
Crest E.L.314.000
N.H.W.L.310.000
F.W.L.311.10
25.00
L.W.L.285.000
Original ground surface
Assumed rock surface
Excavation surface
Curtain grout holes
Elevation in meters
350 m
300
250
200
ROCKFILL DAM (PROFILE OF UPSTREAM)
Axis of coffer dam
Axis of main dam
10.00
10.00
320 m
310
300
290
280
270
260
250
240
230
N.H.W.L.310.000
F.W.L.311.100
Crest E.L.314.000
L.W.L.285.000
Crest EL. 270.000
1:2.5
1:2.5
1:0.3
1:0.3
1:1.9
1:0.2
1:0.2
1:1
Filter
Filter
Rock
Rock
Core
Original ground surface
Weathered rock surface
Blanket grout
Gallery
Curtain grout
SCALE 0 100m (1:2,000)
TYPICAL CROSS SECTION
TENOM PANGI PHASE III
ALTERNATIVE DAM TYPES
SEB / JICA

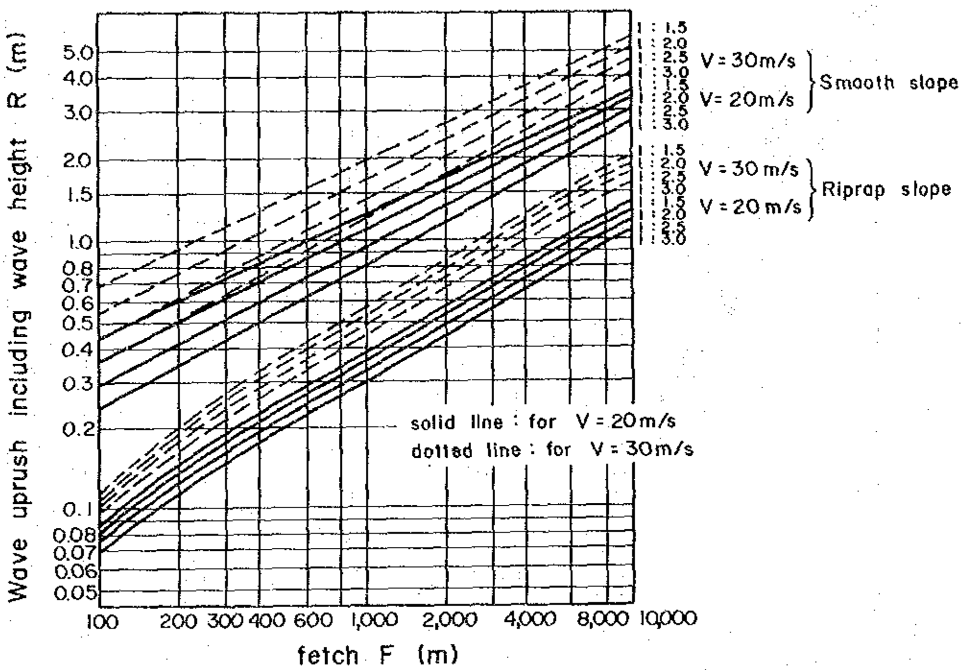


Fig. 5.4 WAVE UPRUSH (INCLUPING WAVE HEIGHT) OBTAINED BY COMBINING THE S.M.B. METHOD WITH SAVILLE METHOD

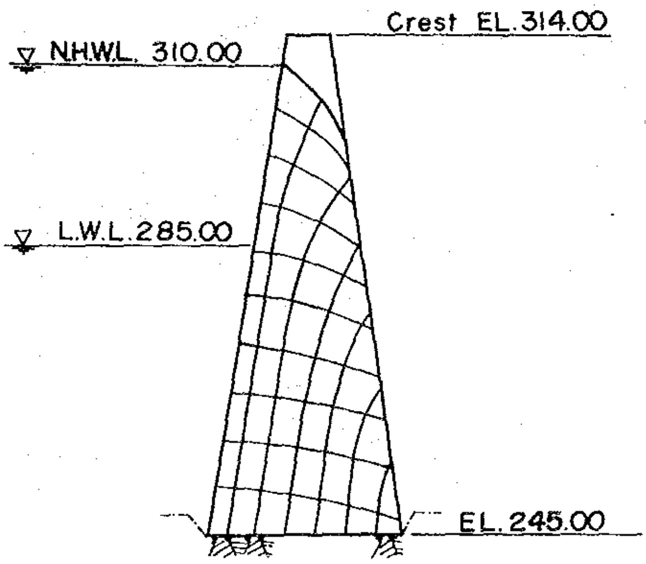
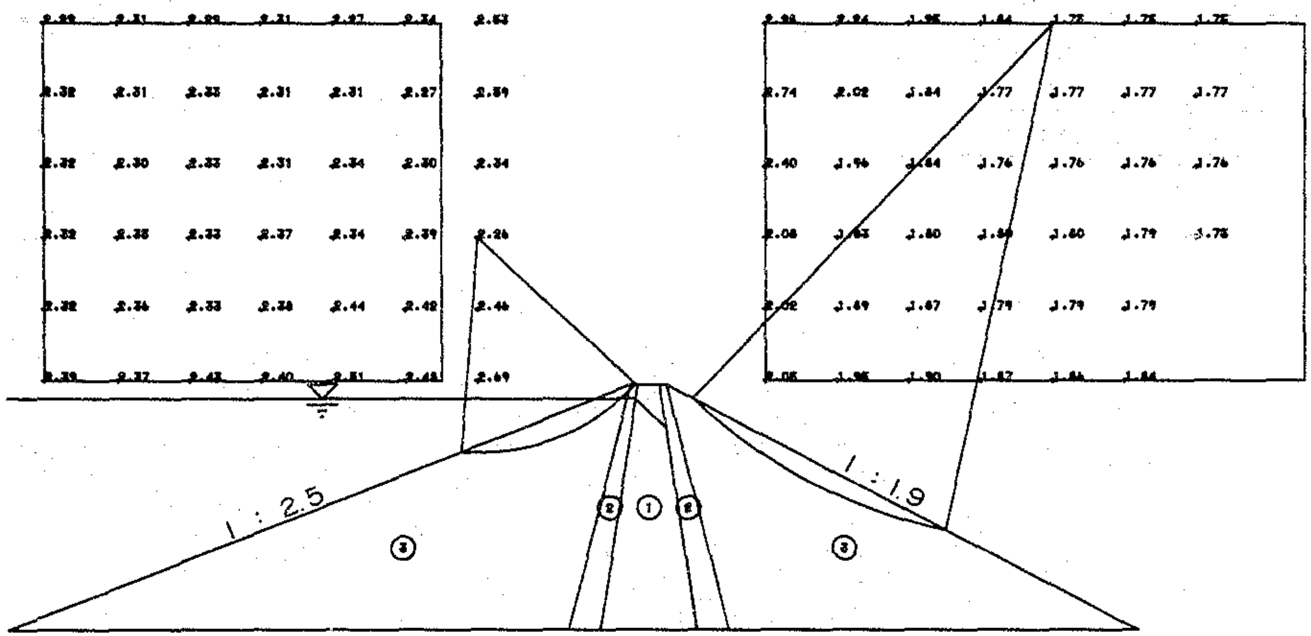


Fig. 5.5 FLOWNET FOR STABILITY ANALYSIS

TENOM PANGI PHASE III

SEB / JICA

FIGURE NO. : 5.6



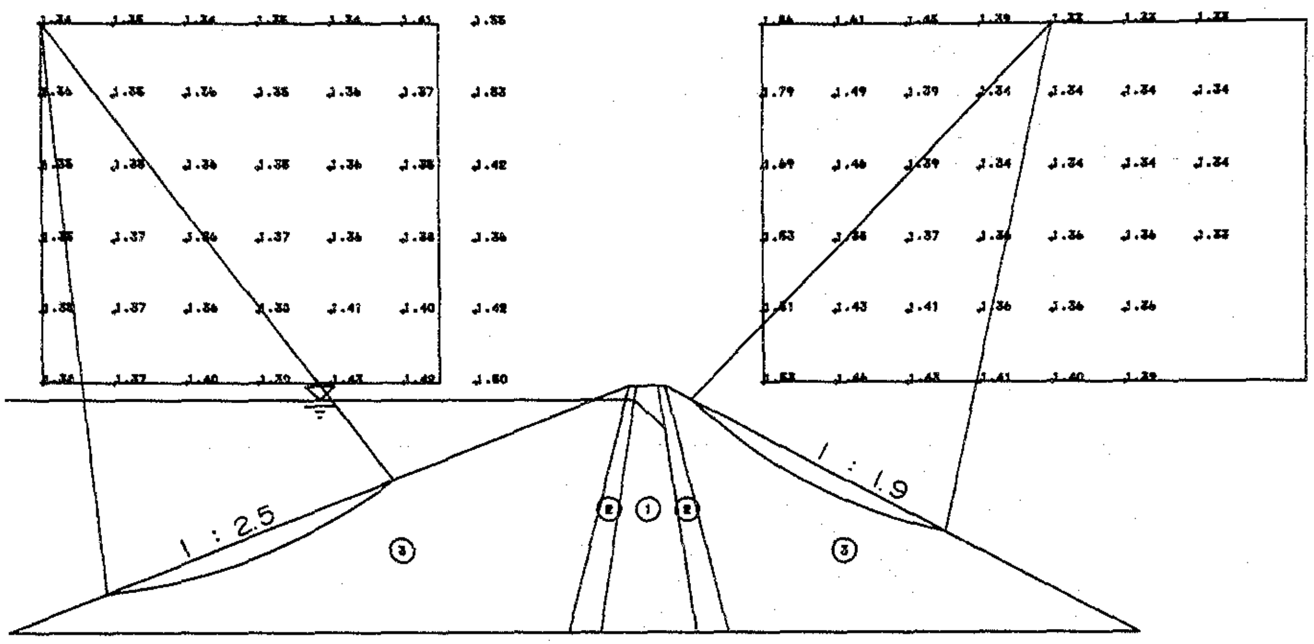
SCALE 0 — 100 m
(1 : 2,000)

TENOM PANGI PHASE III

RESULTS OF STABILITY ANALYSIS
NORMAL CONDITION

SEB / JICA

FIGURE NO. : 5.7



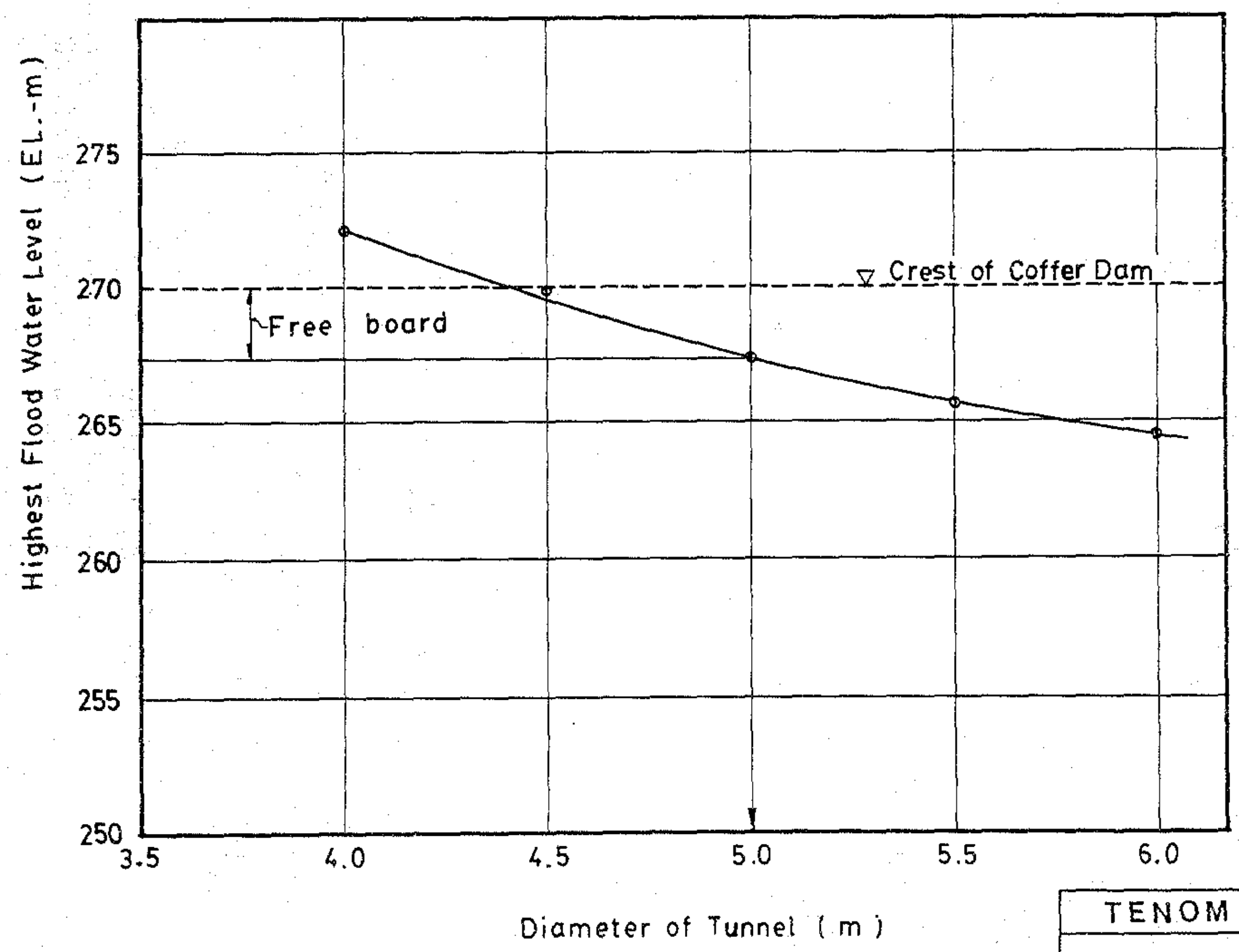
SCALE 0 — 100m
(1 : 2,000)

TENOM PANGI PHASE III

RESULTS OF STABILITY ANALYSIS
SEISMIC CONDITION

SEB / JICA

FIGURE NO. : 5.8

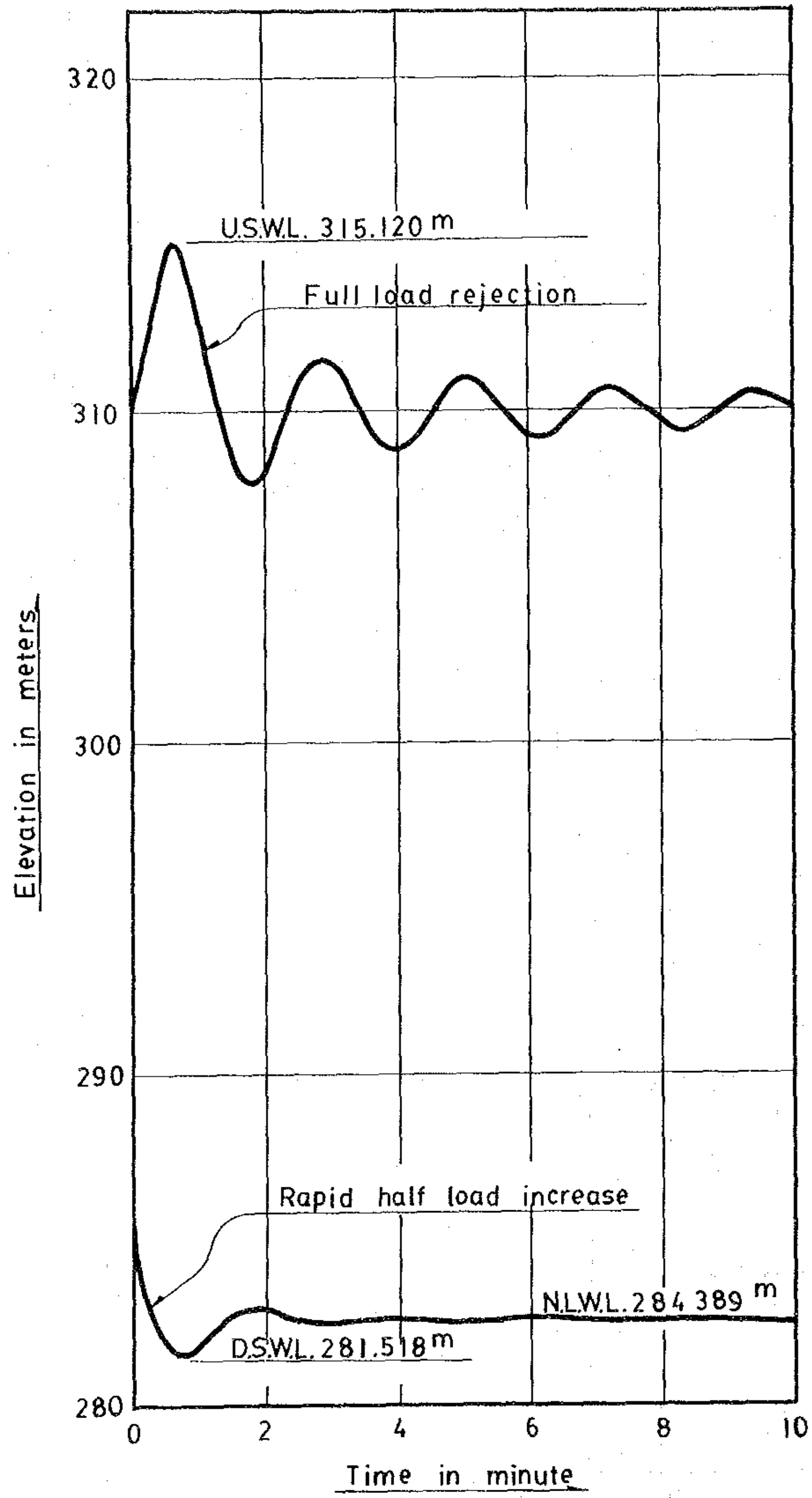


TENOM PANGI PHASE III

DIAMETER OF TWIN DIVERSION TUNNEL

SEB / JICA

FIGURE NO. : 5.9

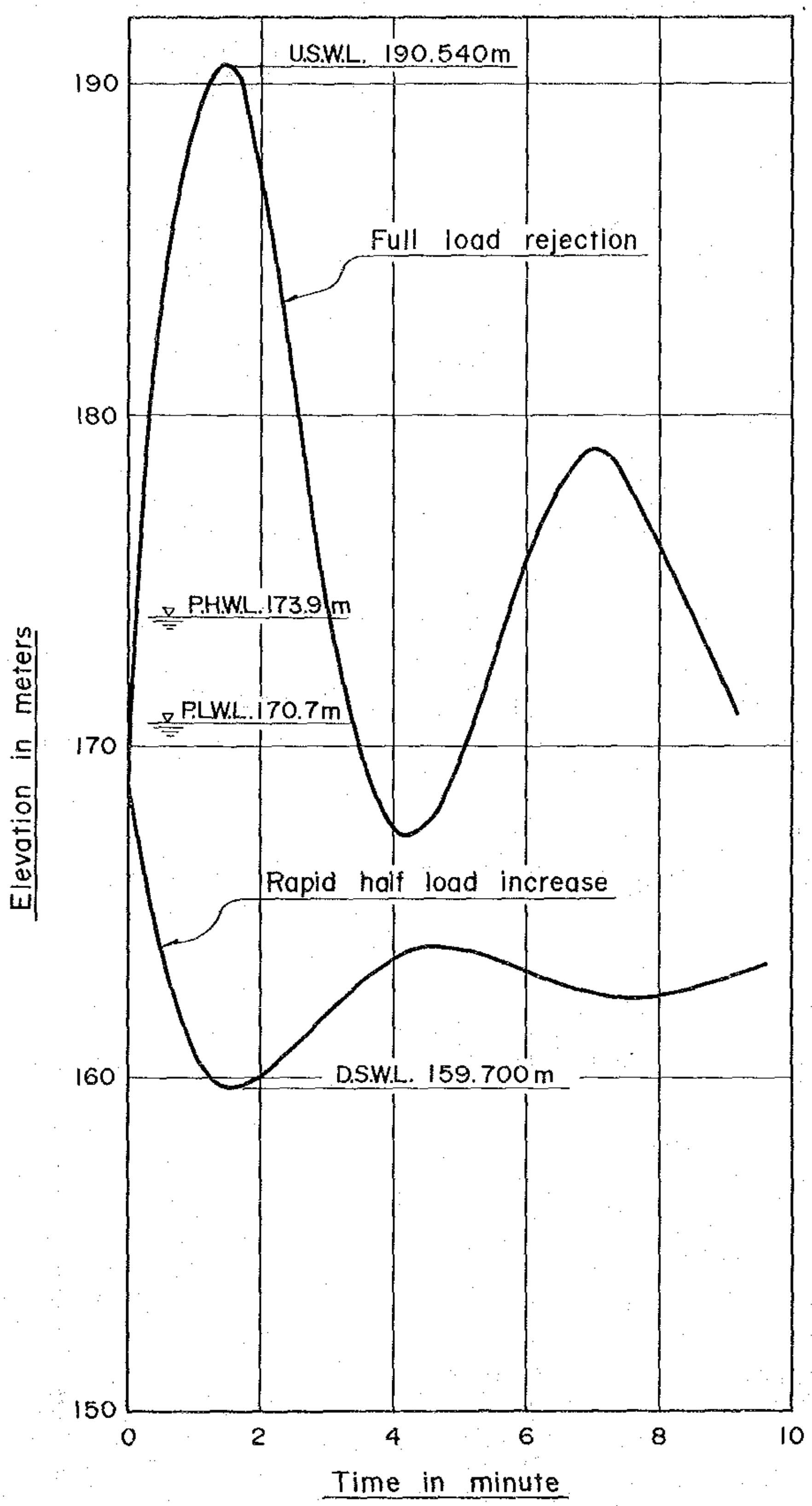


TENOM PANGI PHASE III

SURGING CURVE (SOOK)

SEB / JICA

FIGURE NO. : 5.10

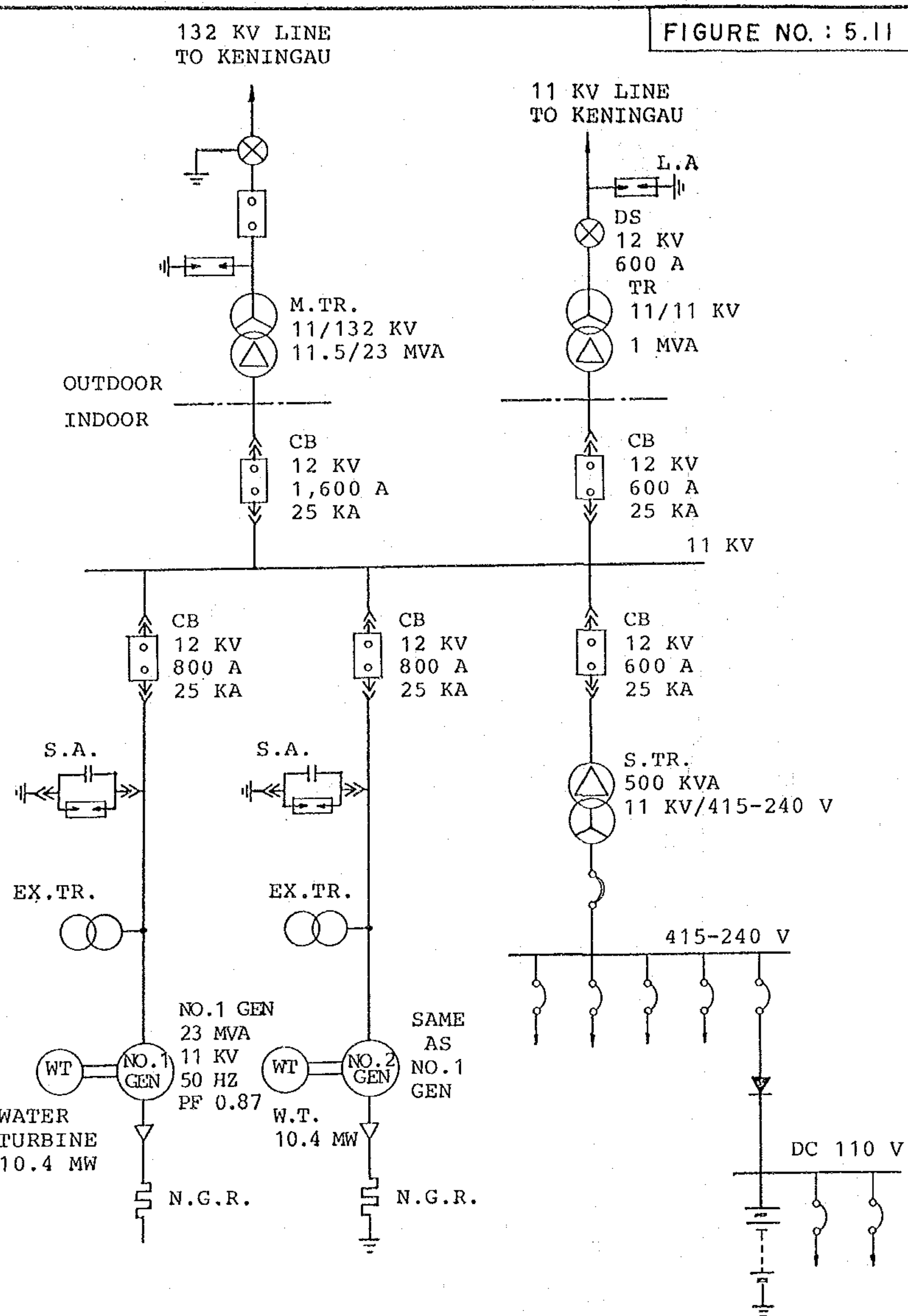


TENOM PANGI PHASE III

SURGING CURVE
(TENOM PANGI EXTENSION)

SEB / JICA

FIGURE NO. : 5.11



TENOM PANGI PHASE III

SOOK POWER STATION

SINGLE LINE CONNECTION DIAGRAM

SEB / JICA

6. CONSTRUCTION PLAN

6.1 General

This chapter presents the construction plan for the proposed Sook dam and power station as well as the extension of the Tenom Pangi power station including basic conditions applied, preparatory works, outline of construction method for permanent facilities and the proposed construction schedule.

The plan is prepared in consideration of the project features, site conditions, data on local conditions collected during the field investigation and also the construction record of existing Tenom Pangi Project (Phases I and II).

6.2 Basic Conditions

6.2.1. Mode of Construction

Construction works for the project may be carried out by several contractors selected on the basis of competitive tender and divided into the following contract categories;

1) Sook dam and power station

(1) International tender

a) Main civil works: River diversion works, main dam, saddle dam, spillway, river outlet, intake, headrace tunnel, surge tank, penstock line, powerhouse and tailrace.

b) Hydro-mechanical works: Gates, valve and steel penstock.

c) Electrical works: Turbines, generators, transformers, switch gear, transmission line.

(2) Local tender

a) Civil works: Access roads and living quarters.

2) Extension of Tenom Pangi power station

(1) International tender

a) Main civil works: Headrace tunnel, surge tank penstock line, powerhouse and tailrace.

b) Hydro-mechanical works: Gates, steel penstock.

c) Hydro-electrical works: Turbines, generators, transformers, switchgear, sub-station equipment.

6.2.2 Work Quantity

Work quantity is estimated on the basis of preliminary design. The major work quantities of the civil works are listed in Tables 6.1 and 6.2.

6.2.3 Workable Day and Hour

The workable day for construction works is assumed as below, taking into account rainy days and non-work days such as Sunday and national holidays.

	Work	Monthly workable day
1.	Earth work, embankment	16 days
2.	Earth work, excavation	18 days
3.	Rock work, exca. & emb.	20 days
4.	Concrete work	20 days
5.	Tunnel work	24 days

Since no seasonal rainfall pattern is observed around the project area, the above workable day is applied throughout a year.

Daily working hour is assumed to be 18 hours with double work shifts (9 hours x 2). However triple work shifts (8 hours x 3) are applied to the Sook diversion works and Tenom Pangi headrace tunnel works. The operating hour of construction equipment is assumed at about 70% of the above working hour.

6.2.4 Source of Earth and Rock Materials

The sources of materials for concrete aggregate and dam embankment works are assumed as below;

Materials	Quantity	Main source
1) Sook dam and power station		
a) Concrete aggregates	182,000 ton	Borrow area C
b) Impervious core materials	460,000 m^3	Borrow area A for main dam and Borrow area B for saddle dams
c) Filter materials	225,000 m^3	Borrow area C
d) Rock materials	1,475,000 m3	Quarry site about 1 km northeast of the main dam
2) Extension of Tenom Pangi power station		
i) Concrete aggregates	147,000 ton	River deposit downstream of the power station and excavated rock in headrace tunnel

The location of borrow areas and quarry site is as shown in Figure 2.7.

6.3 Preparatory Works

6.3.1 Access Road

1) Access to the site

Imported equipment and materials for the project landed at the Kota Kinabalu port or Sepangar port will be transported to the site on rail and/or road. Heavy or bulky cargoes exceeding transportation limit of the railway (35 tons, 2.8 m high and 2.5 m wide) are obliged to be transported on road. Depending on maximum weight and size of a cargoe, improvement of roads including bridges will be required in some portions prior to commencement of the construction works.

2) Access roads in the site

Existing Keningau-Mapulat (KM) road and Keningau-Pensiangan (KP) road including their branch roads will be utilized as access roads for construction of the Sook dam and power station with some improvement. To connect the site with the above existing roads, the following access roads will be newly constructed in the project area.

(1) Permanent road

a) KM road to the power station: about 1.5 km
b) KM road to the crest of main dam: about 2.0 km

(2) Temporary road

a) Quarry site to the main dam site: about 2.0 km
b) Borrow area to the main dam site: about 2.0 km

For extension of the Tenom Pangi power station, no new access road will be needed except the road to the surge tank site since the existing road can be used.

6.3.2 Temporary Building

The contractor's buildings consisting of offices, quarters, labour camps, work shops and warehouses will be constructed near the village of Ansip for the Sook site. SEB main office and quarters will be arranged in Keningau town.

For extension of the Tenom Pangi project, contractor's buildings will be constructed in the project area along the Padas River. For SEB staffs, the existing office and quarters will be used with some extension if required.

6.3.3 Construction Plant

The following construction plants will be required for concrete works.

Plant	Capacity	Q'ty	Location
1) Sook site (Total concrete volume: 81,000m^3)			
Aggregate plant	65 t/hr	1 unit	near Ansip village
Concrete plant	45 m^3/hr	1 unit	- do -
2) Tenom Pangi site (Total concrete volume: 70,000 m^3)			
Aggregate plant	50 t/hr	1 unit	near portal of existing work adit (No.2)
Concrete plant	30 m^3/hr	1 unit	- do -

The location of the temporary facilities is as shown in Figures 6.1 and 6.2.

6.3.4 Power Supply System

Peak power demand for construction use is roughly estimated at 1,000 kW for Sook site and 1,500 kW for Tenom Pangi site. For Tenom Pangi site, the power will be supplied by the existing 11 kV power line running along the Padas River. However, Diesel generator units which meet the requirements are to be provided for Sook site because no suitable power source exists nearby.

6.3.5 Water Supply System

Water consumption during construction is roughly estimated at 6.0 m^3/min and 4.5 m^3/min for the Sook and Tenom Pangi sites respectively. The water should be pumped up to such places as construction plant, temporary buildings, portals of tunnels and grouting sites from the Sook and Pegalan Rivers for the Sook site and from the Padas River for the Tenom Pangi site.

6.3.6 Telecommunication System

Telephone facilities with about 50 extensions will be provided in each project area for internal communication between offices, quarters, camps, construction plant and major work sites.

6.4 Main Construction Works

6.4.1 Sook Damsite

1) River Diversion Work

Prior to commencement of construction works for the main dam and power station, two lanes of diversion tunnel (5 m in inside diameter and 600 m long each) should be constructed on the left bank of the dam site. Two tunnels will be driven concurrently applying full-face cutting method in principle, after portal excavation and coffer dam construction have been completed. The tunnel excavation will be done by such equipment as 2 units of crawler jumbo with 3 booms, 0.8 m^3 tractor shovels of side dump type and 8 ton dump trucks at each cutting face. Steel supports will be unnecessary in principle. However, rock bolt with shotcrete method will be applied for sections comprizing brittle rocks. After completion of tunnel excavation, concrete lining will be carried out employing sliding forms for arch and side wall, invert finisher, 4.5 m^3 truck mixers and a 60 m^3 /hr concrete pump in each tunnel, and then grouting works will follow. It will take about 18 months to complete construction of the tunnels, keeping monthly advance rates for excavation and concrete works at 80 m and 100 m respectively. The river flow of the Sook will be then diverted through the tunnels, constructing coffer dams at the upstream and downstream of the main dam.

2) Main Dam

Excavation of dam foundation which is estimated at about 640,000 m^3 will be executed from the upper portion of both abutments using such equipment as 33 ton bulldozers, 1.2 m^3 backhoes, 4.0 m^3 wheel loaders, 10 m^3/min crawler drills and 20 ton dump trucks. After diversion of the Sook river, the excavation of the riverbed portion will be executed, and followed by grouting works and construction of the grouting gallery. Embankment works for the main dam will be made following the above works. The following construction equipment are selected as the main equipment for the embankment works.

Zone	Volume	Equipment Name	Activity	No.(unit)
Core	240,000m^3	21 t bulldozer	A	1
		2.3 m^3 tractor shovel	A	1
		11 t dump truck	B	4
		21 t bulldozer	C	1
		20 t tamping roller	C	1
		10 t tire roller	C	1
Filter	190,000m^3	21 t bulldozer	A	1
		2.3m^3 tractor shovel	A	2
		11 t dump truck	B	5
		21 t bulldozer	C	1
		8 t vibrating roller	C	1
Rock	1,300,000m^3	20m^3/min crawler drill	A	3
		33 t bulldozer	A	2
		4 m3 wheel loader	A	3
		20 t dump truck	B	10
		33 t bulldozer	C	1
		15 t vibrating roller	C	1

Note:

1) The embankment volume of coffer dam (180,000 m^3) is included in the above volume.

2) Kinds of activity are as follows:

A = Excavation work at borrow or quarry site

B = Hauling work

C = Spreading and compaction works at damsite

It will take around 2 years to complete the embankment work using the above equipment. The impoundment of the reservoir will be started a few month ahead of completion of the embankment work for early commissioning of the generating plants.

3) Saddle Dam

The saddle dam of which embankment volume is estimated at about 370,000 m3 will be constructed similar to the construction of the main dam. The impervious materials for saddle dam embankment will be obtained from the borrow area B which is located near the saddle dam site.

4) Spillway

Concurrently with the dam excavation, spillway excavation of 380,000 m^3 will be done using such equipment as 21 ton bulldozer, 2.3 m^3 tractor shovel, 10 m^3/min, crawler drill and 11 ton dump trucks. Structure concrete of 35,000 m^3 will be placed mainly by 60 m^3/hr concrete pumps. After that, 2 units of spillway gate (11.5 m wide x 7.7 m high) will be installed.

5) Intake and headrace tunnel

First of all, excavation of intake foundation which is estimated at about 61,000 m^3 will be carried out by bench cut method with several approach roads to be constructed between EL.278 m and EL.320 m. The excavation will be done by such equipment as 20 ton bulldozers, 1.2 m^3 backhoes, 2.3 m^3 tractor shovels and 11 ton dump trucks. Then, concrete of 2,200 m^3 for intake structure will be placed by 60 m^3/hr concrete pump and chute.

After completion of excavation work for the intake structure, a headrace tunnel which is 449 m long and 3.9 m in diameter is to be driven from the intake side by a crawler jumbo with 3 booms shifted from diversion work, a 0.8 m^3 tractor shovel of side dump type and 8 ton dump trucks, applying the full-face cutting method. The concrete lining will be done using a needle beam type all-section slide form unit, 40 m^3/hr concrete pump truck and 4.5 m^3 truck mixers.

6) Surge Tank

A vertical shaft of 12 m in diameter and about 50 m in height, of which underground portion is about 35 m, will be excavated by a pilot shaft and enlargement method. The pilot shaft of 2.5 m x 2.5 m, which will be used as a chute in enlargement stage, will be driven upward using raise climber equipped with stoppers. Excavated materials will be hauled out by 8 ton dump trucks through penstock tunnel which should be constructed prior to excavation of the shaft. Excavation for enlargement of the section will be made downward from the final ground level of the surge tank by short step sinking method using 10 m^3/min crawler drills. The initial concrete lining will be required in accordance with the progress of the excavation work in the enlargement stage. The second concrete lining work will be made upward from the shaft bottom after completion of shaft excavation employing slide form, 1 m^3 concrete bucket handled by crane or flexible concrete chute for underground portion, and 60 m^3/hr concrete pump for above-ground portion.

7) Penstock Line

The 56 m long penstock tunnel, which is upstream part of the whole penstock line (l = 139 m), will be excavated using such equipment as leg drills and a 1.4 m^3 wheel loader. An open excavation of 50,000 m^3 for open penstock portion will be done prior to excavation of power house foundation. The foundation concrete for open portion will be placed by 1 m^3 concrete bucket handled by 20 ton truck crane.

The penstock pipes will be transported to the site by truck trailers and fabricated at the site workshop. The truck crane will be used for installation of steel penstock pipes. Installation of penstock pipes in the tunnel can be started after completing excavation work for the surge tank. Finally backfill concrete will be placed around the steel penstock in the tunnel and backfill work with excavated materials will be done for the downstream part of the penstock line.

8) Power House and Tailrace

As the power house is located just downstream of the main dam, foundation excavation of 28,000 m^3 will be commenced after river diversion using such equipment as 20 ton bulldozer, 10 m^3/min crawler drill, 2.3 m^3 tractor shovel and 11 ton dump trucks. After the excavation work, concrete will be placed by 60 m^3/hr concrete pump and 1 m^3 concrete bucket handled by 20 ton truck crane. The draft tubes will be encased in the concrete during construction of substructure using truck crane. The installation of generation equipment will be commenced when an overhead traveling crane has been installed in the superstructure of the power house. As for metal works, four units of tailrace gate shall be installed as soon as completion of concrete works.

6.4.2 Tenom Pangi Extension Works

1) Intake and Headrace Tunnel

Since the intake structure has been already constructed in the previous stage of the Project, only metal works such as installation of gates and trashracks will be required for this stage.

The headrace tunnel is a concrete-lined tunnel of 5.2 m in diameter and 4,150 m in length. Existing two work adits located at about 600 m and 2,900 m downstream from the intake respectively will be used for construction of the headrace tunnel. However, an enlargement of the downstream adit section will be required because the height of the adit is insufficient to adopt the truck hauling method which is deemed to be the most practicable way. In addition to the existing work adits, two more work adits will be provided at the upper and lower portions of inclined tunnel penstock shaft for construction of surge tank and tunnel penstock line and installation of steel penstock pipes. A full-face cutting method will be basically applied for excavation of headrace tunnel. However, timely change to upper heading-then-bottom bench method will be required where geological conditions are poor. It is assumed that at least 80% of tunnel will be excavated by full-face cutting method. The excavation work will be concurrently done at four cutting faces in peak time and mean advance rate per month is estimated at 75 m/face employing a crawler jumbo with 3 booms, a 1.5 m^3 tractor shovel of side dump type and 8 ton dump trucks at each face. A powerful ventilation system will be needed to keep the working condition in the tunnel harmless since Diesel engine of construction equipment will produce much fuems gas.

The concrete lining work will be carried out using needle beam type full section slide forms, 60 m^3/hr concrete pumps and 4.5 m^3 truck mixers. Three sets of the slide form will be necessary in peak time keeping monthly advance rate of 140 m/set. Backfill and consolidation grout will be done by leg drills, grout pumps and grout mixers.

2) Surge Tank

A vertical shaft of 14 m in diameter and 60 m in height will be excavated by a pilot shaft and enlargement method. Construction procedure and equipments are same as for construction of surge tank at Sook site. Prior to the excavation of surge tank, a work adit will be driven to the just downstream portion of surge tank. The excavated materials for surge tank will be hauled out through the new adit.

3) Penstock Line

The underground penstock line, which is 4.0 m of average diameter and 153 m long, consists of the upper horizontal part of 64 m, inclined part of 44 m and lower horizontal part of 45 m. The new work adits will be used for construction of the underground penstock line. The penstock tunnel of the horizontal part will be excavated using such equipment as leg drills, 0.6 m^3 tractor shovels with side dump type and 3 ton dump trucks. For the inclined part, excavation will be done by pilot heading excavation using a raise climber upward, followed by enlarging excavation downward from the top of the tunnel. After completion of initial lining for the tunnel, each piece of 3 m long penstock pipe shell fabricated at site workshop will be carried inside for installation. The joint work of the pipes in the inclined tunnel will be carried out upward from the lowest part using rail-mounted carriers. Finally the backfill concrete will be placed around the steel penstock by 40 m^3/hr concrete pump and concrete chutes.

4) Powerhouse and Tailrace

The powerhouse and tailrace are constructed adjacent to the existing ones. Therefore, special attentions should be required during construction so as not to cause damage and adverse effect to the existing facilities. The excavation work of 60,000 m^3 will be carried out by such equipment as 20t bulldozers with ripper, 2.3 m^3 tractor shovel, 10 m^3/min crawler drill and 11 ton dump trucks. After the excavation work, structure concrete of 15,000 m^3 will be placed with 60 m^3/hr concrete pump truck and 1 m^3 concrete bucket handled by 20 ton truck crane. The draft tubes will be encased in the structure during construction of sub-structure using truck crane. The erection of generating equipment will be commenced when the overhead traveling crane becomes available. As for metal works four units of tailrace gate should be installed immediately after the completion of concrete works. Finishing works in the power house will be carried out in parallel with erection of generating equipment.

6.5 Construction Equipment and Materials

6.5.1 Construction Equipment

The major construction equipment, which will be required for implementation of the Tenom Pangi Phase III project, are listed in Table 6.3. Most of equipment will be necessary to be imported.

6.5.2 Construction Materials

The major construction materials, which will be required for implementation of Sook Dam and Tenom Pangi extension project, are as follows:

No.	Material	Required Q'ty for	
		Sook	Tenom Pangi
1.	Cement	30,000 t	24,000 t
2.	Reinforcement bar	4,000 t	3,100 t
3.	Explosive	530 t	420 t
4.	Fuel	7,000 kℓ	600 kℓ

6.6 Construction Schedule

The construction period of Sook and Tenom Pangi extension project is estimated at 5 years and 4 years respectively as shown in Figures 6.3 and 6.4 The commissioning of generating plant is expected to be accomplished at the both sites in December 1993 starting the construction works in January 1989 at Sook site and in January 1990 at Tenom Pangi site.

According to the construction schedules for both sites, the critical path of construction works is as shown below:

1) Sook site

Preparatory works
↓
Construction of diversion tunnels → (branches to P/H excavation)

Dam excavation
↓
Dam embankment
↓
Impoundment of the reservoir
↓
Commissioning of plant

P/H excavation
↓
P/H sub-structure and super-structure
↓
Installation of O/H traveling crane
↓
Erection of generating plant
→ Commissioning of plant

2) Tenom Pangi site

Preparatory works including improvement of existing work adits
↓
Excavation of headrace tunnel
↓
Concrete lining of headrace tunnel
↓
Grouting work of headrace tunnel
↓
Plug work of headrace tunnel
↓
Commissioning of plant

Table 6.1 (1) MAJOR CIVIL WORK QUANTITY FOR SOOK DAM AND POWER STATION

	Work Item	Unit	Quantity
1.	River diversion work		
	1) Excavation in common	m^3	55,000
	2) " in weathered rock	m^3	4,000
	3) " in rock	m^3	1,000
	4) " in tunnel	m^3	45,000
	5) Concrete in open	m^3	1,800
	6) " in tunnel	m^3	17,000
	7) Reinforcement bars	ton	480
	8) Grouting, consolidation	ton	1,000
2.	Main dam		
	1) Excavation in common	m^3	580,000
	2) " in weathered rock	m^3	32,000
	3) " in rock	m^3	30,000
	4) Embankment in impervious core	m^3	240,000
	5) " in filter	m^3	190,000
	6) " in rock	m^3	1,300,000
	7) Concrete in open	m^3	6,800
	8) Reinforcement bars	ton	410
	9) Grouting, curtain	m	26,000
	10) " , blanket	m	8,000
	11) Shotcrete	m^2	6,000
3.	Saddle dam		
	1) Excavation in common	m^3	90,000
	2) Embankment in impervious core	m^3	220,000
	3) " in filter	m^3	35,000
	4) " in rock	m^3	115,000

Table 6.1 (2) MAJOR CIVIL WORK QUANTITY FOR SOOK DAM AND POWER STATION

	Work item	Unit	Quantity
4.	Spillway		
	1) Excavation in common	m^3	250,000
	2) " in weathered rock	m^3	80,000
	3) " in rock	m^3	50,000
	4) Concrete in open	m^3	35,000
	5) Reinforcement bars	ton	1,400
	6) Shotcrete	m^2	6,000
5.	River outlet work		
	1) Excavation in tunnel	m^3	300
	2) Concrete in tunnel	m^3	2,000
	3) Reinforcement bars	ton	80
	4) Metal work	ton	50
6.	Intake structure		
	1) Excavation in common	m^3	35,000
	2) " in weathered rock	m^3	13,000
	3) " in rock	m^3	5,000
	4) Concrete in open	m^3	2,000
	5) Reinforcement bars	ton	100
7.	Waterway and surge tank		
	1) Excavation in common	m^3	40,000
	2) " in weathered rock	m^3	2,000
	3) " in tunnel	m^3	12,000
	4) " in shaft	m^3	8,500
	5) Concrete in open	m^3	3,500
	6) " in shaft	m^3	1,000
	7) Reinforcement bars	ton	320
	8) Grouting, consolidation	ton	70

Table 6.1 (3) MAJOR CIVIL WORK QUANTITY FOR SOOK DAM AND POWER STATION

	Work item	Unit	Quantity
8.	Penstock line		
	1) Excavation in common	m^3	15,000
	2) " in weathered rock	m^3	10,000
	3) " in rock	m^3	20,000
	4) " in tunnel	m^3	1,000
	5) Concrete in open	m^3	2,000
	6) " in tunnel	m^3	400
	7) Reinforcement	ton	240
9.	Powerhouse and tailrace		
	1) Excavation in common	m^3	4,000
	2) " in weathered rock	m^3	6,000
	3) " in rock	m^3	23,000
	4) Concrete in open	m^3	8,500
	5) Reinforcement bars	ton	450
	6) Powerhouse superstructure	L.S.	
10.	Switch yard		
	1) Excavation in common	m^3	1,000
	2) Embankment in earth materials	m^3	1,000
	3) Concrete in open	m^3	500
	4) Reinforcement bars	ton	20

Table 6.2 MAJOR CIVIL WORK QUANTITY FOR EXTENSION OF TENOM PANGI POWER STATION

Work item	Unit	Quantity
1. Waterway and surge tank		
1) Excavation in common	m^3	40,000
2) " in tunnel	m^3	145,000
3) " in shaft	m^3	19,000
4) Concrete in tunnel	m^3	45,000
5) " in shaft	m^3	5,000
6) Reinforcement bars	ton	2,000
7) Grouting, consolidation	ton	2,100
2. Penstock line		
1) Excavation in tunnel	m^3	13,000
2) Concrete in tunnel	m^3	5,000
3) Reinforcement bars	ton	200
4) Grouting, consolidation	ton	60
3. Powerhouse and tailrace		
1) Excavation in common	m^3	30,000
2) " in weathered rock	m^3	20,000
3) " in rock	m^3	10,000
4) Concrete in open	m^3	15,000
5) Reinforcement bars	ton	900

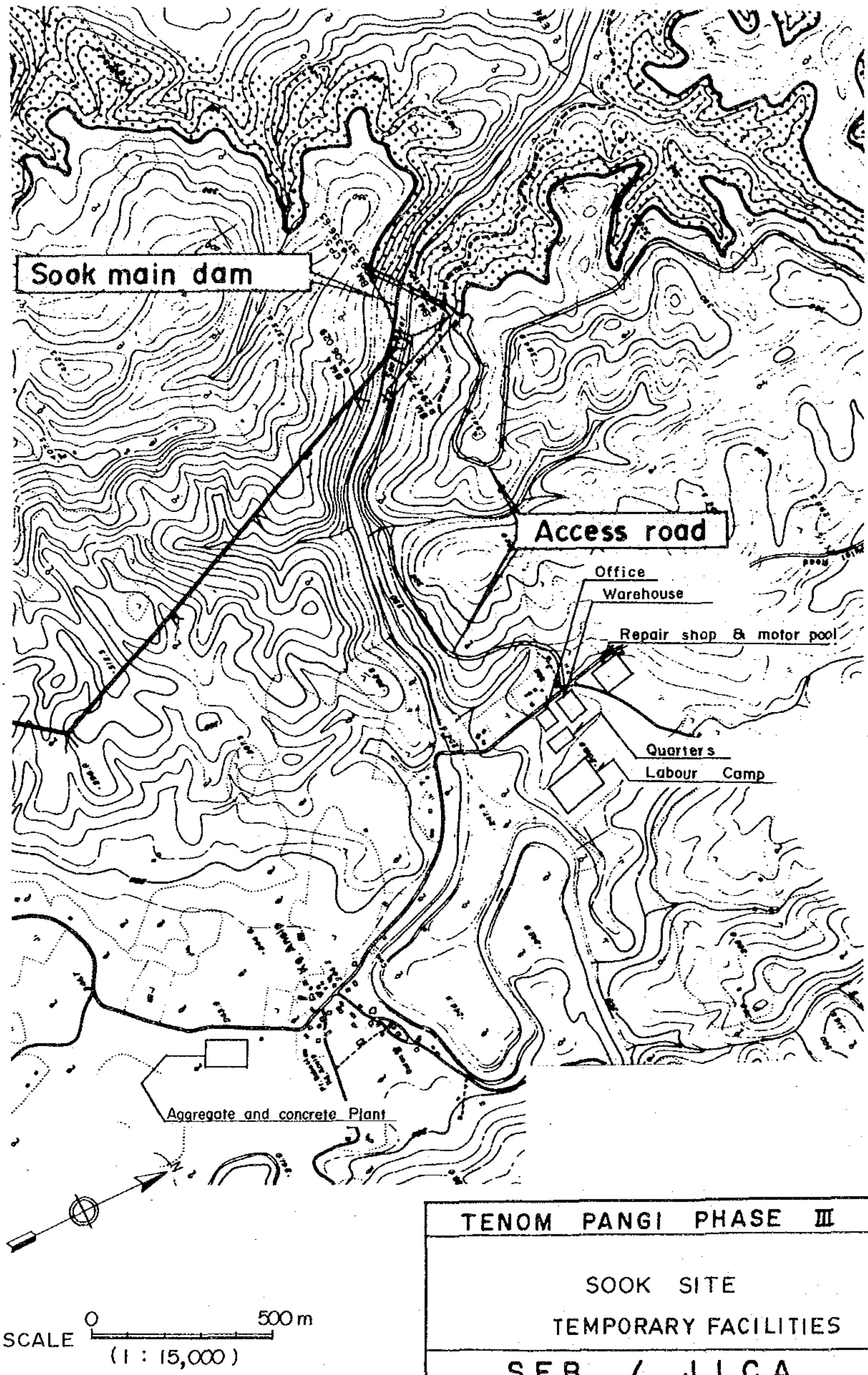
Table 6.3 (1) LIST OF MAJOR CONSTRUCTION EQUIPMENT

No.	Equipment	Required Q'ty for Sook	Required Q'ty for Tenom Pangi
1	Bulldozer, 33 t w/ripper	3	-
2	Bulldozer, 20 t	5	4
3	Bulldozer, 11 t	3	1
4	Tractor shovel, 2.3 m^3	6	4
5	Wheel loader, 4.0 m^3	4	-
6	Wheel loader, 1.4 m^3	1	1
7	Backhoe, 1.2 m^3	2	1
8	Tractor shovel (side dump type), 1.5 m^3	0	4
9	Tractor shovel (side dump type), 0.8 m^3	3	-
10	Dump truck, 20 t	12	-
11	Dump truck, 11 t	20	5
12	Dump truck, 8 t	-	20
13	Dump truck, 3 t	5	5
14	Tamping roller, 20 t (self propelled)	1	-
15	Vibrating roller, 15 t	1	-
16	Vibrating roller, 8 t	1	-
17	Tire roller, 10 t	1	-
18	Road roller, 10 t	2	1
19	Motor grader, 3.7 m	2	1
20	Crawler drill, 20 m^3/min	3	-
21	Crawler drill, 10 m^3/min	5	3
22	Crawler jumbo, 3 booms	4	4
23	Raise climber	1	1
24	Portable air compressor, 20 m^3/min	3	-
25	Portable air compressor, 10 m^3/min	5	3
26	Stationary air compressor, 30 m^3/min	4	4
27	Truck mixer, 3 m^3	10	10
28	Concrete pump truck, 60 m^3/hr	2	2
29	Concrete pump, 40 m^3/hr	1	2
30	Concrete bucket, 1.0 m^3	4	4
31	Boring machine, 5.5 KW	10	-
32	Grout pump, 11 KW	8	6
33	Grout mixer, 600 lit. x 2	8	6

Table 6.3 (2) LIST OF MAJOR CONSTRUCTION EQUIPMENT

No.	Equipment	Required Q'ty for	
		Sook	Tenom Pangi
34	Concrete spraying machine, 8 m^3/hr	1	1
35	Cargo truck, 8 t	3	2
36	Cargo truck, 5 t	5	3
37	Truck crane, 30 t	1	1
38	Truck crane, 20 t	2	1
39	Truck tractor with semi-trailer, 300 t	1	1
40	Water sprinkler truck, 8 kℓ	2	1
41	Full tank truck, 5 kℓ	2	1
42	Aggregate plant, 65 t/hr	1	-
43	Aggregate plant, 50 t/hr	-	1
44	Concrete plant, 45 m^3/hr	1	-
45	Concrete plant, 30 m^3/hr	-	1

FIGURE NO. : 6.1



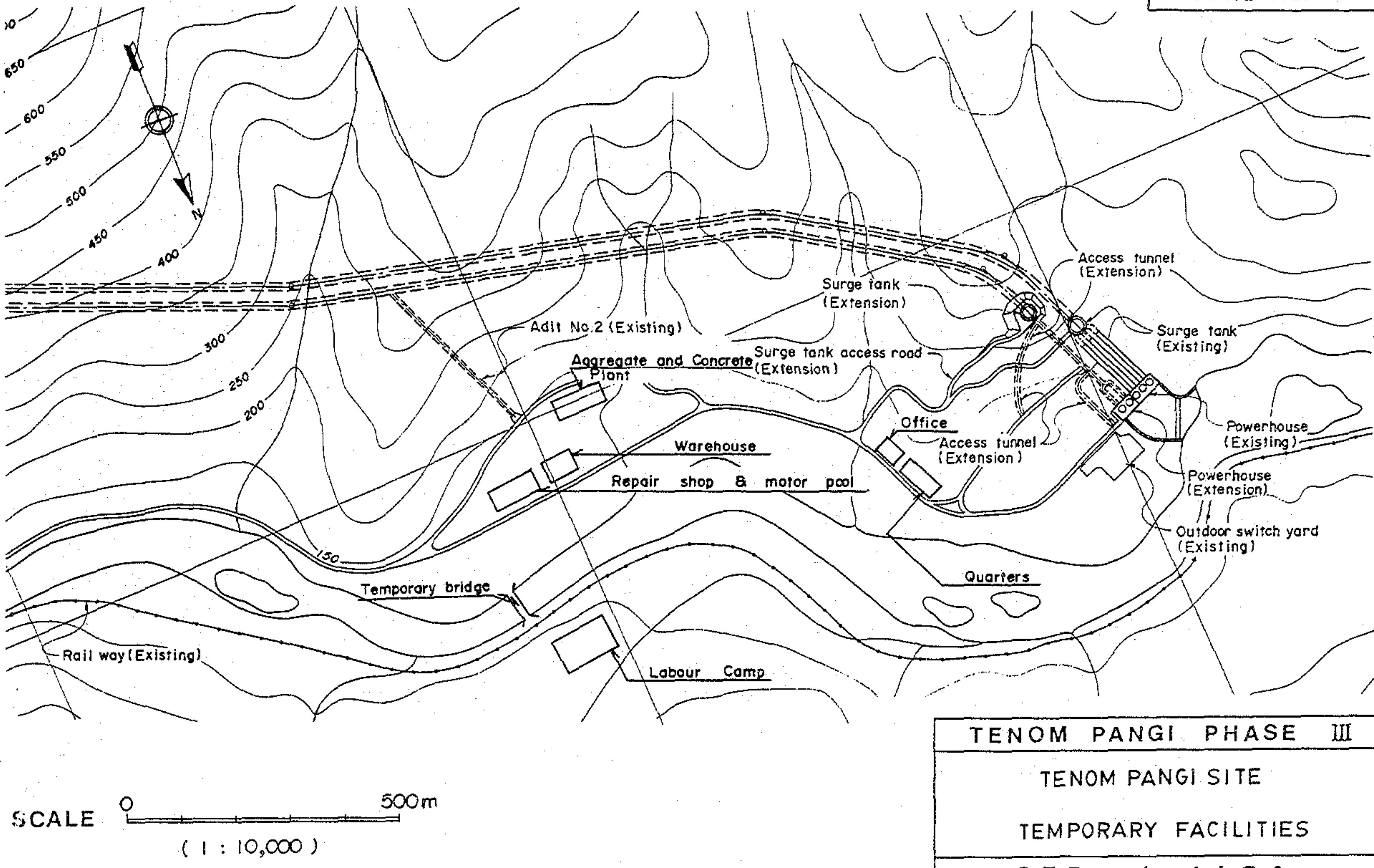
TENOM PANGI PHASE III

SOOK SITE

TEMPORARY FACILITIES

SEB / JICA

FIGURE NO. : 6.2



TENOM PANGI PHASE III

TENOM PANGI SITE

TEMPORARY FACILITIES

SEB / JICA

FIG.6.3 CONSTRUCTION SCHEDULE OF SOOK DAM PROJECT (1)

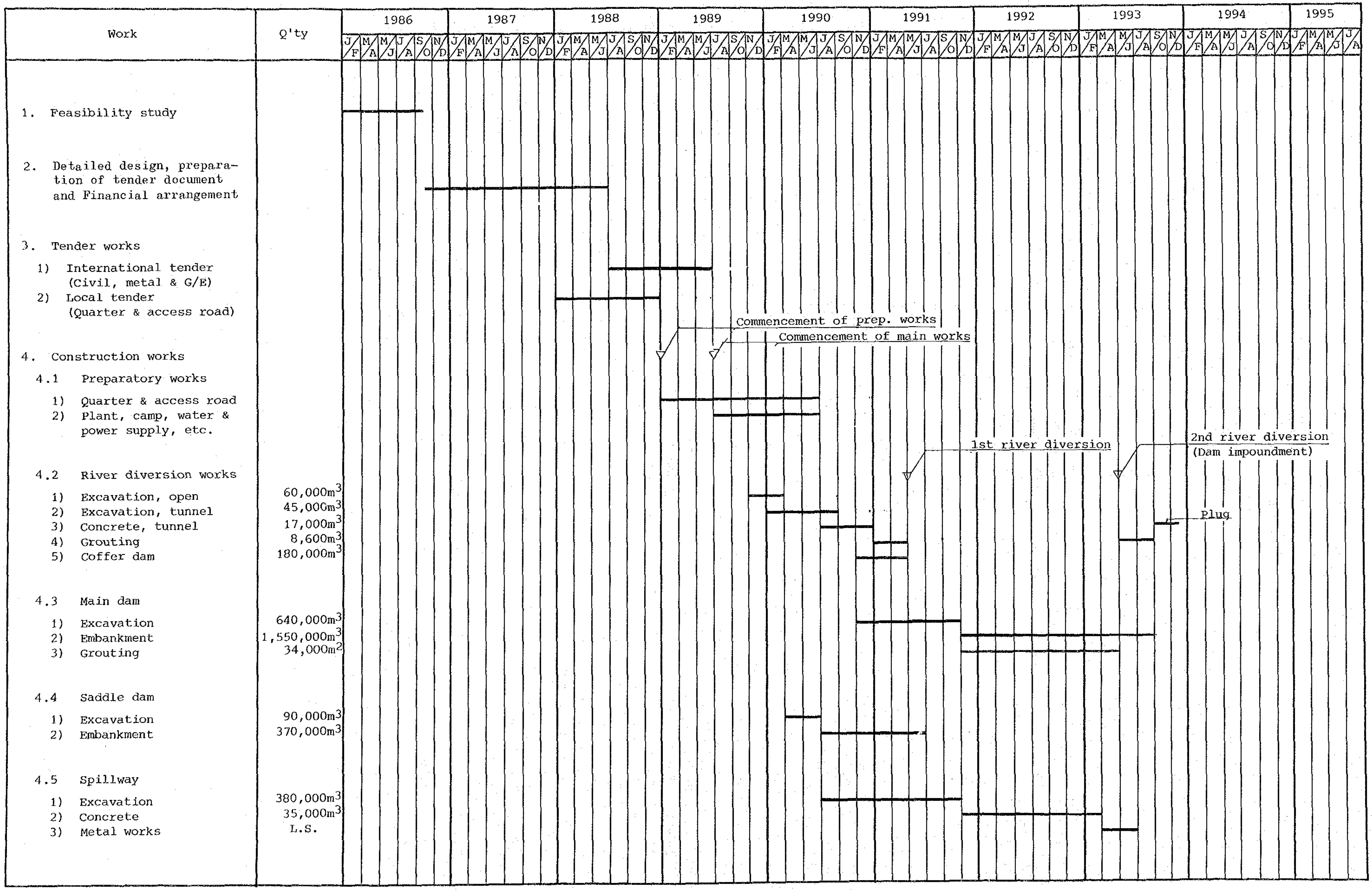


FIG. 6.3 CONSTRUCTION SCHEDULE OF SOOK DAM PROJECT (2)

Work	Q'ty
4.6 River outlet	
1) Concrete	2,000m^3
2) Metal works	L.S.
4.7 Intake structure	
1) Excavation	53,000m^3
2) Concrete	2,000m^3
3) Metal works	L.S.
4.8 Headrace tunnel	
1) Excavation, tunnel	12,000m^3
2) Concrete, tunnel	3,500m^3
3) Grouting	70t
4.9 Surge tank	
1) Excavation, open	42,000m^3
2) Excavation, shaft	8,500m^3
3) Concrete, shaft with grouting	1,000m^3
4.10 Penstock line	
1) Excavation, open	47,000m^3
2) Excavation, tunnel	1,000m^3
3) Concrete, open	2,000m^3
4) Concrete, tunnel	400m^3
5) Metal works	L.S.
4.11 Powerhouse & Tailrace	
1) Excavation	33,000m^3
2) Concrete	8,500m^3
3) Building works	L.S.
4) Metal works	L.S.
5) Electrical (G/E) works	10MW x 2
4.12 132 kV transmission line	ℓ = 10km

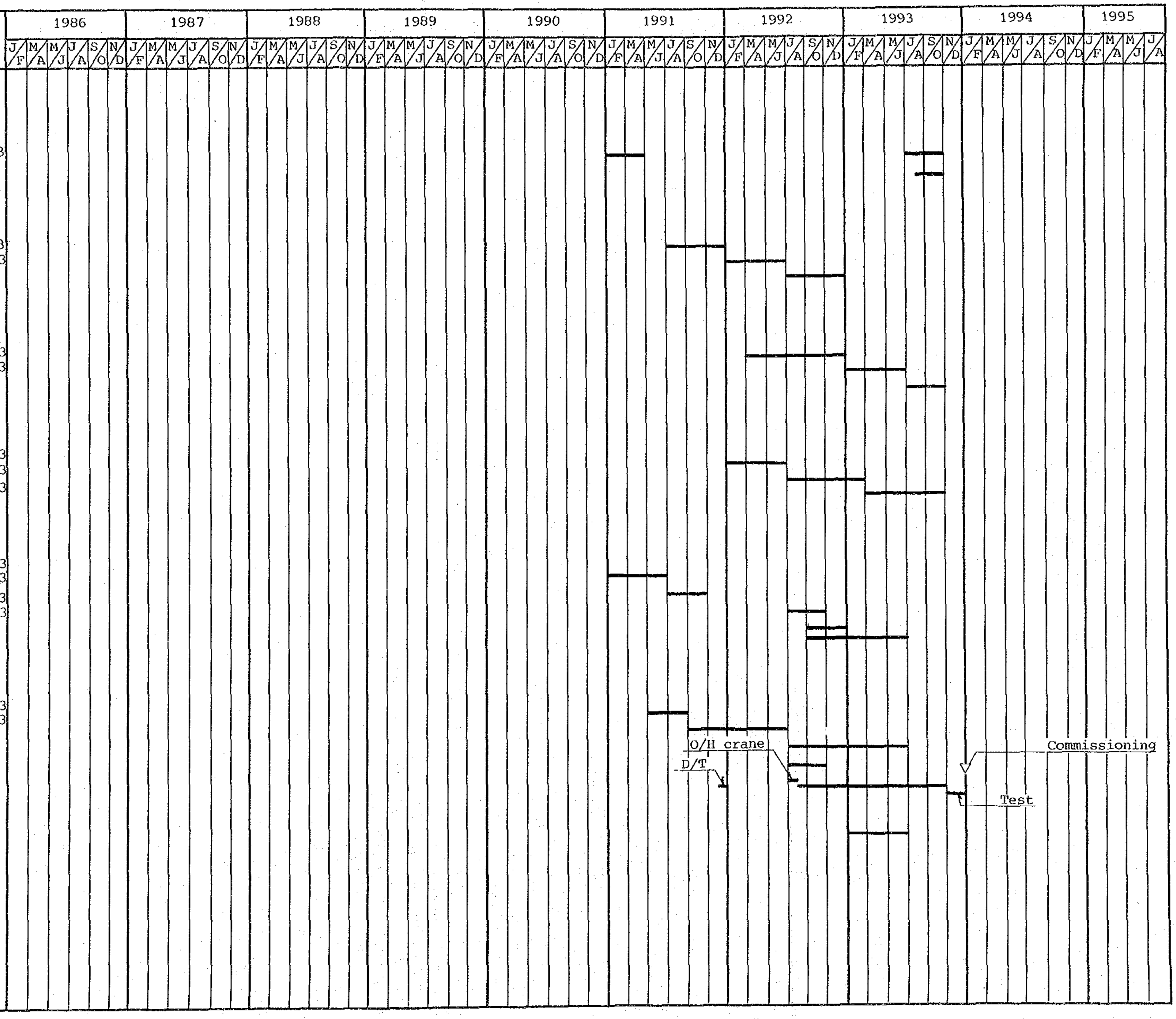
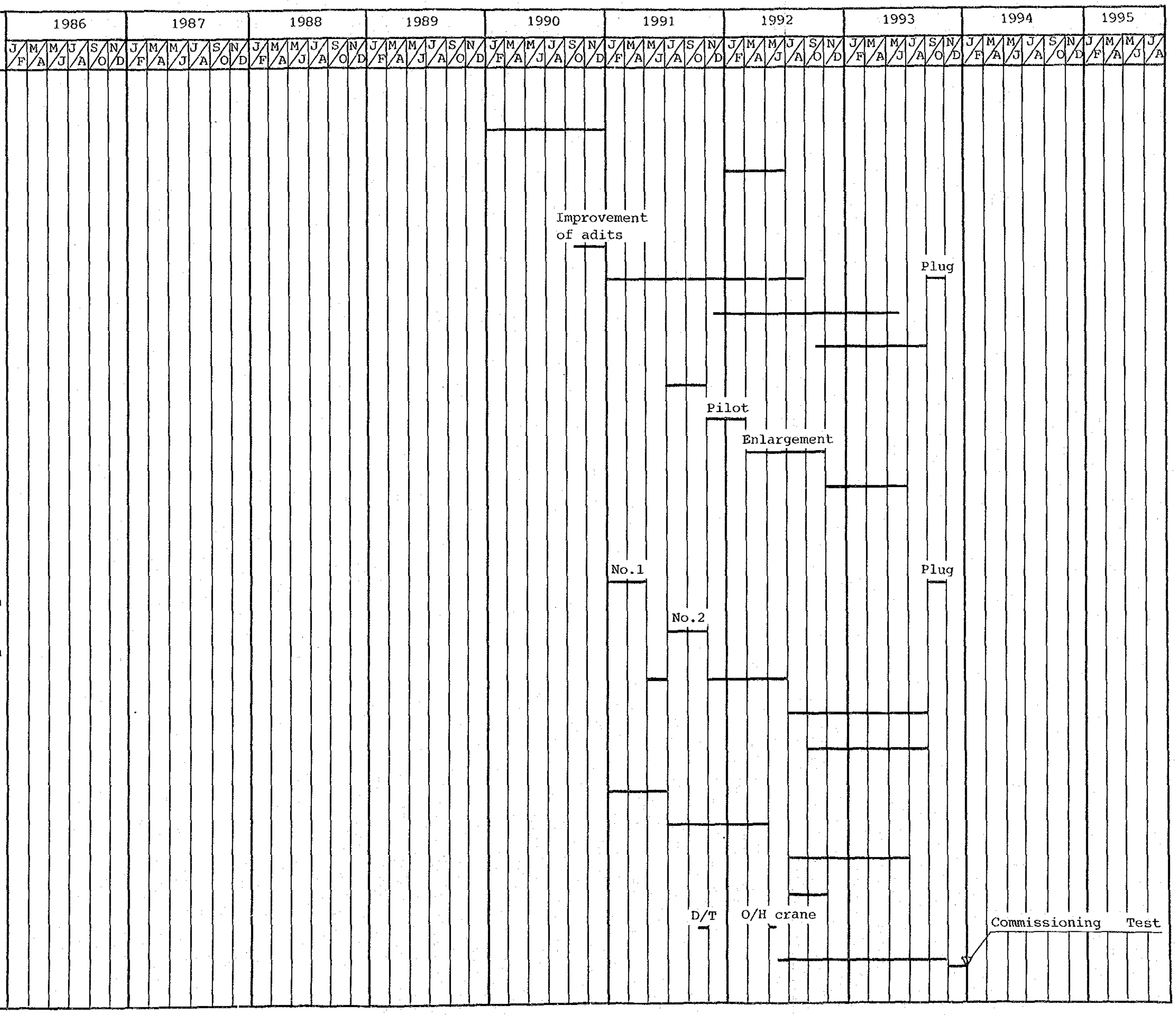


Fig.6.4 CONSTRUCTION SCHEDULE OF TENOM PANGI EXTENSION PROJECT

Work	Q'ty
1. Construction works	
1.1 Preparatory works	
1.2 Intake	
1) Metal works	L.S.
1.3 Headrace tunnel	
1) Excavation, tunnel	145,000 m^3
2) Concrete, tunnel	45,000 m^3
3) Grouting	2,100 t
1.4 Surge tank	
1) Excavation, open	40,000 m^3
2) Excavation, shaft	19,000 m^3
3) Concrete, shaft with grouting	5,000 m^3
1.5 Penstock line	
1) Access tunnel	No.1: ℓ=125 m No.2: ℓ=130 m
2) Excavation, tunnel	13,000 m^3
3) Concrete, tunnel	5,000 m^3
4) Metal works	L.S.
1.6 Powerhouse & Tailrace	
1) Excavation	60,000 m^3
2) Concrete	15,000 m^3
3) Building works	L.S.
4) Metal works	L.S.
5) Electrical (G/E) works	22MW x 2



7. CONSTRUCTION COST ESTIMATE

7.1 General

Implementation cost of the project is estimated on the basis of the preliminary design and the proposed construction plan and schedule. The cost estimates are prepared at the price level as of the end of 1985 or the beginning of 1986, using the exchange rates of 2.45 M$ or 200 Yen to 1 US dollar. The basic conditions applied for the cost estimates are summarized as below:

1) Unit prices for the civil works are estimated on the basis of the proposed construction plan and the construction cost data for the similar type of the projects in Sabah or in the neighbouring areas which have been completed recently. The estimated unit prices are summarized in Table 7.1.

2) The current prices of materials and labour wages are referred to estimate the above unit prices, which are shown in Table 7.2.

3) The cost for the electro-mechanical equipment including installation are estimated on the basis of the unit price per ton derived from the recent contract prices in the international market for the similar works. The adopted unit prices for metal works are shown in Table 7.3.

4) The costs of engineering services and administration are estimated at 8 per cent of the direct construction cost.

5) Costs for relocation of road, transmigration and land acquisition in the area to be submerged by the proposed reservoir are estimated as a compensation cost, which is shown in Table 7.4.

6) The contingency for unforeseen changes in physical conditions is estimated by 10 per cent of direct construction cost plus engineering service, administration and compensation cost.

7) Price contingency is estimated by 40 per cent of the total construction cost anticipating the unforeseen economic dislocation, price changes, etc.

8) Taxes and duties are assumed to be included in the financial costs since the materials, labours, etc., used for the project are estimated on the market price.

7.2 Construction cost

The total construction cost excluding price contingency is estimated at US$174,139,000 which consists of US$101,555,000 for the Sook dam and power station and US$72,584,000 for extension of Tenom Pangi power station. Including the price contingency, the total project implementation cost is estimated at US$243,800,000 which comprises US$142,200,000 for the Sook dam and power station and US$101,600,000 for the Tenom Pangi extension. Their breakdowns are summarized in Tables A-7.1(1) to (7) and 7.2(1) to (3).

7.3 Local and Foreign Currency Portions

The construction costs are divided into local and foreign currency portions based on the following assumption:

Items included in foreign currency portion	Items included in local currency portion
- Construction plants and equipment including spare parts	- Cement
	- Reinforcement bar
- Structural steel and steel support	- Explosive
	- Fuel, oils and lubricants
- Metal works such as gates, valves, trash racks, penstocks, etc.	- Timber
- Generating equipment such as generators, turbines and switchgear equipment	- Salaries and wages for local supervisors and workers
- Transmission line and substation equipment	- Overhead and profit for local contractors
- Salaries and expenses for foreign supervisory personnel	
- Overhead and profit for foreign contractors	

Local and foreign currency portions of the project costs are estimated as shown in Tables 7.5(1) and (2).

7.4 Disbursement Schedule

The Tenom Pangi Project, Phase III, is recommended to be executed for seven years and a half; two years and a half for detailed design and contracting of the works and another five years for construction works including preparatory works. The disbursement schedule of the project cost is worked out as shown in Table 7.6 taking into account progress of the works in the proposed construction schedule. No advance payment is assumed in the disbursement schedule.

Table 7.1 UNIT PRICES

Work item	Unit	Rate(US$)
Excavation		
- Common	m^3	4.0
- Weathered rock	m^3	8.0
- Rock	m^3	12.0
- Tunnel	m^3	70.0
- Underground shaft	m^3	85.0
Embankment		
- Impervious core	m^3	8.0
- Filter	m^3	13.0
- Rock	m^3	8.0
Concrete		
- Open structure	m^3	120.0
- Tunnel and shaft	m^3	160.0
- Shotcrete	m^2	45.0
Reinforcement bar	ton	750.0
Grouting		
- Curtain and blanket	m	110.0
- Consolidation	ton	700.0

Table 7.2 PRICE OF MAJOR CONSTRUCTION MATERIALS AND LABOUR WAGES

Item	Unit	Price (M$)
Cement	ton	250
Reinforcement bar	ton	1,160
H-shaped steel	ton	1,290
L-shaped steel	ton	1,140
Gasoline	kℓ	1,200
Diesel oil	kℓ	800
Machine oil	kℓ	3,000
Explosive	kg	26
Detonator	pcs	5
Timber	m^3	280
Foreman	man day	90
Electrician	"	45
Bar bender	"	36
Mechanic	"	52
Carpenter	"	42
Operator (Heavy equipment)	"	68
" (Light equipment)	"	42
Welder	"	45
Plumber	"	39
Blacksmith	"	45
Drill man	"	55
Masonry	"	53
Grount man	"	40
Unskilled labours	"	24

Table 7.3 UNIT PRICE FOR METAL WORKS

Work item	Unit	Rate(US$)
Diversion gate	ton	3,800
Spillway gate	ton	7,000
River out facility	ton	8,000
Intake trash rack	ton	3,500
Intake gate	ton	7,000
Tailrace gate	ton	6,500
Penstock	ton	3,600

Table 7.4 PRELIMINARY ESTIMATE OF COMPENSATION COST

Item		Unit	Quantity	Unit Price (M$1,000)	Amount (M$1,000)
1. Land					30,935
(1)	Forest	km^2	3.2	150	480
(2)	Bushy	km^2	14.7	150	2,205
(3)	Rubber	km^2	4.4	2,500	11,000
(4)	Agriculture	km^2	1.2	2,500	3,000
(5)	Grazing	km^2	4.3	2,500	10,750
(6)	Housing lot	km^2	0.7	5,000	3,500
2. Buildings, etc.					6,459
(1)	Private house	nos	334	9.0	3,006
(2)	Cemetery	nos	304	0.5	152
(3)	Public house	nos	8	9.0	72
(4)	School	nos	20	6.0	120
(5)	Clinic	nos	3	8.0	24
(6)	Church	nos	5	7.0	35
(7)	Rice mill	nos	2	25.0	50
(8)	Saw mill	nos	3	1,000.0	3,000
3. Road					7,630
(1)	District road	km	8.7	500	4,350
(2)	Timber road	km	6.3	200	1,260
(3)	Village road	km	20.2	100	2,020
	Total				45,024
			(Equivalent to US$18,400,000)		

Table 7.5 (1) LOCAL AND FOREIGN COMPONENTS OF PROJECT COST FOR SOOK DAM AND POWER STATION 1/

(Unit: US$)

Work Item	Local Component	Foreign Component	Total
1. Preparatory Work	2,709,000	651,000	3,360,000
2. River Diversion Work	2,981,000	5,010,000	7,991,000
3. Main Dam	11,755,000	12,049,000	23,804,000
4. Saddle Dam	1,786,000	2,009,000	3,795,000
5. Spillway	4,805,000	3,305,000	8,110,000
6. River Outlet Work	192,000	249,000	441,000
7. Intake Structure	372,000	277,000	649,000
8. Waterway and Surge Tank	1,148,000	1,737,000	2,885,000
9. Penstock Line	565,000	464,000	1,029,000
10. Powerhouse and Tailrace	1,692,000	983,000	2,675,000
11. Switch Yard	57,000	34,000	91,000
12. Hydro-mechanical Works	1,023,000	4,094,000	5,117,000
13. Generating Equipment	750,000	6,750,000	7,500,000
14. Transmission Line	150,000	850,000	1,000,000
15. Total of Items 1. to 14.	29,985,000	38,462,000	68,447,000
16. Engineering and Administration	1,095,000	4,381,000	5,476,000
17. Compensation	18,400,000	0	18,400,000
18. Physical Contingency	4,948,000	4,284,000	9,232,000
19. Total of Items 1. to 18.	54,428,000	47,127,000	101,555,000
20. Price Contingency	28,472,000	12,173,000	40,645,000
21. Grand Total	82,900,000	59,300,000	142,200,000

1/ : Interest during construction, which is estimated at US$11,275,000 for Local Component, US$4,578,000 for Foreign Component and US$15,853,000 in total, is not included.

Table 7.5 (2) LOCAL AND FOREIGN COMPONENTS OF PROJECT COST FOR EXTENSION OF TENOM PANGI POWER STATION 1/

(Unit: US$)

Work Item	Local Component	Foreign Component	Total
1. Preparatory Work	4,074,000	1,386,000	5,460,000
2. Intake Structure	390,000	210,000	600,000
3. Waterway and Surge Tank	8,359,000	15,513,000	23,872,000
4. Penstock Line	691,000	1,306,000	1,997,000
5. Powerhouse and Tailrace	2,808,000	1,534,000	4,342,000
6. Hydro-mechanical Works	1,365,000	5,461,000	6,826,000
7. Generating Equipment	1,800,000	10,200,000	12,000,000
8. Substation Equipment	900,000	5,100,000	6,000,000
9. Total of Items 1. to 8.	20,387,000	40,710,000	61,097,000
10. Engineering and Administration	988,000	3,900,000	4,888,000
11. Compensation	0	0	0
12. Physical Contingency	2,138,000	4,461,000	6,599,000
13. Total of Items 1. to 12.	23,513,000	49,071,000	72,584,000
14. Price Contingency	14,487,000	14,529,000	29,016,000
15. Grand Total	38,000,000	63,600,000	101,600,000

1/ : Interest during construction, which is estimated at US$4,852,000 for Local Component, US$3,976,000 for Foreign Component and US$8,828,000 in total, is not included.

Table 7.6 (1) YEARLY DISBURSEMENT OF CONSTRUCTION COST FOR SOOK DAM AND POWER STATION

(Unit: US$1,000)

	Work Item	Total Amount	1989	1990	1991	1992	1993
1.	Preparatory Work3,360	3,360	2,016	1,334	-	-	-
2.	River Diversion Work	7,991	443	4,883	887	-	1,778
3.	Main Dam	23,804	-	3,662	6,408	10,986	2,748
4.	Saddle Dam	3,795	237	2,846	712	-	-
5.	Spillway	8,110	-	1,520	3,041	3,041	508
6.	River Outlet Work	441	-	-	220	-	221
7.	Intake Structure	649	-	-	216	433	-
8.	Waterway and Surge Tank	2,885	-	-	-	1,511	1,374
9.	Penstock Line	1,029	-	-	571	458	-
10.	Powerhouse and Tailrace	2,675	-	-	81	1,234	1,360
11.	Switch Yard	91	-	-	-	-	91
12.	Hydro-mechanical Works	5,117	-	-	-	2,653	2,464
13.	Generating Equipment	7,500	-	-	394	2,368	4,738
14.	Transmission Line	1,000	-	-	-	-	1,000
	Sub-total	68,447	2,696	14,255	12,530	22,684	16,282
15.	Engineering and Administration	5,476	2,415	790	652	1,014	605
16.	Compensation	18,400	1,000	1,000	1,000	7,700	7,700
17.	Physical Contingency	9,232	611	1,604	1,418	3,139	2,460
	Total	101,555	6,722 1/	17,649	15,600	34,537	27,047
18.	Price Contingency	40,645	2,711	7,060	6,240	13,815	10,819
	Grand Total	142,200	9,433	24,709	21,840	48,352	37,866

1/: Engineering cost for detail design is included in 1989. (US$2,200,000)

Table 7.6 (2) YEARLY DISBURSEMENT OF CONSTRUCTION COST FOR EXTENSION OF TENOM PANGI POWER STATION

(Unit: US$1,000)

	Work Item	Total Amount	1989	1990	1991	1992	1993
1.	Preparatory Work	5,460	-	5,460	-	-	-
2.	Intake Structure	600	-	-	200	200	200
3.	Waterway and Surge Tank	23,872	-	917	5,814	10,710	6,431
4.	Penstockd Line	1,997	-	-	703	703	591
5.	Powerhouse and Tailrace	4,342	-	-	1,860	1,549	933
6.	Hydro-mechanical Works	6,826	-	-	620	3,722	2,484
7.	Generating Equipment	12,000	-	-	570	4,570	6,860
8.	Substation Equipment	6,000	-	-	1,200	3,000	1,800
	Sub-total	61,097	0	6,377	10,967	24,454	19,299
9.	Engineering and Administration	4,888	2,000	201	460	1,310	917
10.	Compensation	0	0	0	0	0	0
11.	Physical Contingency	6,599	200	657	1,142	2,576	2,024
	Total	72,584	2,200 1/	7,235	12,569	28,340	22,240
12.	Price Contingency	29,016	862	2,894	5,028	11,336	8,896
	Grand Total	101,600	3,062	10,129	17,597	39,676	31,136

1/: Engineering cost for detail design is included in 1989. (US$2,200,000)