3.6.2 Geological Investigations

Further geological investigation is necessary to ensure safe and economical design as summarized below and shown in Table 3.6.1.

Item	Quantity		Unit Price	Amount
- Drilling	2,260	m	F.CFA 152,000	Mill. F.CFA 343.5
- Seismic Prospecting	9.6	km	F.CFA 7,610,000	Mill. F.CFA 73.0
- Laboratory Test				
for soil	70	samples	L.S.	Mill. F.CFA 12.7
for rock	80	samples	L.S.	Mill. F.CFA 12.7
- In-situ rock test				
block shear test	2	numbers	F.CFA 6,90,000	Mill. F.CFA 12.2
plate loading test	2	numbers	F.CFA 1,520,000	Mill. F.CFA 3.0
hydraulic fracturing test	3	numbers	F.CFA 15,200,000	Mill. F.CFA 30.4
- Test pit	30	numbers	F. CFA 50,800	Mill. F.CFA 1.5
- Total				Mill. F.CFA 489.0

Like the cost of the further topographic survey, cost estimate of the further geological investigations comes from the past actual costs. Its update is required for the sound estimate before the survey work.

3.6.3 Meteo-hydrologic Works

Recommendation for the further meteo-hydrologic works is detailed in Chapter 8, Appendix III - Hydrology and Meteorology and summarized below.

(1) Continuous observation of rainfall and other meteorological data including air temperature, humidity, evaporation and wind

(2) Periodical discharge measurements of the Ntem, Ndjo'o and Biwome rivers following the technical specification prepared in this study

(3) Spot discharge measurements in the subdivided channels around the proposed dam site

(4) Continuous reading of staff gauges installed during this study period

(5) Periodical water sampling and storage of suspended load data of the above three rivers, especially in flood season

Table 3.2.1 Estimated Basin Rainfall

Year	Interpolated Annual Rainfall (mm) Station												Annual Basin Rainfall (mm)			
	Akom II	Ambam	Djoum	Ebolowa	Mvangan	Nyabessan	Oveng	Sangmelima	Oyem	Bitam	Minvoul	Mefo	Ntem Nyabessan	Ntem Ngoazik	Ndjo'o Abem	Biwome Nyabessan
1951	1,398	1,704	1,855	1,629	1,874	1,570	1,789	1,931	1,934	2,534	1,715	1,985	1,881	1,791	1,849	1,714
1952	1,797	2,463	1,864	1,973	2,249	2,130	2,016	2,362	1,804	2,273	2,251	2,770	2,208	2,131	2,561	2,334
1953	1,261	1,886	1,327	1,620	1,712	1,611	1,441	1,470	1,433	1,342	1,528	2,173	1,583	1,545	1,989	1,775
1954	1,395	1,840	1,625	1,727	1,862	1,706	1,598	1,532	1,740	1,904	1,579	2,125	1,748	1,687	1,988	1,815
1955	1,221	1,566	1,599	1,627	1,719	1,762	1,480	1,276	1,730	1,689	1,371	1,842	1,585	1,568	1,816	1,656
1956	1,260	1,936	1,234	1,996	1,836	1,911	1,641	1,908	1,980	2,158	1,883	2,224	1,921	1,867	2,122	1,882
1957	1,362	1,698	1,824	1,805	1,921	1,679	1,680	1,501	1,472	1,724	1,553	1,978	1,689	1,657	1,880	1,732
1958	1,071	1,103	1,614	1,527	1,546	1,198	1,518	1,450	1,656	1,471	1,512	1,363	1,444	1,500	1,309	1,240
1959	1,272	1,307	2,077	1,848	1,918	1,270	1,852	1,711	1,902	1,755	1,839	1,574	1,729	1,790	1,475	1,409
1960	862	1,268	1,379	2,132	1,702	1,133	1,742	1,953	1,750	1,890	1,778	1,534	1,684	1,689	1,403	1,244
1961	665	1,141	835	1,788	1,339	1,174	1,280	1,408	2,014	1,174	1,346	1,402	1,356	1,421	1,327	1,144
1962	1,350	1,866	1,473	1,999	1,926	1,109	1,708	1,840	1,034	1,593	1,652	2,152	1,668	1,567	1,811	1,648
1963	987	1,600	1,364	1,788	1,662	1,485	1,592	1,766	2,165	1,902	1,874	1,877	1,775	1,783	1,749	1,532
1964	1,085	1,614	1,465	1,807	1,719	1,635	1,578	1,592	2,071	2,008	704	1,891	1,541	1,419	1,807	1,607
1965	1,075	1,636	1,609	2,238	1,934	1,969	1,813	1,831	2,255	1,694	567	1,914	1,584	1,528	1,932	1,708
1966	1,094	1,660	1,743	2,434	2,056	1,928	1,982	2,052	2,438	2,484	1,999	1,939	2,087	2,088	1,935	1,713
1967	1,254	1,829	1,551	2,037	1,921	1,916	1,675	1,623	1,905	2,340	1,653	2,114	1,890	1,805	2,049	1,832
1968	1,336	1,985	1,478	1,667	1,812	1,576	1,554	1,611	1,466	2,224	1,642	2,275	1,790	1,642	2,046	1,831
1969	1,322	1,710	1,688	1,947	1,923	1,609	1,761	1,798	1,858	2,229	1,794	1,991	1,870	1,815	1,866	1,707
1970	1,256	1,855	1,685	2,338	2,076	1,744	1,869	1,843	2,118	2,370	1,831	2,141	2,011	1,943	2,011	1,796
1971	881	1,453	1,180	1,924	2,010	1,444	1,570	1,539	1,837	1,938	1,585	1,725	1,700	1,702	1,633	1,424
1972	693	1,540	763	2,003	1,633	1,892	1,571	1,646	2,053	2,246	1,671	1,815	1,781	1,756	1,840	1,540
1973	927	1,460	898	1,827	1,606	1,758	1,589	1,746	1,955	2,191	1,752	1,732	1,751	1,744	1,741	1,527
1974	1,353	1,716	1,928	1,985	1,484	1,608	1,604	1,918	1,863	2,170	1,891	1,997	1,827	1,742	1,870	1,718
1975	1,331	1,325	2,049	2,081	1,500	1,641	2,352	1,599	1,947	1,704	1,633	1,593	1,721	1,771	1,609	1,537
1976	1,967	1,515	2,102	1,828	1,501	1,677	2,932	1,947	1,781	2,022	1,915	1,789	1,899	1,932	1,752	1,805
1977	1,865	1,729	2,221	1,826	1,422	1,441	3,113	1,419	1,222	1,525	1,487	2,010	1,712	1,672	1,824	1,812
1978	1,415	1,404	1,466	1,747	1,420	1,441	1,601	1,709	1,797	1,995	1,722	1,674	1,658	1,629	1,598	1,540
1979	1,658	1,753	1,430	2,155	1,763	1,553	1,599	1,438	1,820	2,034	1,502	2,035	1,749	1,650	1,877	1,801
1980	1,303	1,903	1,661	1,622	1,206	1,498	1,556	1,518	1,374	2,109	1,567	1,892	1,652	1,473	1,763	1,626
1981	1,090	1,471	1,538	1,588	1,758	1,524	1,408	1,499	1,590	1,945	1,552	1,950	1,624	1,583	1,811	1,604
1982	1,877	1,707	1,859	1,714	2,090	1,461	1,490	1,674	1,594	2,096	1,693	2,084	1,775	1,707	1,880	1,855
1983	1,361	1,468	1,409	1,331	1,532	1,324	1,436	1,576	1,212	1,683	1,614	1,735	1,506	1,471	1,601	1,521
1984	2,564	1,743	1,674	1,941	2,096	1,698	1,783	1,885	1,625	1,966	1,865	2,025	1,858	1,847	1,918	2,076
1985	1,189	1,684	1,730	2,043	1,980	1,792	1,870	2,015	1,837	2,084	1,970	1,964	1,917	1,922	1,908	1,711
1986	1,565	1,376	1,298	1,852	1,844	1,481	1,475	1,433	1,559	1,553	1,498	1,645	1,555	1,579	1,591	1,578
1987	1,810	1,678	1,395	1,944	2,157	1,520	1,534	1,436	1,371	1,555	1,500	1,958	1,644	1,628	1,815	1,796
1988	2,247	1,907	1,677	1,817	2,168	1,614	1,726	1,801	1,342	1,889	1,796	2,194	1,824	1,772	2,004	2,046
1989	1,909	1,325	1,389	1,609	1,812	1,455	1,509	1,618	1,558	1,722	1,648	1,593	1,589	1,623	1,548	1,638
Mean	1,367	1,637	1,563	1,866	1,787	1,588	1,725	1,689	1,745	1,928	1,639	1,915	1,738	1,703	1,808	1,679

Table 3.2.2 Mean Annual Runoff of The Ntem

Station : Nyabessan   River : Ntem (26,350 km2)

Year	Mean Annual Runoff			Specific Discharge
	(m3/s)	(mm)	(10^6m3)	(m3/s/km2)
1957 *	409	489	12,898	0.0155
1958	218	261	6,883	0.0083
1959	379	454	11,952	0.0144
1960	452	542	14,290	0.0171
1961	353	423	11,139	0.0134
1962	441	528	13,905	0.0167
1963	396	474	12,486	0.0150
1964	447	537	14,141	0.0170
1965	470	562	14,819	0.0178
1966	588	704	18,541	0.0223
1967	468	560	14,767	0.0178
1968	437	524	13,814	0.0166
1969	461	551	14,532	0.0175
1970	460	551	14,509	0.0175
1971	318	380	10,025	0.0121
1972	337	404	10,642	0.0128
1973	341	408	10,750	0.0129
1974	403	483	12,725	0.0153
1975	363	435	11,460	0.0138
1976	420	504	13,274	0.0159
1977	373	446	11,755	0.0141
1978	365	437	11,505	0.0138
1979	363	435	11,451	0.0138
1980	358	430	11,325	0.0136
1981	376	450	11,852	0.0143
1982	416	498	13,134	0.0158
1983	249	298	7,857	0.0095
1984	440	528	13,913	0.0167
1985	490	586	15,440	0.0186
1986	328	393	10,358	0.0125
1987	357	427	11,246	0.0135
1988	465	558	14,703	0.0176
Mean	398	476	12,565	0.0151

* Including interpolated data

Table 3.2.3 Runoff Ratio of The Ntem

Basin	Nyabessan				Ngoazik			
C.A.	26,350 km2				18,100 km2			
Year	Runoff (m3/sec)	Runoff (mm)	Rainfall (mm)	Ratio (%)	Runoff (m3/sec)	Runoff (mm)	Rainfall (mm)	Ratio (%)
1951			1,881.0				1,791.0	
1952			2,208.0				2,131.0	
1953			1,583.0				1,545.0	
1954			1,748.0		195.5	340.6	1,687.0	20.2%
1955			1,585.0		213.9	372.7	1,568.0	23.8%
1956			1,921.0		313.9	546.9	1,867.0	29.3%
1957	409.0	489.5	1,689.0	29.0%	273.5	476.5	1,657.0	28.8%
1958	218.3	261.3	1,444.0	18.1%	143.7	250.4	1,500.0	16.7%
1959	379.0	453.6	1,729.0	26.2%	260.1	453.2	1,790.0	25.3%
1960	451.9	540.8	1,684.0	32.1%	319.6	556.8	1,689.0	33.0%
1961	353.2	422.7	1,356.0	31.2%	216.8	377.7	1,421.0	26.6%
1962	440.9	527.7	1,668.0	31.6%	288.8	503.2	1,567.0	32.1%
1963	395.9	473.8	1,775.0	26.7%	303.5	528.8	1,783.0	29.7%
1964	447.2	535.2	1,541.0	34.7%	292.9	510.3	1,419.0	36.0%
1965	469.9	562.4	1,584.0	35.5%	305.5	532.3	1,528.0	34.8%
1966	587.9	703.6	2,087.0	33.7%	396.0	690.0	2,088.0	33.0%
1967	468.3	560.5	1,890.0	29.7%	279.2	486.5	1,805.0	27.0%
1968	436.9	522.9	1,790.0	29.2%	312.4	544.3	1,642.0	33.1%
1969	460.8	551.5	1,870.0	29.5%	327.1	569.9	1,815.0	31.4%
1970	460.1	550.7	2,011.0	27.4%	295.5	514.9	1,943.0	26.5%
1971	317.9	380.5	1,700.0	22.4%	203.7	354.9	1,702.0	20.9%
1972	336.5	402.7	1,781.0	22.6%	217.4	378.8	1,756.0	21.6%
1973	340.9	408.0	1,751.0	23.3%	209.2	364.5	1,744.0	20.9%
1974	403.5	482.9	1,827.0	26.4%	236.9	412.8	1,742.0	23.7%
1975	363.4	434.9	1,721.0	25.3%	222.9	388.4	1,771.0	21.9%
1976	419.8	502.4	1,899.0	26.5%	248.3	432.6	1,932.0	22.4%
1977	372.8	446.2	1,712.0	26.1%	211.3	368.2	1,672.0	22.0%
1978	364.8	436.6	1,658.0	26.3%	226.7	395.0	1,629.0	24.2%
1979	363.1	434.6	1,749.0	24.8%	219.4	382.3	1,650.0	23.2%
1980	358.1	428.6	1,652.0	25.9%	225.4	392.7	1,473.0	26.7%
1981	375.8	449.8	1,624.0	27.7%	222.3	387.3	1,583.0	24.5%
1982	416.5	498.5	1,775.0	28.1%	248.5	433.0	1,707.0	25.4%
1983	249.1	298.1	1,506.0	19.8%	144.1	251.1	1,471.0	17.1%
1984	440.0	526.6	1,858.0	28.3%	242.2	422.0	1,847.0	22.8%
1985	489.6	586.0	1,917.0	30.6%	320.9	559.1	1,922.0	29.1%
1986	328.4	393.0	1,555.0	25.3%	186.7	325.3	1,579.0	20.6%
1987	356.6	426.8	1,644.0	26.0%	216.9	377.9	1,628.0	23.2%
1988	465.0	556.5	1,824.0	30.5%	270.1	470.6	1,772.0	26.6%
1989			1,589.0				1,623.0	
Sample	32	32	39	32	35	35	39	35
Mean	398.2	476.5	1,738.1	27.5%	251.7	438.6	1,703.6	25.8%
Min.	218.3	261.3	1,356.0	18.1%	143.7	250.4	1,419.0	16.7%
Max.	587.9	703.6	2,208.0	35.5%	396.0	690.0	2,131.0	36.0%

Table 3.2.4 Flow Duration Curve of The Ntem

Year : 1957 - 1991
Maximum : 2,111 (m3/s)
Minimum : 15 (m3/s)
Average : 398 (m3/s)
Catchment Area : 26,350 (km2)

Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)
1	1439.0	26	532.1	51	285.0	76	155.6
2	1268.5	27	517.0	52	276.9	77	151.6
3	1163.5	28	503.8	53	268.7	78	147.7
4	1097.3	29	492.8	54	263.1	79	145.2
5	1044.2	30	481.9	55	257.3	80	141.5
6	1003.4	31	468.4	56	251.5	81	139.0
7	967.1	32	455.1	57	246.0	82	135.4
8	935.0	33	442.1	58	240.4	83	131.8
9	903.4	34	429.2	59	233.1	84	128.4
10	872.3	35	419.1	60	228.8	85	125.0
11	839.8	36	406.6	61	222.6	86	121.0
12	806.9	37	396.8	62	217.0	87	117.2
13	778.4	38	387.5	63	212.4	88	112.9
14	753.9	39	379.9	64	207.5	89	108.8
15	733.2	40	370.5	65	203.1	90	104.9
16	712.8	41	361.1	66	199.3	91	100.6
17	689.5	42	351.9	67	194.6	92	95.2
18	669.8	43	343.4	68	189.9	93	89.8
19	650.3	44	336.2	69	183.3	94	86.0
20	631.4	45	327.3	70	178.0	95	80.2
21	609.5	46	320.7	71	174.3	96	74.8
22	591.2	47	312.1	72	169.3	97	68.8
23	576.1	48	305.7	73	166.4	98	63.2
24	560.6	49	299.4	74	161.0	99	52.9
25	544.0	50	291.1	75	158.2	100	15.2

Table 3.2.5 Flow Duration Curve of The Ndjo'o

Year : 1957 - 1988
Maximum : 54 (m3/s)
Minimum : 1.1 (m3/s)
Average : 11 (m3/s)
Catchment Area : 550 (km2)

Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)
1	38.3	26	15.0	51	6.8	76	3.7
2	36.1	27	14.6	52	6.7	77	3.3
3	33.6	28	14.1	53	6.5	78	3.3
4	32.0	29	13.3	54	6.5	79	3.3
5	30.5	30	12.9	55	6.4	80	3.2
6	29.3	31	12.1	56	6.3	81	3.2
7	28.3	32	11.5	57	6.2	82	2.8
8	27.2	33	10.7	58	6.1	83	2.8
9	26.3	34	10.3	59	6.0	84	2.8
10	25.2	35	9.7	60	6.0	85	2.5
11	24.4	36	9.4	61	5.9	86	2.5
12	23.5	37	8.8	62	5.6	87	2.4
13	22.7	38	8.7	63	5.6	88	2.4
14	21.8	39	8.3	64	5.4	89	2.4
15	21.0	40	8.0	65	5.2	90	2.4
16	20.3	41	7.9	66	5.1	91	2.1
17	19.7	42	7.8	67	4.8	92	2.1
18	19.0	43	7.7	68	4.6	93	2.1
19	18.3	44	7.5	69	4.2	94	2.1
20	17.8	45	7.4	70	4.2	95	2.1
21	17.3	46	7.4	71	4.2	96	2.1
22	16.6	47	7.2	72	4.1	97	2.1
23	16.2	48	7.1	73	3.7	98	2.0
24	15.8	49	6.9	74	3.7	99	2.0
25	15.4	50	6.9	75	3.7	100	1.1

Table 3.2.6 Flow Duration Curve of The Biwome

Year : 1957 - 1988
Maximum : 122 (m3/s)
Minimum : 2.5 (m3/s)
Average : 25 (m3/s)
Catchment Area : 1,250 (km2)

Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)
1	87.1	26	34.0	51	15.5	76	8.3
2	82.0	27	33.1	52	15.2	77	7.6
3	76.4	28	32.1	53	14.9	78	7.6
4	72.7	29	30.3	54	14.9	79	7.6
5	69.4	30	29.4	55	14.6	80	7.4
6	66.6	31	27.5	56	14.3	81	7.4
7	64.3	32	26.2	57	14.1	82	6.4
8	61.8	33	24.4	58	13.9	83	6.3
9	59.7	34	23.4	59	13.7	84	6.3
10	57.2	35	21.9	60	13.7	85	5.7
11	55.4	36	21.4	61	13.4	86	5.7
12	53.4	37	20.0	62	12.7	87	5.5
13	51.5	38	19.7	63	12.7	88	5.4
14	49.7	39	18.8	64	12.4	89	5.4
15	47.8	40	18.1	65	11.8	90	5.4
16	46.1	41	17.9	66	11.5	91	4.8
17	44.8	42	17.6	67	10.9	92	4.8
18	43.1	43	17.4	68	10.4	93	4.8
19	41.5	44	17.1	69	9.4	94	4.8
20	40.5	45	16.9	70	9.4	95	4.8
21	39.4	46	16.7	71	9.4	96	4.8
22	37.8	47	16.5	72	9.2	97	4.8
23	36.8	48	16.2	73	8.5	98	4.5
24	35.9	49	15.8	74	8.5	99	4.5
25	35.0	50	15.8	75	8.5	100	2.5

Table 3.2.7 Combined Flow Duration Curve

Year : 19587- 1988
Maximum : 2,194(m3/s)
Minimum : 24 (m3/s)
Average : 436 (m3/s)
Catchment Area : 28,150 (km2)

Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)	Time (%)	Runoff (m3/s)
1	1556.0	26	572.0	51	311.0	76	170.0
2	1362.0	27	556.0	52	304.0	77	167.0
3	1249.0	28	543.0	53	294.0	78	163.0
4	1186.0	29	531.0	54	287.0	79	160.0
5	1134.0	30	518.0	55	279.0	80	156.0
6	1089.0	31	507.0	56	273.0	81	152.0
7	1049.0	32	493.0	57	267.0	82	149.0
8	1012.0	33	478.0	58	261.0	83	146.0
9	979.0	34	466.0	59	255.0	84	142.0
10	948.0	35	453.0	60	248.0	85	138.0
11	912.0	36	443.0	61	242.0	86	135.0
12	878.0	37	433.0	62	237.0	87	131.0
13	844.0	38	424.0	63	231.0	88	126.0
14	819.0	39	415.0	64	226.0	89	122.0
15	797.0	40	405.0	65	221.0	90	119.0
16	770.0	41	394.0	66	216.0	91	114.0
17	745.0	42	384.0	67	211.0	92	108.0
18	723.0	43	375.0	68	206.0	93	103.0
19	696.0	44	365.0	69	201.0	94	97.1
20	675.0	45	356.0	70	196.0	95	92.4
21	657.0	46	348.0	71	190.0	96	86.9
22	639.0	47	340.0	72	186.0	97	80.2
23	623.0	48	332.0	73	182.0	98	72.8
24	604.0	49	325.0	74	177.0	99	66.1
25	588.0	50	318.0	75	174.0	100	23.7

Table 3.2.8 Flood Records at Nyabessan and Ngoazik

Date	Nyabessan (26,350 km2) Peak Flow (m3/S)	Nyabessan (26,350 km2) Specific Discharge (m3/S/km2)	Date	Ngoazik (18,100 km2) Peak Flow (m3/S)	Ngoazik (18,100 km2) Specific Discharge (m3/S/km2)
			Nov. 13, 1963	589	0.0325
			Nov. 5, 1954	639	0.0353
			Nov.11, 1955	608	0.0336
			Nov.13, 1956	704	0.0389
Oct. 20, 1957	1,387	0.0526	Oct. 17, 1957	856	0.0473
Oct. 23, 1958	883	0.0335	Oct. 21, 1958	601	0.0332
Nov. 2, 1959	1,439	0.0546	Nov.29, 1959	875	0.0483
Nov. 2, 1960	1,611	0.0611	Nov. 13, 1960	957	0.0529
Nov. 2, 1961	982	0.0373	Nov. 10, 1961	620	0.0343
Jun. 3, 1962	1,171	0.0444	Oct. 14, 1962	647	0.0357
Oct.22, 1963	1,022	0.0388	Oct. 18, 1963	809	0.0447
Nov. 9, 1964	1,574	0.0597	Nov. 6, 1964	1,013	0.0560
Oct. 29, 1965	1,361	0.0517	Oct. 27, 1965	778	0.0430
Nov. 8, 1966	1,404	0.0533	Jun. 25, 1966	813	0.0449
Oct. 30, 1967	1,818	0.0690	Oct. 30, 1967	985	0.0544
Nov. 15, 1968	1,090	0.0414	May 13, 1968	700	0.0387
Novt. 6, 1969	1,310	0.0497	Nov. 6, 1969	793	0.0438
Nov. 9, 1970	2,111	0.0801	Nov. 10, 1970	1,299	0.0718
Nov. 1, 1971	1,220	0.0463	Oct. 28, 1971	782	0.0432
Nov. 5, 1972	1,148	0.0436	Oct. 24, 1972	778	0.0430
Oct. 25, 1973	939	0.0356	Nov. 5, 1973	566	0.0313
Novt. 2, 1974	1,101	0.0418	May 10, 1974	670	0.0370
Nov. 17, 1975	1,306	0.0496	Nov.19, 1975	685	0.0378
Nov. 22, 1976	1,120	0.0425	Nov. 22, 1976	685	0.0378
Nov. 11, 1977	1,248	0.0474	Nov. 4, 1977	724	0.0400
May 16,1978	1,063	0.0403	May 14, 1978	691	0.0382
Oct. 31, 1979	1,240	0.0471	Oct. 29, 1979	722	0.0399
Nov. 14, 1980	1,099	0.0417	Oct. 13, 1980	755	0.0417
Nov. 11, 1981	1,165	0.0442	Oct. 21, 1981	643	0.0355
NOv. 4, 1982	1,639	0.0622	Nov. 4, 1982	1,002	0.0554
Nov. 13, 1983	924	0.0351	Nov. 13, 1983	571	0.0315
Oct. 13, 1984	1,054	0.0400	Oct. 9, 1984	644	0.0356
Nov. 2, 1985	1,632	0.0619	Oct. 30, 1985	1,002	0.0554
Oct. 29, 1986	1,204	0.0457	Oct. 27, 1986	745	0.0412
Oct. 22, 1987	1,431	0.0543	Oct. 19, 1987	789	0.0436
Nov. 6, 1988	1,754	0.0666	Nov. 5, 1988	1,036	0.0572
Nov.18, 1990	1,217	0.0462	Nov. 19, 1990	811	0.0448

Table 3.2.9 RECORDED MAXIMUM FLOOD AT NYABESSAN

Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)
1	94	32	613	63	1,556	94	657
2	92	33	644	64	1,653	95	591
3	119	34	683	65	1,788	96	547
4	189	35	720	66	1,903	97	504
5	267	36	740	67	2,010	98	482
6	248	37	807	68	2,079	99	445
7	259	38	875	69	2,089	100	414
8	265	39	953	70	2,111	101	390
9	295	40	928	71	2,073	102	364
10	350	41	914	72	2,016	103	343
11	373	42	886	73	2,010	104	323
12	359	43	896	74	1,959	105	308
13	359	44	883	75	1,852	106	299
14	347	45	883	76	1,754	107	299
15	343	46	879	77	1,653	108	295
16	347	47	946	78	1,570	109	285
17	347	48	974	79	1,474	110	267
18	352	49	989	80	1,378	111	263
19	345	50	1,059	81	1,314	112	263
20	378	51	1,120	82	1,220	113	248
21	390	52	1,195	83	1,171	114	255
22	437	53	1,310	84	1,037	115	273
23	485	54	1,302	85	974	116	291
24	482	55	1,327	86	967	117	308
25	504	56	1,361	87	953	118	308
26	521	57	1,327	88	949	119	321
27	544	58	1,310	89	953	120	334
28	585	59	1,365	90	931	121	338
29	591	60	1,374	91	862	122	352
30	610	61	1,327	92	793		
31	622	62	1,452	93	723		

Table 3.2.10(1) HYDROGRAPH OF PROBABLE FLOOD AT NYABESSAN(10-year)

Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)
1	77	32	499	63	1,268	94	535
2	75	33	525	64	1,347	95	482
3	97	34	557	65	1,457	96	445
4	154	35	586	66	1,551	97	411
5	218	36	603	67	1,638	98	393
6	202	37	658	68	1,694	99	362
7	211	38	713	69	1,703	100	338
8	216	39	776	70	1,720	101	317
9	241	40	756	71	1,690	102	296
10	285	41	745	72	1,643	103	279
11	304	42	722	73	1,638	104	263
12	292	43	731	74	1,596	105	251
13	292	44	719	75	1,510	106	244
14	283	45	719	76	1,429	107	244
15	279	46	717	77	1,347	108	241
16	283	47	771	78	1,279	109	232
17	283	48	794	79	1,202	110	218
18	287	49	806	80	1,123	111	214
19	281	50	863	81	1,071	112	214
20	308	51	913	82	994	113	202
21	317	52	974	83	955	114	208
22	356	53	1,068	84	845	115	222
23	395	54	1,061	85	794	116	237
24	393	55	1,081	86	788	117	251
25	411	56	1,109	87	776	118	251
26	424	57	1,081	88	774	119	261
27	443	58	1,068	89	776	120	272
28	477	59	1,113	90	759	121	276
29	482	60	1,120	91	703	122	287
30	497	61	1,081	92	646		
31	507	62	1,184	93	589		

Table 3.2.10(2) HYDROGRAPH OF PROBABLE FLOOD AT NYABESSAN(20-year)

Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)
1	85	32	551	63	1,401	94	591
2	82	33	580	64	1,488	95	532
3	107	34	615	65	1,610	96	492
4	171	35	648	66	1,713	97	454
5	240	36	666	67	1,810	98	434
6	223	37	727	68	1,871	99	400
7	233	38	788	69	1,881	100	373
8	239	39	858	70	1,900	101	351
9	266	40	835	71	1,867	102	327
10	315	41	823	72	1,815	103	309
11	336	42	798	73	1,810	104	291
12	323	43	807	74	1,763	105	277
13	323	44	795	75	1,668	106	270
14	313	45	795	76	1,579	107	270
15	309	46	792	77	1,488	108	266
16	313	47	851	78	1,413	109	257
17	313	48	877	79	1,327	110	240
18	317	49	890	80	1,241	111	237
19	311	50	954	81	1,183	112	237
20	340	51	1,009	82	1,098	113	223
21	351	52	1,076	83	1,055	114	230
22	393	53	1,179	84	933	115	246
23	436	54	1,172	85	877	116	262
24	434	55	1,195	86	871	117	277
25	454	56	1,225	87	858	118	277
26	469	57	1,195	88	855	119	289
27	489	58	1,179	89	858	120	301
28	527	59	1,229	90	839	121	305
29	532	60	1,237	91	776	122	317
30	549	61	1,195	92	714		
31	560	62	1,307	93	651		

Table 3.2.10(3) HYDROGRAPH OF PROBABLE FLOOD AT NYABESSAN(100-year)

Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)
1	103	32	668	63	1,695	94	716
2	100	33	702	64	1,802	95	644
3	129	34	744	65	1,949	96	596
4	206	35	784	66	2,074	97	549
5	291	36	807	67	2,191	98	525
6	270	37	879	68	2,265	99	485
7	282	38	954	69	2,277	100	451
8	289	39	1,038	70	2,300	101	424
9	322	40	1,011	71	2,259	102	396
10	381	41	996	72	2,197	103	374
11	406	42	966	73	2,191	104	352
12	391	43	977	74	2,135	105	336
13	391	44	962	75	2,019	106	326
14	379	45	962	76	1,911	107	326
15	374	46	958	77	1,802	108	322
16	379	47	1,031	78	1,710	109	311
17	379	48	1,062	79	1,607	110	291
18	383	49	1,078	80	1,502	111	287
19	376	50	1,154	81	1,432	112	287
20	411	51	1,221	82	1,329	113	270
21	424	52	1,303	83	1,277	114	278
22	476	53	1,428	84	1,130	115	298
23	528	54	1,419	85	1,062	116	317
24	525	55	1,446	86	1,054	117	336
25	549	56	1,483	87	1,038	118	336
26	567	57	1,446	88	1,034	119	349
27	593	58	1,428	89	1,038	120	364
28	638	59	1,488	90	1,015	121	369
29	644	60	1,497	91	939	122	383
30	664	61	1,446	92	864		
31	678	62	1,583	93	788		

Table 3.2.10(4) HYDROGRAPH OF PROBABLE FLOOD AT NYABESSAN(200-year)

Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)
1	111	32	720	63	1828	94	772
2	108	33	757	64	1943	95	695
3	139	34	802	65	2101	96	642
4	223	35	846	66	2236	97	592
5	314	36	870	67	2362	98	566
6	291	37	948	68	2442	99	523
7	305	38	1028	69	2455	100	487
8	311	39	1119	70	2480	101	458
9	347	40	1090	71	2436	102	427
10	411	41	1074	72	2368	103	403
11	438	42	1041	73	2362	104	379
12	422	43	1053	74	2301	105	362
13	422	44	1037	75	2177	106	352
14	408	45	1037	76	2061	107	352
15	403	46	1033	77	1943	108	347
16	408	47	1111	78	1844	109	335
17	408	48	1145	79	1732	110	314
18	413	49	1162	80	1619	111	309
19	405	50	1245	81	1544	112	309
20	444	51	1316	82	1433	113	291
21	458	52	1404	83	1376	114	300
22	513	53	1539	84	1218	115	321
23	569	54	1529	85	1145	116	342
24	566	55	1559	86	1136	117	362
25	592	56	1599	87	1119	118	362
26	612	57	1559	88	1115	119	377
27	639	58	1539	89	1119	120	392
28	687	59	1604	90	1094	121	398
29	695	60	1614	91	1013	122	413
30	716	61	1559	92	931		
31	731	62	1706	93	850		

Table 3.2.10(5) HYDROGRAPH OF PROBABLE FLOOD AT NYABESSAN(1000-year)

Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)
1	129	32	836	63	2,123	94	896
2	125	33	879	64	2,256	95	807
3	162	34	932	65	2,440	96	746
4	258	35	982	66	2,596	97	687
5	364	36	1,010	67	2,743	98	658
6	338	37	1,101	68	2,836	99	607
7	354	38	1,194	69	2,851	100	565
8	362	39	1,300	70	2,880	101	532
9	403	40	1,266	71	2,829	102	496
10	477	41	1,247	72	2,750	103	468
11	509	42	1,209	73	2,743	104	441
12	490	43	1,223	74	2,673	105	420
13	490	44	1,204	75	2,528	106	409
14	474	45	1,204	76	2,393	107	409
15	468	46	1,200	77	2,256	108	403
16	474	47	1,290	78	2,142	109	389
17	474	48	1,330	79	2,012	110	364
18	480	49	1,349	80	1,881	111	359
19	471	50	1,446	81	1,794	112	359
20	515	51	1,529	82	1,664	113	338
21	532	52	1,631	83	1,598	114	348
22	596	53	1,788	84	1,415	115	373
23	661	54	1,776	85	1,330	116	397
24	658	55	1,811	86	1,320	117	420
25	687	56	1,857	87	1,300	118	420
26	711	57	1,811	88	1,295	119	438
27	742	58	1,788	89	1,300	120	456
28	798	59	1,863	90	1,271	121	462
29	807	60	1,875	91	1,176	122	480
30	832	61	1,811	92	1,082		
31	849	62	1,982	93	987		

Table 3.2.10(6) HYDROGRAPH OF PROBABLE FLOOD AT NYABESSAN(10000-year)

Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)	Time (day)	Runoff (m3/s)
1	154	32	1,001	63	2,543	94	1,074
2	150	33	1,053	64	2,703	95	967
3	194	34	1,116	65	2,923	96	894
4	310	35	1,176	66	3,110	97	824
5	436	36	1,210	67	3,286	98	788
6	405	37	1,319	68	3,398	99	727
7	424	38	1,431	69	3,415	100	677
8	433	39	1,557	70	3,450	101	637
9	483	40	1,517	71	3,389	102	594
10	572	41	1,494	72	3,295	103	560
11	609	42	1,448	73	3,286	104	528
12	587	43	1,465	74	3,202	105	503
13	587	44	1,443	75	3,028	106	489
14	568	45	1,443	76	2,867	107	489
15	560	46	1,437	77	2,703	108	483
16	568	47	1,546	78	2,566	109	466
17	568	48	1,593	79	2,410	110	436
18	575	49	1,616	80	2,253	111	430
19	564	50	1,732	81	2,149	112	430
20	617	51	1,831	82	1,993	113	405
21	637	52	1,954	83	1,915	114	417
22	714	53	2,142	84	1,695	115	446
23	792	54	2,128	85	1,593	116	476
24	788	55	2,169	86	1,581	117	503
25	824	56	2,225	87	1,557	118	503
26	851	57	2,169	88	1,552	119	524
27	889	58	2,142	89	1,557	120	546
28	956	59	2,232	90	1,523	121	553
29	966	60	2,246	91	1,409	122	575
30	996	61	2,169	92	1,296		
31	1,017	62	2,374	93	1,182		

Table 3.2.11 MONTHLY SUMMARY OF SUSPENDED LOAD (Ntem)

Unit : (ton/day) ton/year

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	Total
1957	954	406	484	983	1,613	1,760	905	307	878	4,396	3,628	2,171	1,540	562,265
1958	529	299	247	602	1,251	552	122	47	172	2,103	1,825	1,078	735	268,446
1959	410	308	237	532	1,646	795	376	230	1,088	4,277	5,194	2,374	1,456	531,353
1960	506	520	622	1,447	1,277	1,781	681	503	681	4,282	5,893	2,828	1,752	641,139
1961	899	953	538	1,532	1,234	1,534	346	158	707	3,007	3,161	1,184	1,271	463,960
1962	296	271	910	3,621	3,590	2,190	671	313	926	2,840	2,476	2,140	1,687	615,749
1963	608	482	864	1,104	1,908	1,132	1,364	508	1,621	3,890	2,636	1,190	1,442	526,425
1964	559	344	551	1,849	2,073	1,519	657	204	610	3,246	5,178	1,815	1,550	567,472
1965	838	678	1,258	1,843	2,067	1,865	818	534	1,525	4,612	4,134	1,333	1,792	654,050
1966	512	471	490	1,898	4,473	3,843	3,205	1,043	1,577	3,363	5,315	2,141	2,361	861,780
1967	606	451	338	472	2,051	2,557	882	269	1,480	5,780	5,556	1,911	1,863	679,910
1968	554	544	901	1,112	3,033	2,490	635	252	1,085	2,978	3,880	2,370	1,653	604,943
1969	669	719	1,901	2,296	1,939	1,516	687	551	1,383	3,552	4,435	1,343	1,749	638,463
1970	460	334	907	1,084	1,237	2,080	938	562	1,274	4,334	7,174	1,358	1,812	661,266
1971	622	231	468	1,019	871	696	429	315	1,110	3,438	3,348	1,195	1,145	418,014
1972	300	212	486	1,402	1,139	1,083	351	269	1,304	3,344	3,823	1,052	1,231	450,372
1973	611	385	591	1,055	1,547	2,211	809	526	944	2,452	2,424	913	1,206	440,072
1974	389	419	646	1,131	2,846	2,025	570	565	1,145	2,954	3,926	1,426	1,504	548,818
1975	395	608	591	1,460	1,266	810	700	269	372	2,583	4,804	2,306	1,347	491,629
1976	597	560	761	1,343	1,388	2,398	1,107	370	584	3,703	4,358	1,801	1,581	578,546
1977	598	547	694	1,329	766	505	493	512	572	3,763	4,601	2,293	1,390	507,173
1978	498	160	462	1,340	3,401	2,225	931	259	949	2,549	2,444	873	1,341	489,489
1979	407	278	690	1,120	1,981	1,686	844	388	1,132	2,770	3,439	1,110	1,320	481,928
1980	446	229	297	1,135	1,039	1,586	380	533	1,402	3,737	3,883	1,192	1,322	483,744
1981	432	233	439	921	2,343	1,732	539	242	873	2,890	4,107	1,173	1,327	484,373
1982	715	458	631	974	2,449	1,377	613	336	1,335	3,434	5,339	1,314	1,581	577,096
1983	360	161	142	490	1,106	770	376	136	267	1,999	2,945	1,630	865	315,753
1984	354	181	506	1,008	1,369	1,806	2,088	1,422	2,400	3,940	3,391	1,414	1,657	606,325
1985	697	320	424	2,182	1,822	1,535	932	828	1,908	4,822	5,814	1,717	1,917	699,655
1986	532	479	891	893	1,180	1,526	296	175	864	3,619	2,922	847	1,185	432,634
1987	223	144	245	713	863	643	674	368	1,987	4,320	4,494	1,593	1,356	494,828
1988	515	300	439	762	2,247	1,798	923	457	1,479	4,175	6,528	2,326	1,829	669,457
1989	658	444	297	1,162	2,299	1,643	922	436	-	-	-	-	-	-
1990	-	-	-	318	1,394	1,397	202	512	2,018	3,363	4,838	2,719	-	-
1991	1,090	237	977	-	-	-	-	-	-	-	-	-	-	-
Mean	554	393	615	1,239	1,844	1,620	778	423	1,141	3,531	4,179	1,640	1,497	545,223

Table 3.2.12 MONTHLY SUMMARY OF SUSPENDED LOAD (Ndjo'o)

Unit : ton/day ton/year

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean	Total
1957	11.2	6.7	22.8	23.0	59.1	31.9	10.1	5.7	77.3	140.0	94.1	20.8	41.9	15,290
1958	11.5	6.5	23.3	23.8	57.9	28.9	10.2	5.8	77.6	139.8	95.0	21.0	41.8	15,252
1959	11.5	6.4	24.0	23.8	60.2	32.7	9.6	6.0	76.1	136.4	88.6	20.4	41.3	15,073
1960	11.7	6.6	23.1	22.5	59.1	33.1	10.3	5.9	78.4	130.9	94.5	20.8	41.4	15,114
1961	11.3	6.4	22.9	23.3	58.3	30.9	10.6	5.9	75.8	143.4	93.2	20.6	41.9	15,289
1962	11.7	6.6	22.7	23.5	57.6	28.3	10.1	6.1	74.6	140.6	101.3	20.6	42.0	15,322
1963	11.7	6.6	22.7	23.5	57.6	28.3	10.1	6.1	74.6	140.6	101.3	20.6	42.0	15,322
1964	11.8	6.3	23.3	23.8	60.1	27.8	10.3	6.0	74.6	131.9	100.6	20.7	41.4	15,122
1965	11.3	6.4	23.3	23.8	55.4	30.4	10.4	5.9	78.6	140.2	93.2	20.9	41.6	15,200
1966	11.0	6.2	23.1	23.6	62.3	30.8	10.3	6.1	70.6	145.3	109.0	20.6	43.2	15,785
1967	11.3	6.8	23.1	22.8	60.2	32.3	10.7	6.0	76.0	134.9	94.8	21.0	41.7	15,209
1968	12.0	6.6	23.3	22.2	55.1	30.3	10.1	6.0	75.1	133.0	93.1	20.5	40.6	14,822
1969	11.0	6.4	23.8	23.5	59.5	29.5	10.9	6.1	76.5	136.2	100.1	21.0	42.0	15,341
1970	11.4	6.5	21.5	23.2	58.3	33.4	10.5	6.0	72.4	138.5	100.3	21.1	41.9	15,298
1971	11.2	6.7	23.1	23.7	57.2	32.5	10.8	5.7	71.3	136.7	95.2	20.5	41.2	15,045
1972	11.2	6.5	24.0	23.1	59.0	32.4	10.6	5.7	69.3	139.5	97.8	20.4	41.6	15,195
1973	10.9	6.4	23.9	23.3	59.1	30.6	10.6	5.9	79.0	139.7	97.6	20.6	42.3	15,438
1974	11.1	6.3	22.7	23.1	57.1	32.7	10.0	6.0	74.8	144.1	99.9	20.7	42.4	15,465
1975	11.5	6.7	22.5	23.5	59.0	32.2	11.5	6.2	79.8	138.1	96.6	20.5	42.3	15,452
1976	11.4	6.2	23.0	22.9	60.1	31.2	10.3	5.9	77.0	144.0	103.4	21.2	43.1	15,717
1977	11.1	7.0	23.3	22.8	59.5	31.6	11.2	5.9	76.4	148.8	107.0	20.6	43.8	15,975
1978	11.3	6.7	22.5	23.2	54.7	31.7	10.2	5.7	75.0	143.4	103.6	20.3	42.4	15,460
1979	11.3	6.5	22.6	23.1	55.5	33.0	10.5	6.1	72.1	135.4	91.6	20.9	40.7	14,855
1980	11.4	6.4	23.1	23.4	58.7	30.4	11.4	5.8	72.5	137.4	104.9	20.8	42.2	15,396
1981	10.8	6.5	22.6	22.2	54.6	29.9	10.5	6.0	72.2	142.7	104.8	20.8	42.0	15,314
1982	11.9	6.4	22.2	22.9	55.9	30.5	10.5	5.9	71.6	127.9	97.1	20.7	40.3	14,709
1983	11.3	6.7	23.1	24.1	60.2	30.5	11.3	5.7	76.6	137.7	102.5	20.9	42.6	15,532
1984	11.7	6.8	24.1	22.9	60.7	31.3	10.5	5.8	78.1	138.4	100.0	20.7	42.6	15,538
1985	10.7	6.2	24.3	23.1	58.9	28.7	11.5	5.7	76.5	135.5	100.0	21.0	41.8	15,270
1986	11.4	6.7	23.5	23.3	55.7	30.9	10.4	6.0	71.9	135.7	90.2	20.8	40.5	14,797
1987	11.4	6.4	23.5	23.3	60.5	32.2	10.6	5.8	70.4	146.7	102.3	20.5	42.8	15,624
1988	10.9	6.2	23.5	24.1	56.9	30.1	10.3	5.9	77.6	135.2	96.1	20.4	41.4	15,122
Mean	11.3	6.5	23.1	23.3	58.2	31.0	10.5	5.9	75.0	138.7	98.4	20.7	41.9	15,292

Table 3.2.13 RESULT OF WATER QUALITY TEST

Test Item	River / Location / Sampling Date	Ntem Nyabessan 10/1/91	Ntem Nyabessan 10/1/91	Ntem Nyabessan 10/1/91	Ntem Nyabessan 20/6/92	Ndjo'o Nyabessan 10/1/91	Ndjo'o Nyabessan 10/1/91	Ndjo'o Nyabessan 20/6/92	Biwome Nyabessan 10/1/91	Biwome Nyabessan 10/1/91	Biwome Nyabessan 20/6/92
Color (ppm Pt)		200	200	200	-	130	146	-	100	110	-
Turbidity	(Turbidity Unit)	23	15	20	-	10	12	-	9	8	-
pH		7.2	7.4	7.5	6.34	7.4	7.45	6.51	7.7	7.4	6.66
T.A.C. (mg CaCO3/l)		-	-	-	4.88	-	-	5.49	-	-	5.49
Conductivity at 26deg.	(μS/cm)	23	21	20	21.2	29	25	18.6	32	27	19.2
Cation											
Ca++	(mg/l)	1.55	1.3	1.3	0.96	1.5	1.45	0.84	1.7	1.7	0.84
Mg++	(mg/l)	0.6	0.3	0.5	0.5	0.6	0.6	0.44	0.7	0.7	0.51
K+	(mg/l)	0.6	0.6	0.5	0	0.5	0.4	0	0.4	0.4	0
Na+	(mg/l)	0.9	0.9	0.9	1.06	1.3	1.25	1.38	1.1	1.1	1.43
NH4+	(mg/l)	0.6	0.7	0.7	-	0.5	0.5	-	0.4	0.4	-
Fe++	(mg/l)	1.3	1.5	1.3	-	1.3	1.3	-	1	1.05	-
Mn++	(mg/l)	0.38	0.36	0.35	-	0.24	0.23	-	0.2	0.19	-
Anion											
CO3--	(mg/l)	-	-	-	-	-	-	-	-	-	-
CO3H-	(mg/l)	11	9.15	6.11	4.88	12.8	12.2	5.49	11	13.4	5.49
Cl-	(mg/l)	2.5	3.5	4.3	0.99	3.5	2.8	0.71	0	0	0.89
PO4--	(mg/l)	4	4.1	4.1	-	2.5	2.6	-	2	2	-
SO4--	(mg/l)	7	8	7	1.06	5	6	0.96	5	5	0.87
NO2-	(mg/l)	0.03	0.02	0.02	-	0.02	0.02	-	0.01	0.01	-
NO3-	(mg/l)	-	-	-	-	-	-	0.62	-	-	0.87
Total salinity	(mg/l)	30	30	27	-	29	29	-	24	21	-
Sio2	(mg/l)	-	-	-	7.54	-	-	7.08	-	-	8.2
Al2O3	(mg/l)	-	-	-	0.28	-	-	0.16	-	-	0.09
Fe2O3	(mg/l)	-	-	-	0.25	-	-	0.16	-	-	0.09

Table 3.3.1 Comparison of Dam Axes

Alternatives Check Items	Dam site 1	Dam site 2	Dam site 3	Dam site 4	Dam site 5
Utilization of Water	Ntem river water only. Diversion scheme shall be needed.	Ntem river water only. Diversion scheme shall be needed.	Ntem river water only. Diversion scheme shall be needed.	Ntem river water only. Diversion scheme shall be needed.	All the river water
FSL/Tailrace Cross Head	390 m / 335 m (55 m)	388 m / 335 m (53 m)	389 - 390 m / 335 m (54 m)	390 m / 335 m (55 m)	390 m / 335 m (55 m)
Probable Dam Scale	H = 10 m (maximum) l = 2,200 m	H = 8 m (maximum) l = 2,300 m	H = 10 m (maximum) l =1,900 m	H = 10 m (maximum) l = 2,000 m	H = 15 m (maximum) l = 4,200 m
Dam Type	Earth fill	Earth fill	Earth fill	Earth fill	Earth fill
Topographic Condition					
Right Bank	Very Good	Fair (complicated topographic condition)	Good	Very Good	Fair (complicated topographic condition)
River bed	Rock exposed (470 m wide)	Medium (water depth, 3 - 5)	Rock scattered	Medium	Poor (water depth, 3 - 5)
Left Bank	Long and flat (low)	Long and flat (low)	Long and Flat (low)	Fairly Good	Long and flat (low)
Geological Condition	Two depression zones to be acrossed. Lowered the rock line at the right bank. Thick soll at the right bank.	One depression zone to be acrossed. Rock line of the right bank is El. 383 m.	One depression zone to be acrossed. Rock line at the right bank is below El. 390 m.	One depression zone at the 100 m upstream of the axis. Rock line lowered at the right bank (El. 375 m).	Faults problem (active or stable) should be clear. Very thick laterite at the right half of the axis.
Local Communication	Expected to improve	Expected to improve	Not change	Not change	Change to Inconvenient
Impact to Memve Ele waterfalls	Not serious	Not serious	Not serious	Not serious	Not serious
Recommendation	To be abandoned	To be abandoned	To be abandoned	To be studied	To be abandoned

Table 3.4.1 Construction Materials

1) Alternative Damsite and Dam Type

Alternative Damsite 1, 2, 3, 4, 5: Zoned Earthfill Dam
(Earthfill, Filter, Drain, Rock and Random zone)

2) Dam Type and Source of Construction Material

Damsite,	Borrow nos of Impervious core	Filter Sand / Rock fill
1.	E1, E7, E8	S1, S2/R1, R3
2.	E2, E3, E6, E7	S1, S2/R1, R3
3.	E2, E3, E6, E7	S1, S2/R1, R3
4.	E2, E3, E6, E7	S1, S2/R1, R3
5.	E4, E5, E6	S1, S2/R1, R4
6.	------------	S1, S2/R1, R2

Table 3.4.2 Design Parameters of Embankment Materials (for Preliminary Design)

Item	Earthfill Zone	Filter Zone	Rockfill Zone (Riprap)
Specific Gravity (Gs)	2.68	2.7	2.7
Dry Density (rd t/m3)	1.7	2.2*	2.7*
Void Ratio (e)	0.56	0.5	0.01
Wet Density (rt t/m3)	2.02	2.3*	2.7
Water Content (W %)	20.8#	10*	5*
Effective Cohesion (C' t/m3)	0.5*	0*	0*
Effective phi (p)	21	26*	40*
Coefficient of Permeability (K cm/sec)*	1 x 10 - 6	1 x 10 - 2	free-draining

Seismic coefficient (G) ------------- k = 0.01 (for 100 years)

Note *: the figures are inferred from the relationship between the other available data, or derived from empirical way.

#: the figure is the same figure of the optimum moisture content obtained by compaction test.

Table 3.4.3 Material Quantities

Materials		Estimated Volume (cubic meters)	Location
Earth fill	E1	>450,000	600m upstream of Village boat station. Right bank top of alternative dam axis 1. Checked by TP 9 to TP 12, BD 16 and BQ 17.
	E2	>300,000	Right bank top of alternative dam axis 3. Checked by TP 14.
	E3	>750,000	Right bank top of alternative dam axis 4. Checked by TP 3, SD4(2) and BD 1.
	E4	>360,000	Right bank top of the Ntem river between Njoo and Biwome rivers. Checked by TP 2.
	E5	>682,500	Left bank of alternative dam axes. Checked by SW 2.
	E6	>900,000	Left bank of alternative dam axes. Checked by TP 7.
	E7	>562,500	Left bank of alternative dam axis 1 and 2. Checked by TP 5 and 6.
	E8	>300,000	Left bank of alternative dam axis 1. 400m NW of Aloum 1 village.
River sand	S1	200,000	600m upstream of Village boat station. Immediately downstream of alternative dam axis 1. Submerging at rainy season.
	S2	some 10,000 (Unknown)	Along the river course of Ntem river (upstream). Not available in rainy season (submerging).
Quarry Rock	R1	1,440,000	Steep ridge along the waterway route between Pondage site and Reservoir area. Top soil is within a few meters. Checked by BW 11.
	R2	720,000	Terrace along Gorge Du Ntem. Rock will come from the excavation of P/H and tail race waterway. Checked by BQ 13 and BQ 14.
	R3	3,000,000 (Assumed)	4km ESE of waterway and 4km SSE of dam sites. Future survey is needed (no data is available).
	R4	Unknown	8 to 10km WNW of alternative dam axis 5. Downstream right bank of Ntem river, Ebungu. Rock exposed.

Table 3.5.1 Environmental Checklist (1)

	Check Items	Major	Small	None	Not Clear	Problems	Action & Countermeasures Planned	Remarks
Pollution	1. Deterioration of water quality (including detrimental changes in water temperature) in the dam reservoir and downstream			X				The water quality in the reservoir and the downstream can be diluted and kept clean by circulation of reservoir water in a short period (2 to 3 days) because of the run-of-river type development.
Natural Environment	1. Effect on ecology		X			The reservoir created by dam construction has an area of 19 km2. Water rise due to the dam is about 10m. A part of equatorial forest will be submerged and animals living in this area will be ridded to the surrounding.	In the swamp zone sharing large part of the submerged area, there are many wild palm trees and few marketable trees. As to the marketable trees growing on the higher land, following measures are conceived. 1) allocation of felling/cutting of marketable trees in the reservoir area to forest exploiters. 2) Having contracts with peasant woodcutters for opening and clearing hauling roads. To protect the animals in the reservoir area from drowning and being isolated in small islands, it is recommended to carry out beating drums and gun shots in the air regularly for many days before impounding the reservoir.	
	2. Effect on landscape					Memve Ele waterfalls having a height of 35m exist just downstream the proposed dam site. It is considered that the discharge passing through the falls become small due to diversion of water for power generation.	There are two tributaries, the Ndjo'o and Biwome, jointing with the Ntem river between the dam site and Memve Ele falls. The average discharge of both the Ndjo'o and Biwome 28m3/sec can be used as a compensation flow. Furthermore, river outlet facilities will be provided for the dam body.	The dam site is located at the very remote area and the transportation means are poor. So, the tourism for this area is not popular now.
Socio-economic Environment	1. Effect of construction of the facility on the historical and cultural heritage			X				The influence zone close to the project possesses little historical and cultural heritage.
	2. Effect on existing Infrastructure			X				There is no specific infrastructure to be affected by the project devcelopment.
	3. Resettlement		X			Numbers of houses affected are only 9.	The cost of resettlement is estimated at 7.5 million F.CFA. The compensation cost for the cultivated lands and agriculture is greater than that of resettlement and estimated at around 80 million F. CFA.	

Table 3.5.1 Environmental Checklist (2)

Socio-economic Environment	4. Effect on traffic mean		X			The public road connecting Ma'an with Nyabessan will be cut of by submergence at two bridges, near Alen II and between Nemeyong and Alen I.	The formation height of road near the bridges may be elevated by embankment and replacement of the bridges (span is less than 10m) will be required. The transportation mean to cross the Ntem river is carried out by a canoe. The dam crest road can be utilized for communication between Nyabessan village and villages at the opposite bank.	
	5. Effect on other downstream water utilization			X				Water used for the power generation is put back to the Ntem river at the tailrace outlet about 4km downstream of the dam. There is no private house along the river course between the dam site and the tailrace outlet. As the project is of run-of-river type, the flow condition downstream the tailrace outlet will not change remarkably but be a little regulated.
	6. Occurrence of diseases such as malaria, caused by insects or water		X			The entomological investigation assesses the existence of notable vectors, simulium of human onchocera (creeping disease), anopheles of malaria and tse-tse flies of sleeping sickness (trypanosomiasis)from the view point of medical and veterinary interest.	It is important to envisage an adequate anti-vector campaign program based on local strategies. While hygienic measures and health education are also important to the population.	
Others	1. Effect on the environment during construction period		X			As there is few private house around the construction site, noise and vibration by construction will not affect on the residents. However, it is expected that vehicle for transportation of construction materials and equipment will cause noise and vibration and affect on the residents living along the existing road.	The road will be improved by grading and widening, and speed limitation should be considered before the commencement of construction.	
	2. Environmental Monitoring		X				The monitoring for the health problem due to creation of water impounding reservoir is very important for the project.	In general it has been assessed that impact on the environment is not serious in comparison with other hydropower projects because of the run-of-river type development.

Table 3.6.1 Geological Investigation Works

Location	Drilling (* - 1)		Seismic Prospecting (km)	Laboratory Test		In-situ Rock Test	Test Pit	
	Number of Holes	Total Length (m)		Number of Test for Soil	Number of Test for Rock		Number of Pits	Total Length (m)
Main Dam	30	620	2.0	20	30	-	8	64
Waterway	40	1,000	4.0	20	20	-	6	48
Penstock Intake Dam	8	240	0.6	10	10	-	6	48
Powerhouse	3	180	-	-	10	6	-	-
Borrow Area	4	120	-	20	-	-	10	80
Quarry Site	5	100	1.0	-	10 (* - 2)	-	-	-
Total	90	2,260	7.6	70	80	6	30	240

<Note> (* - 1): Permeability tests are carried out in some drill holes.
(* - 2): Alkali aggregate reaction test by Mortar bar method is included.

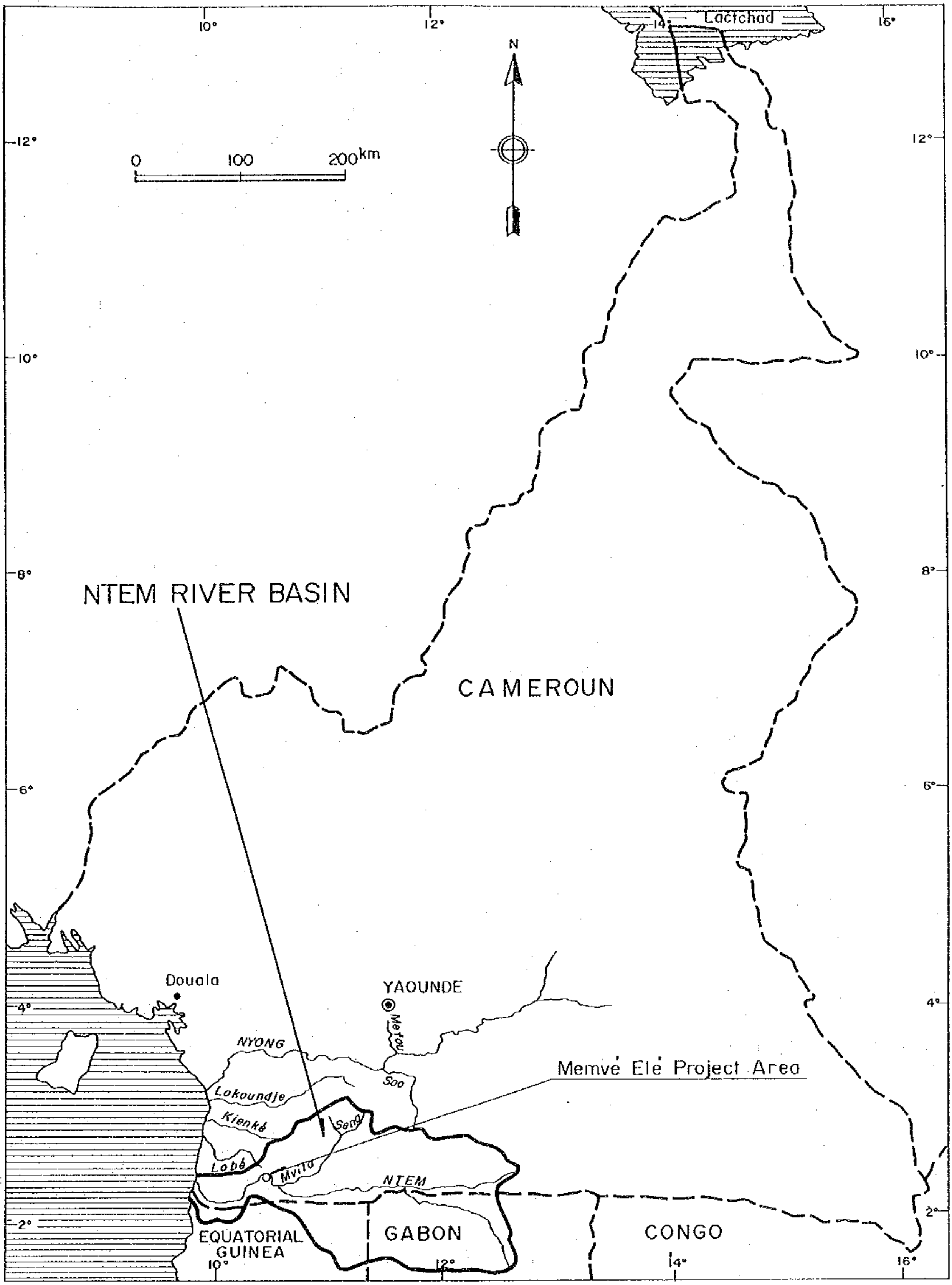

Fig. 3.2.1 LOCATION MAP OF THE NTEM RIVER BASIN

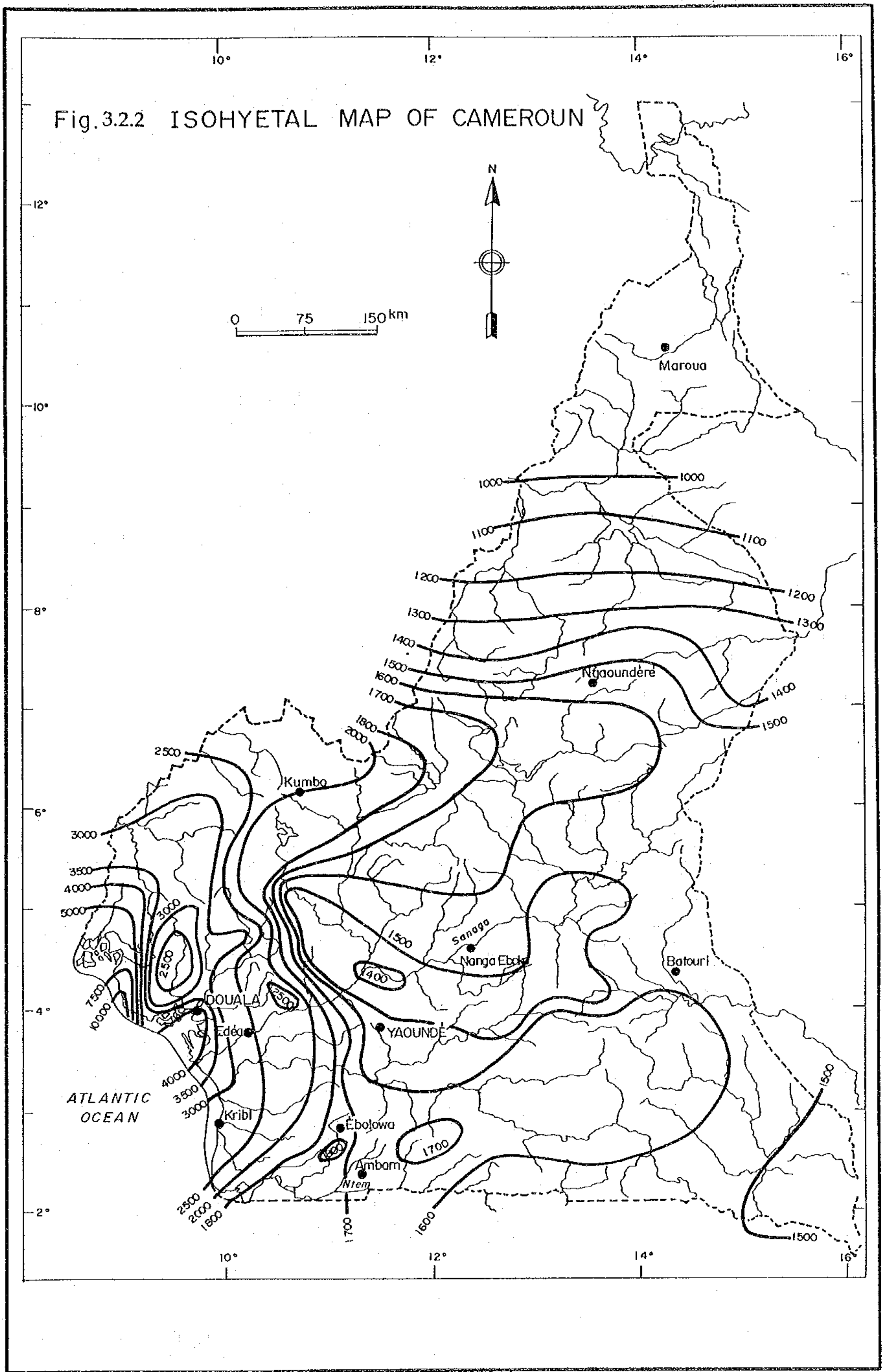
Fig.3.2.2 ISOHYETAL MAP OF CAMEROUN
N
0 75 150 km
Maroua
Ngaoundere
Kumbo
Sanaga
Nanga Eboko
Batouri
DOUALA
Edéa
YAOUNDE
ATLANTIC OCEAN
Kribi
Ebolowa
Ambam
Ntem
1000
1100
1200
1300
1400
1500
1600
1700
1800
2000
2500
3000
3500
4000
5000
7500
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10°
12°
14°
16°
2°
4°
6°
8°

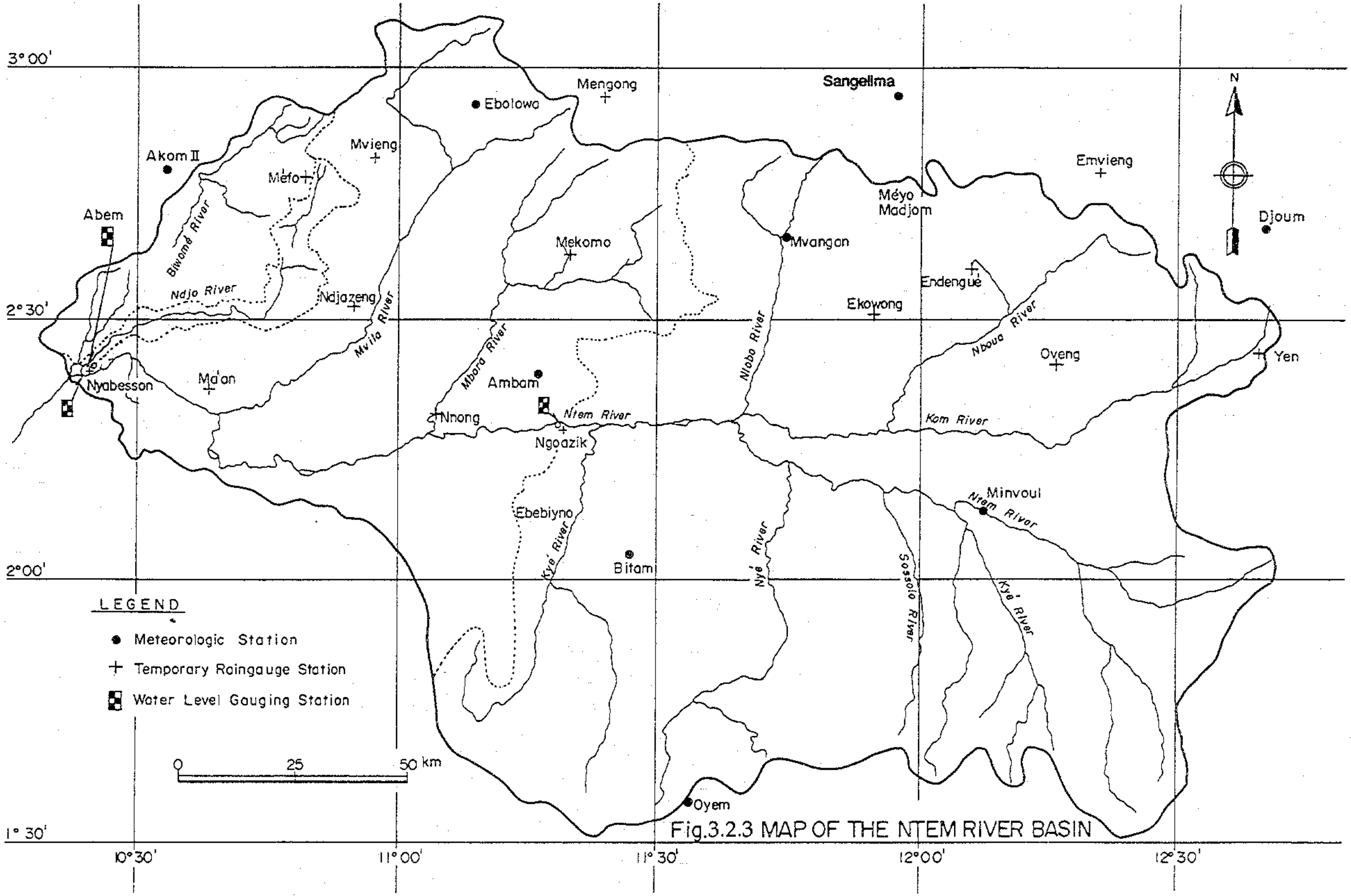


Fig.3.2.3 MAP OF THE NTEM RIVER BASIN

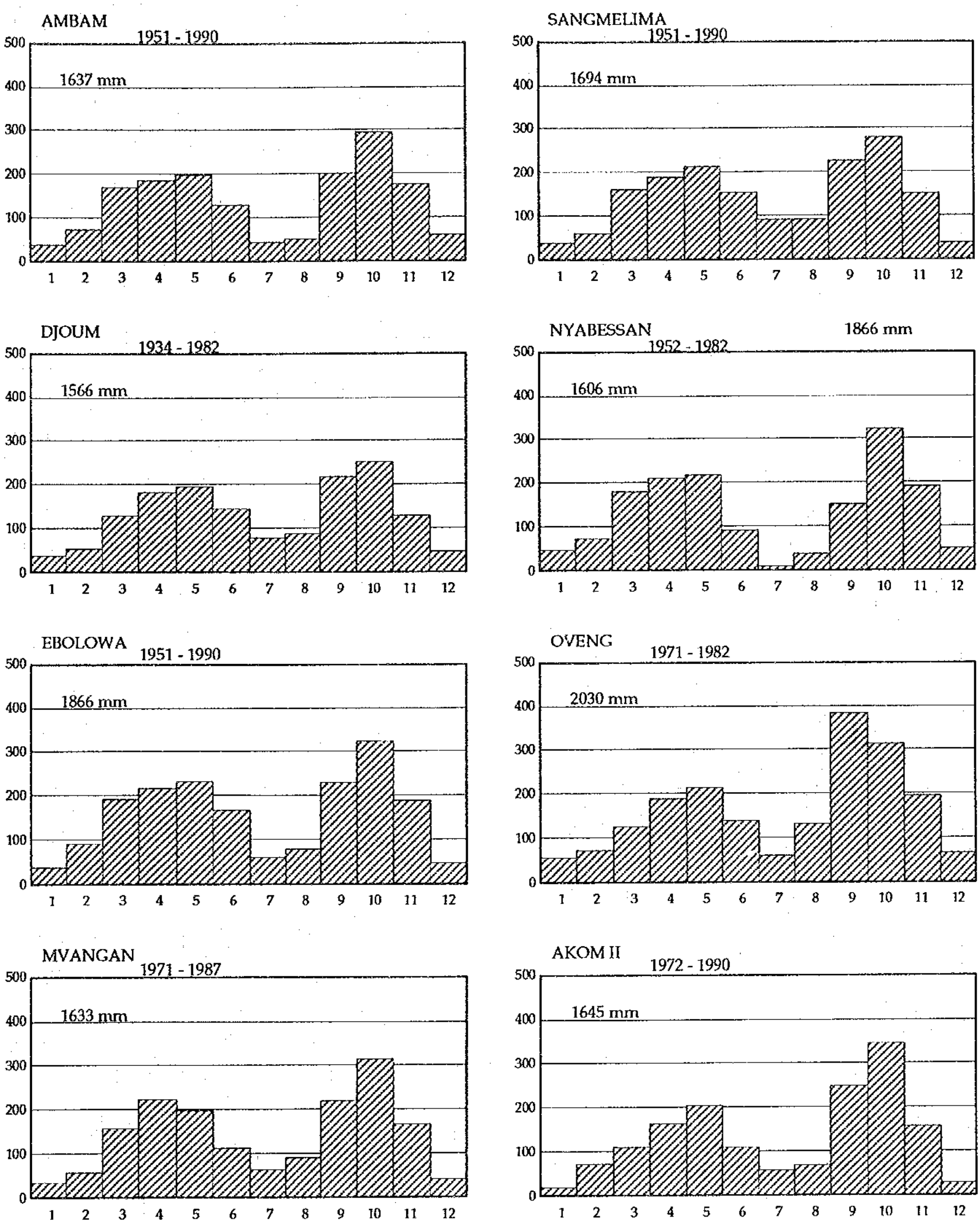
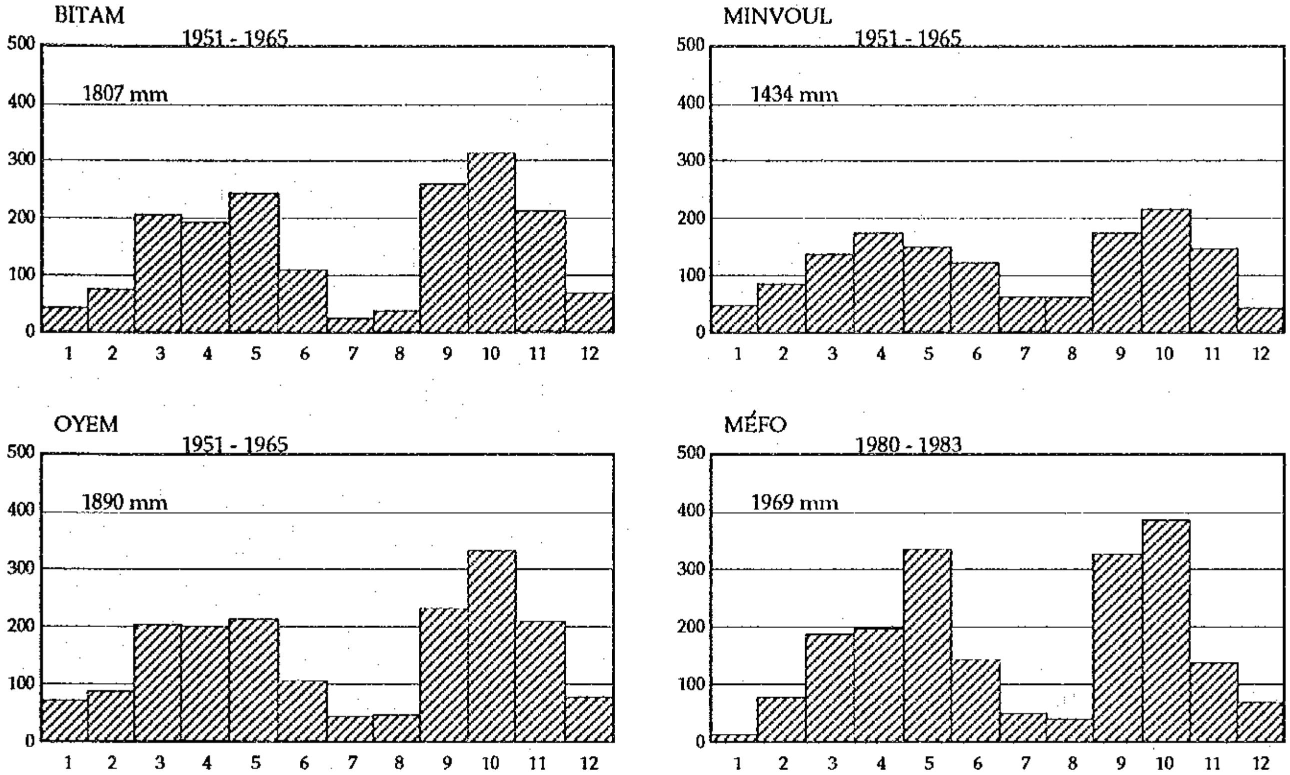


Fig. 3.2.4 (1) MONTHLY RAINFALL PATTERN OF EACH STATION



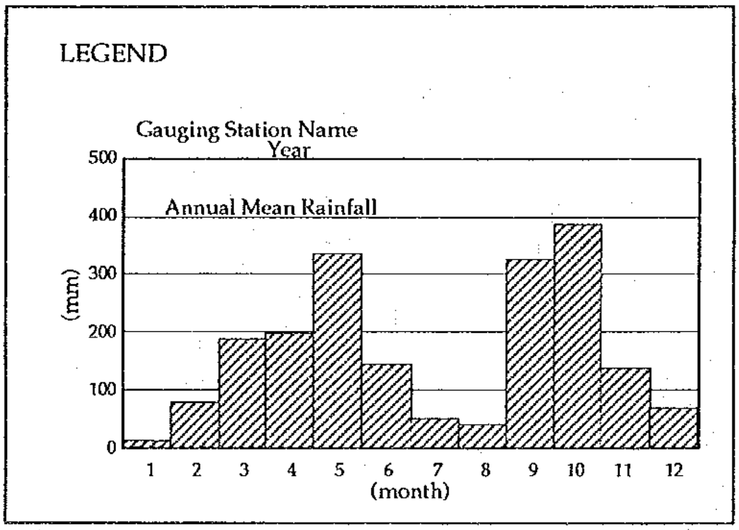


Fig. 3.2.4 (2) MONTHLY RAINFALL PATTERN OF EACH STATION

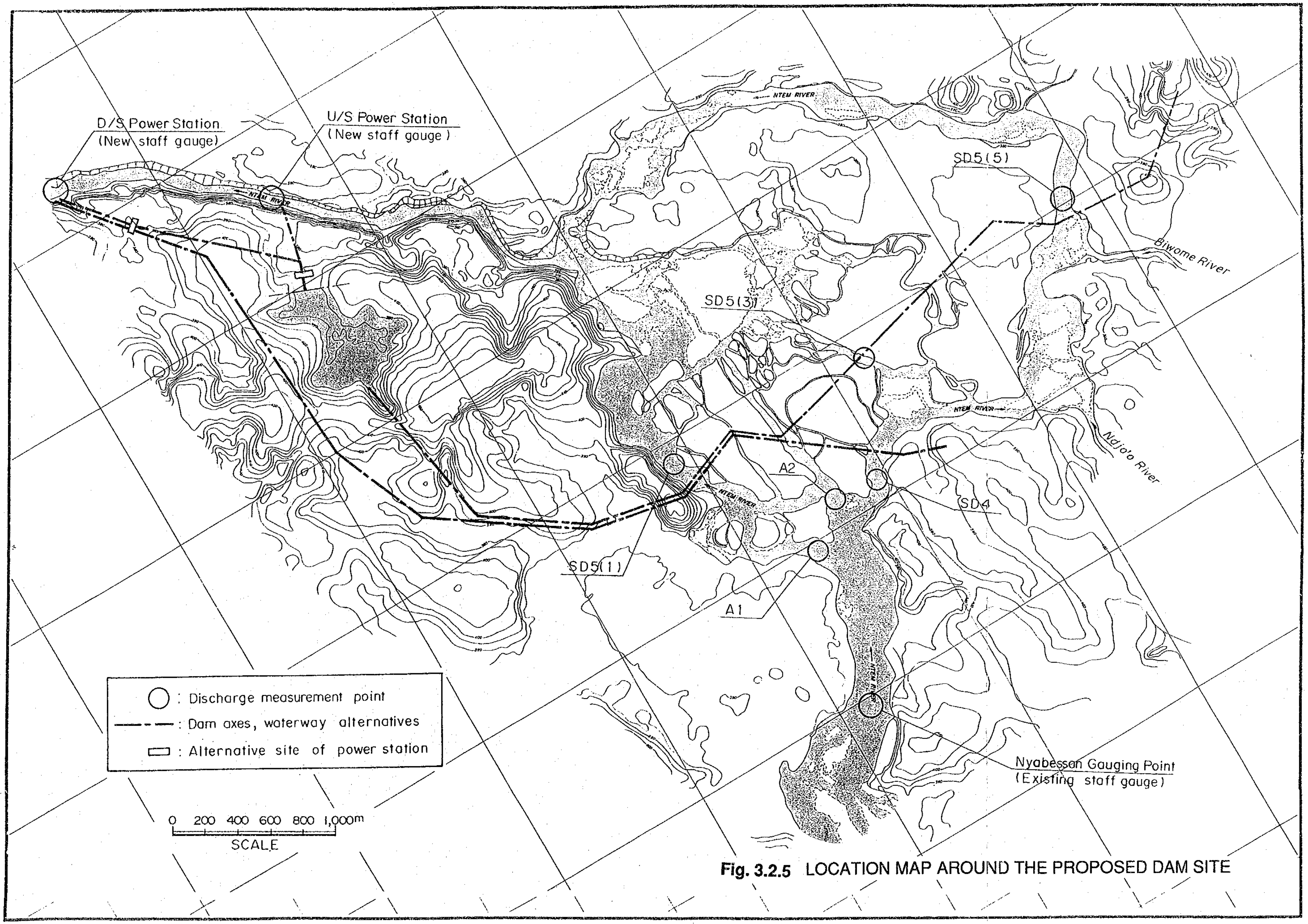


Fig. 3.2.5 LOCATION MAP AROUND THE PROPOSED DAM SITE

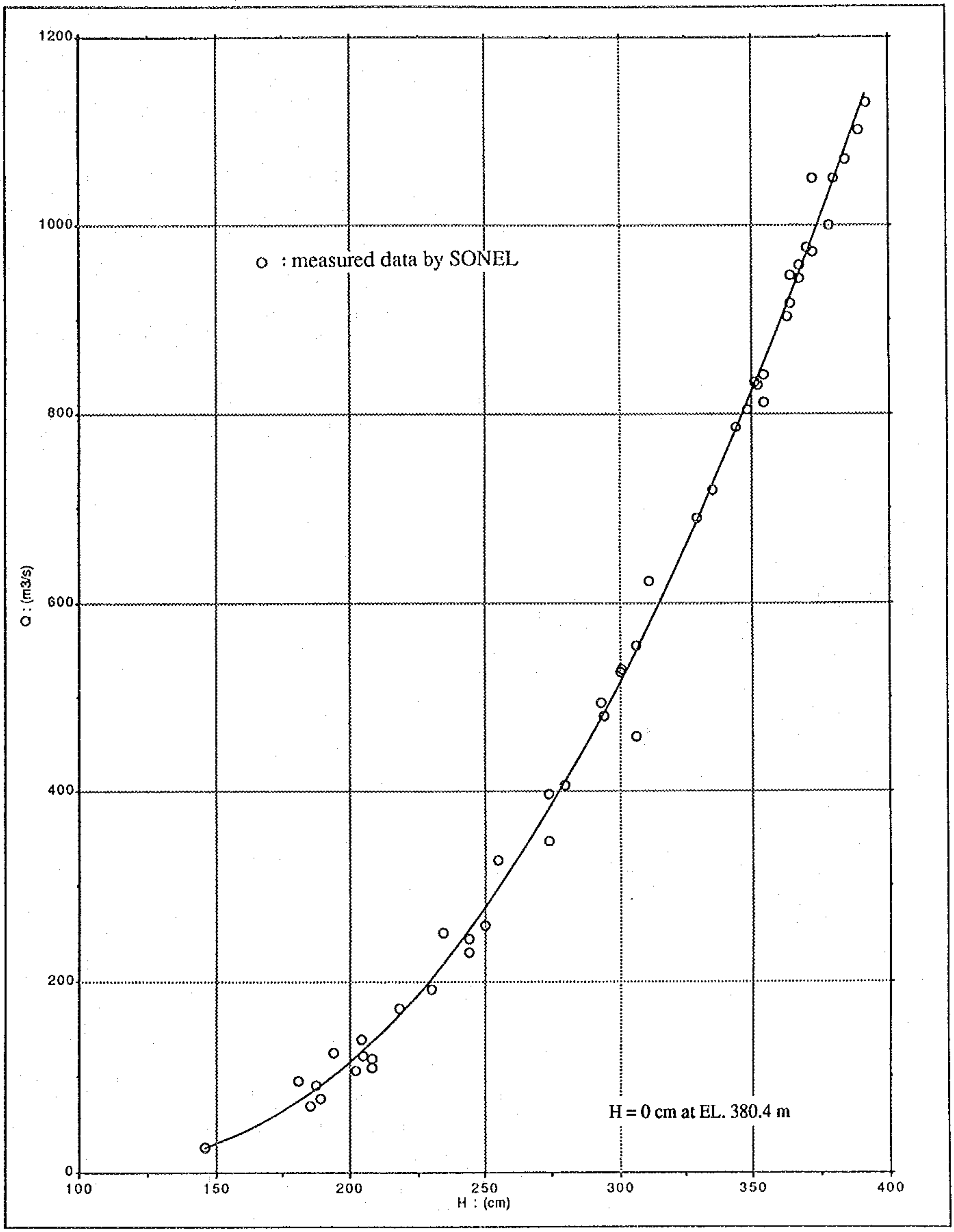


Fig.3.2.6 FLOW RATING CURVE AT NYABESSAN ON THE NTEM RIVER

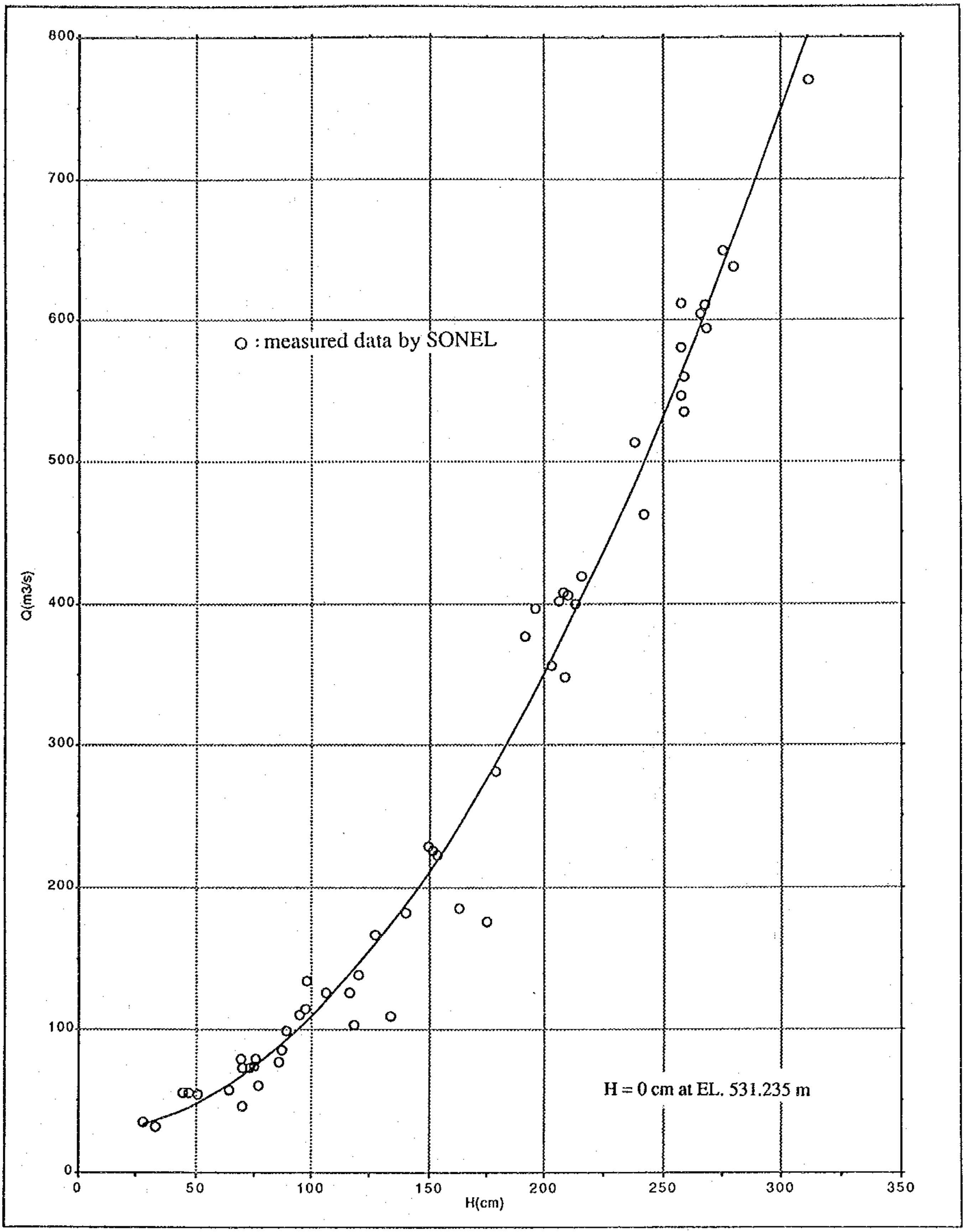


Fig.3.2.7 FLOW RATING CURVE AT NGOAZIK ON THE NTEM RIVER

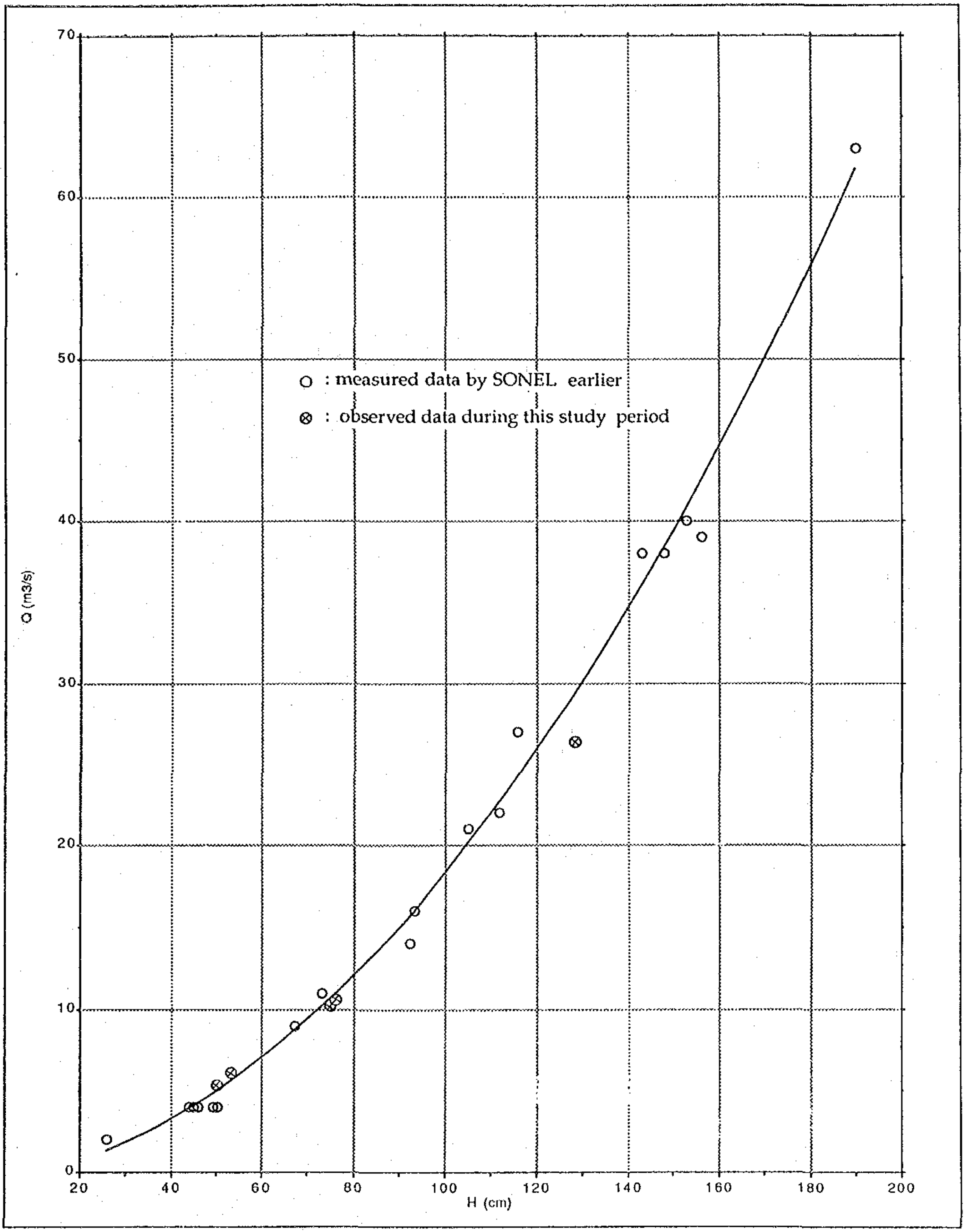


Fig.3.2.8 FLOW RATING CURVE AT ABEM ON THE NDJO'O RIVER

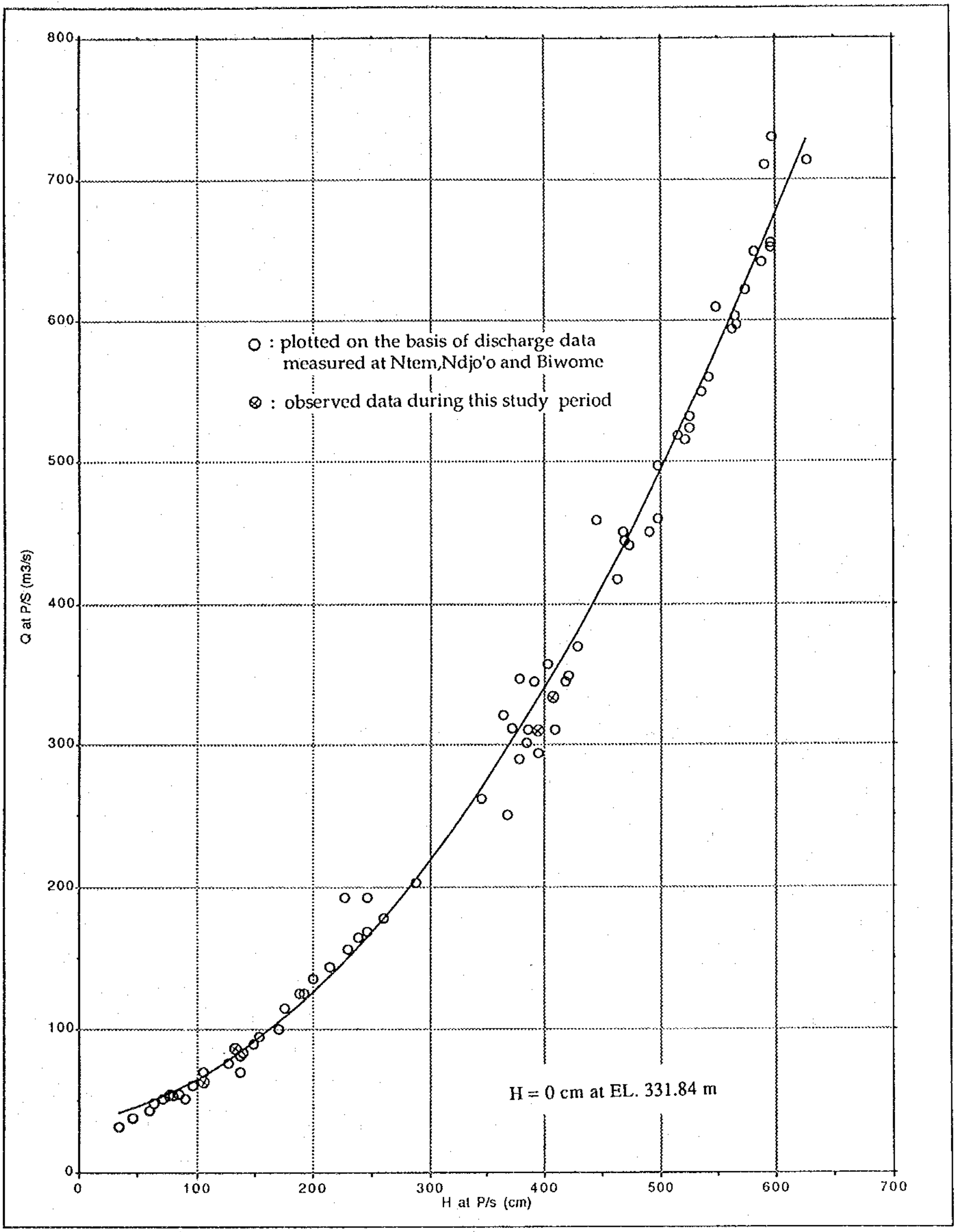


Fig.3.2.9 FLOW RATING CURVE AT DOWNSTREAM POWER STATION SITE

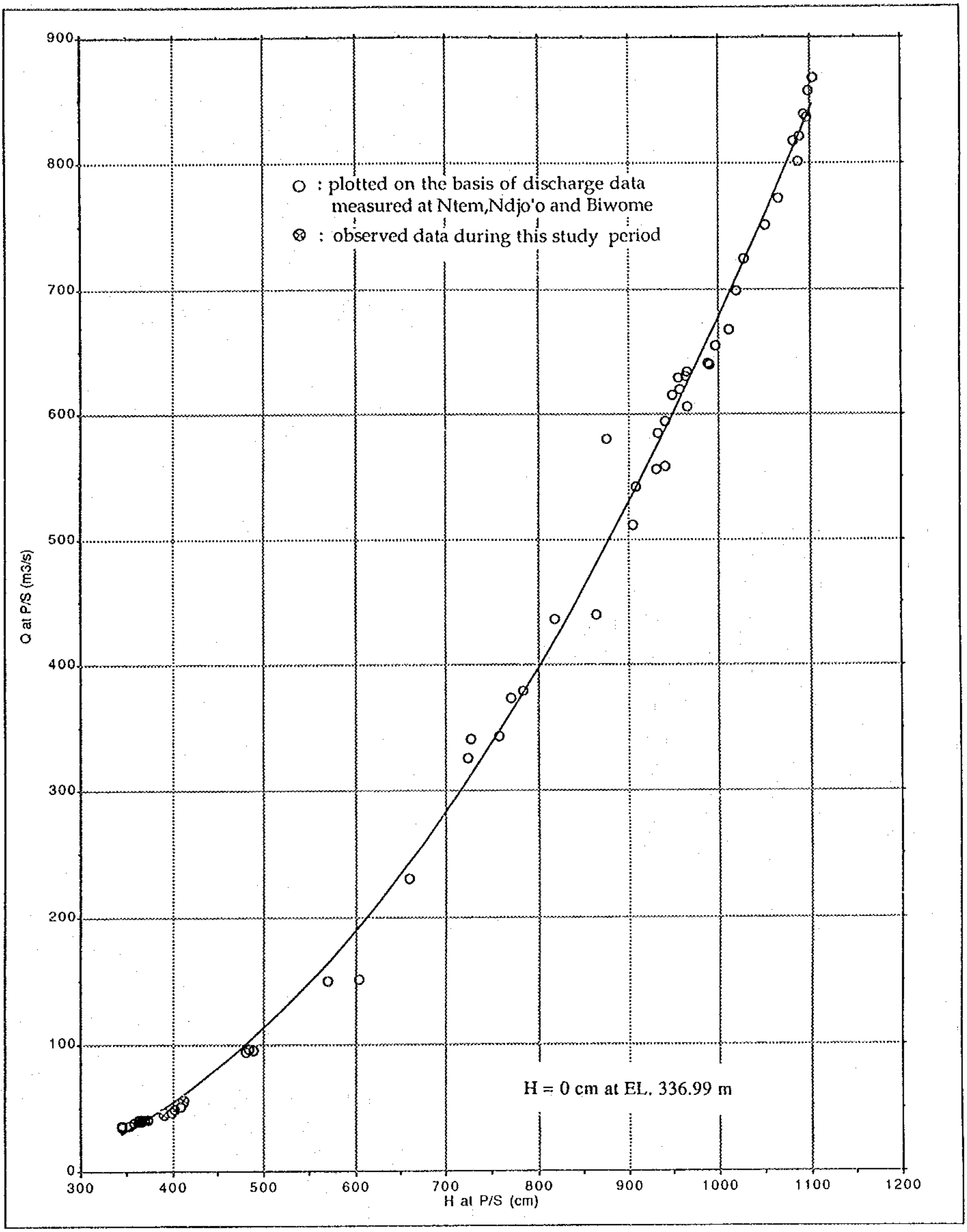
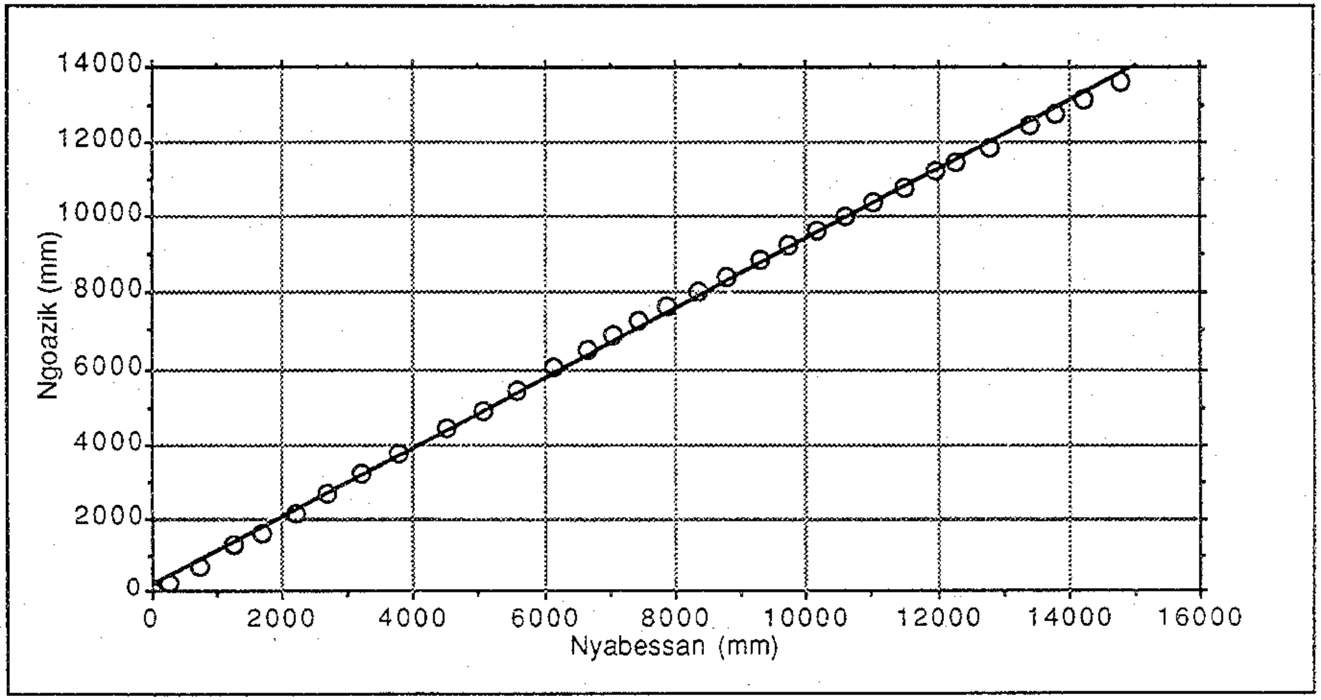


Fig.3.2.10 FLOW RATING CURVE AT UPSTRAEM POWER STATION SITE



(Data Period : 1958 - 1988)

Fig 3.2.11 RUNOFF MASS CURVE (Accumulated Annual Runoff Depth)

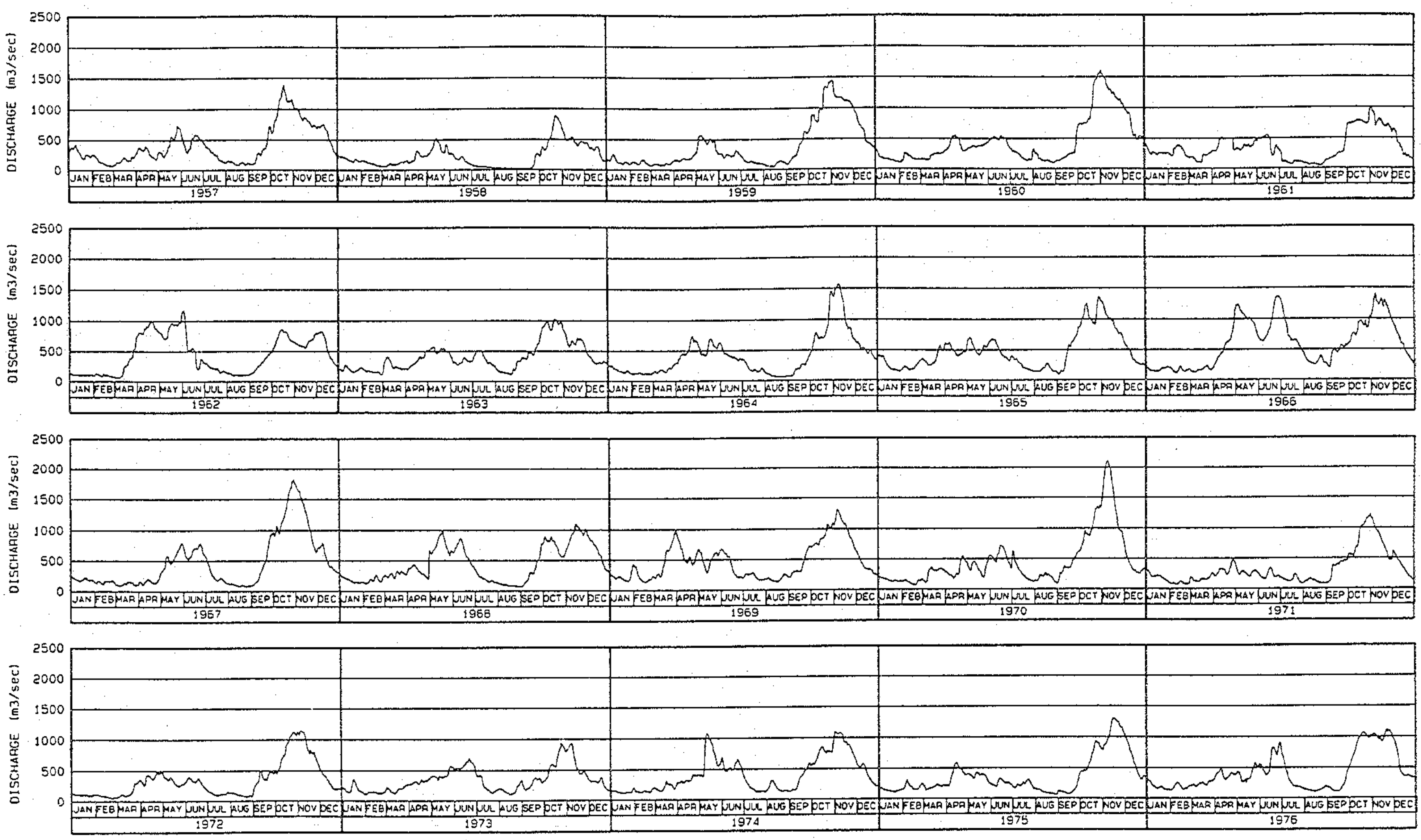


Fig.3.2.12(1) DAILY DISCHARGE RECORD AT NYABESSAN ON THE NTEM

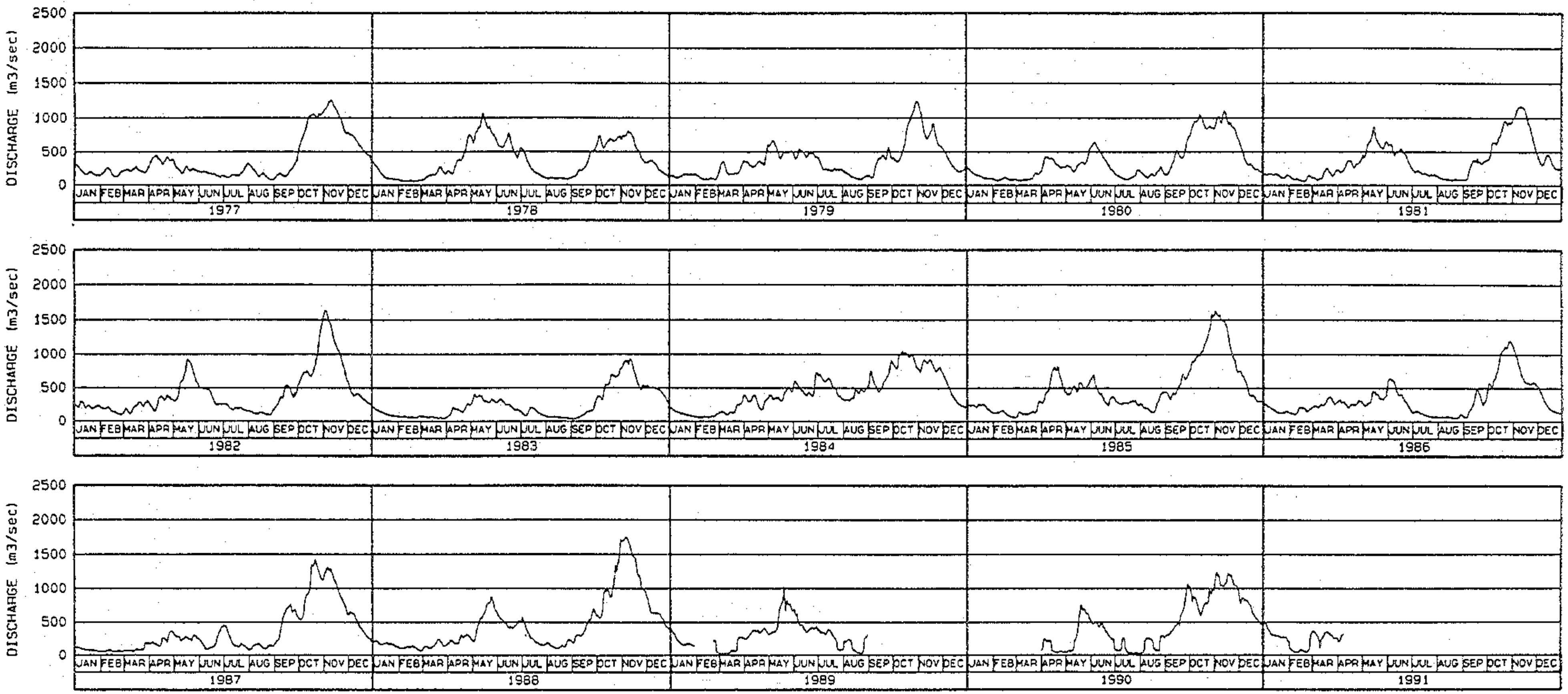


Fig.3.2.12(2) DAILY DISCHARGE RECORD AT NYABESSAN ON THE NTEM

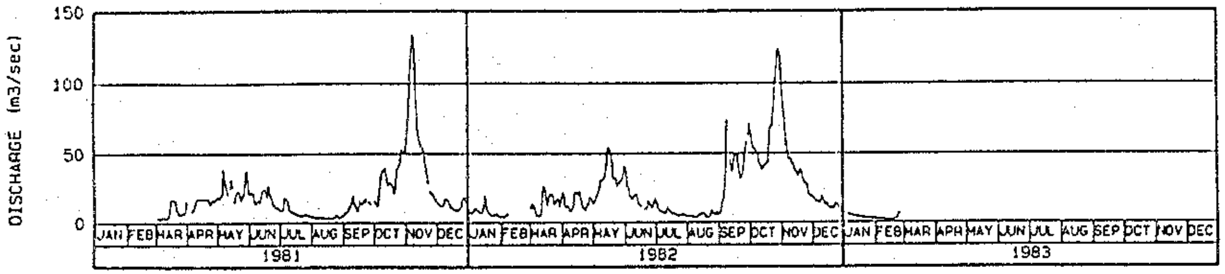


Fig.3.2.13 DAILY DISCHARGE RECORD AT ABEM ON THE NDJO'O RIVER

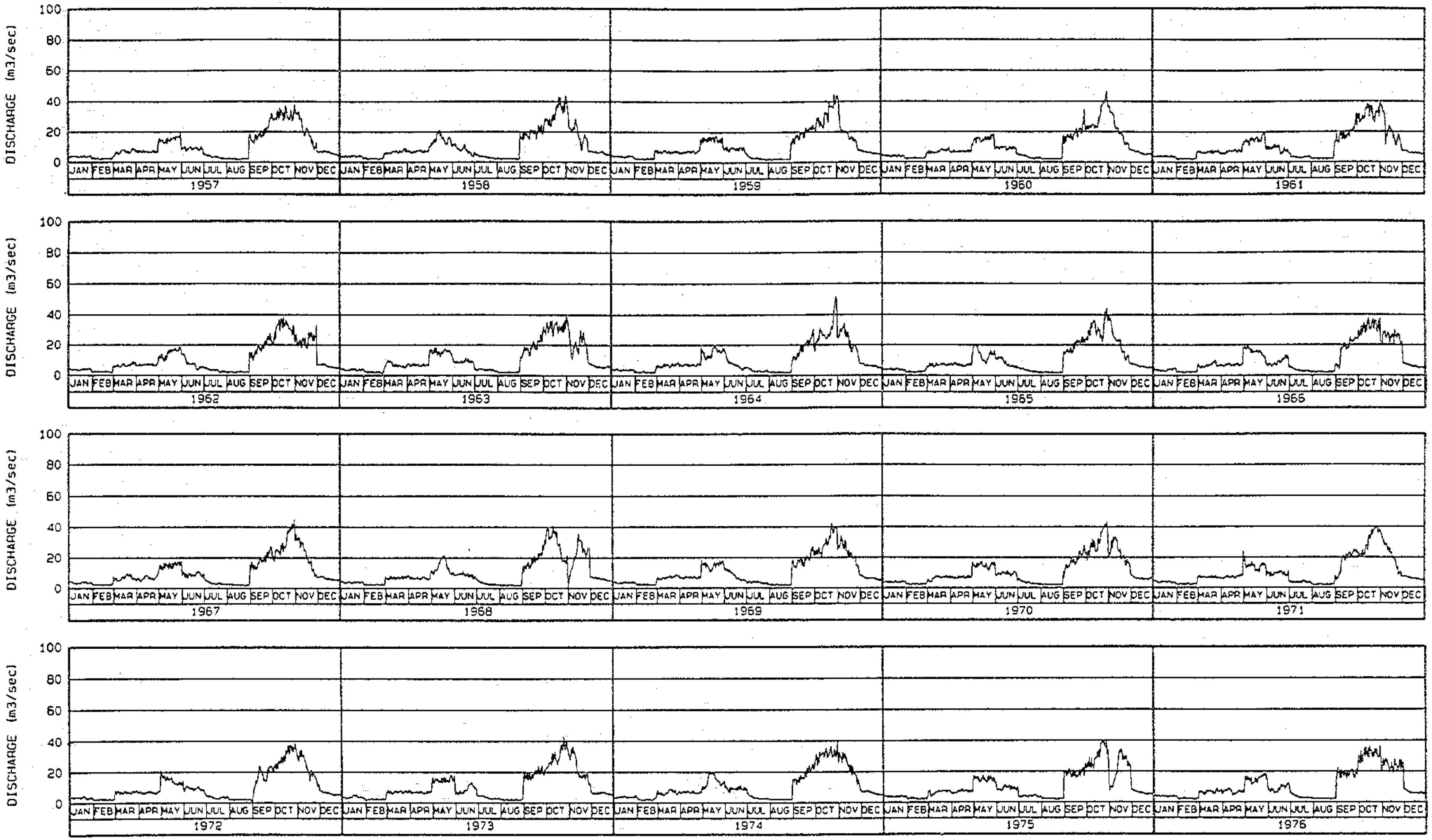


Fig.3.2.14(1) ESTIMATED DAILY DISCHARGE AT ABEM ON THE NDJO'O

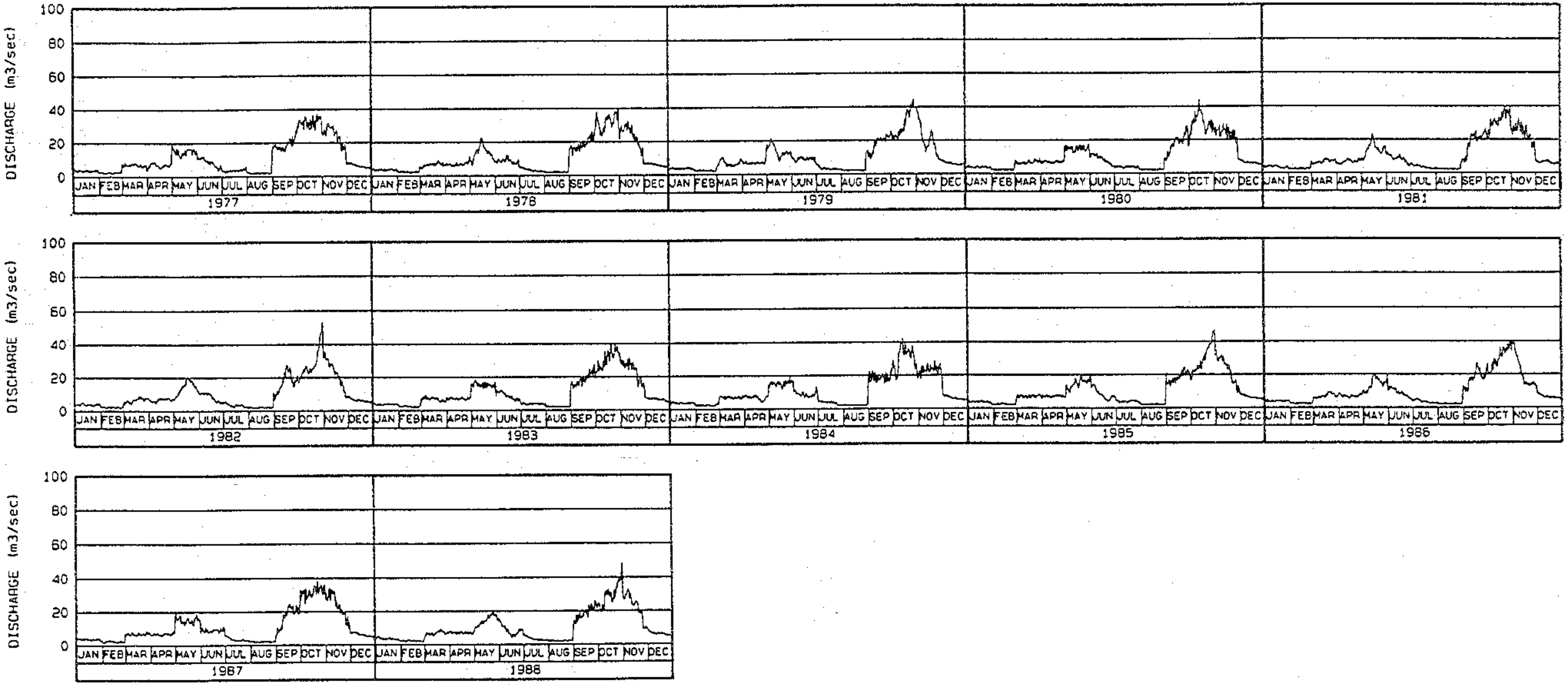


Fig.3.2.14(2) ESTIMATED DAILY DISCHARGE AT ABEM ON THE NDJO'O

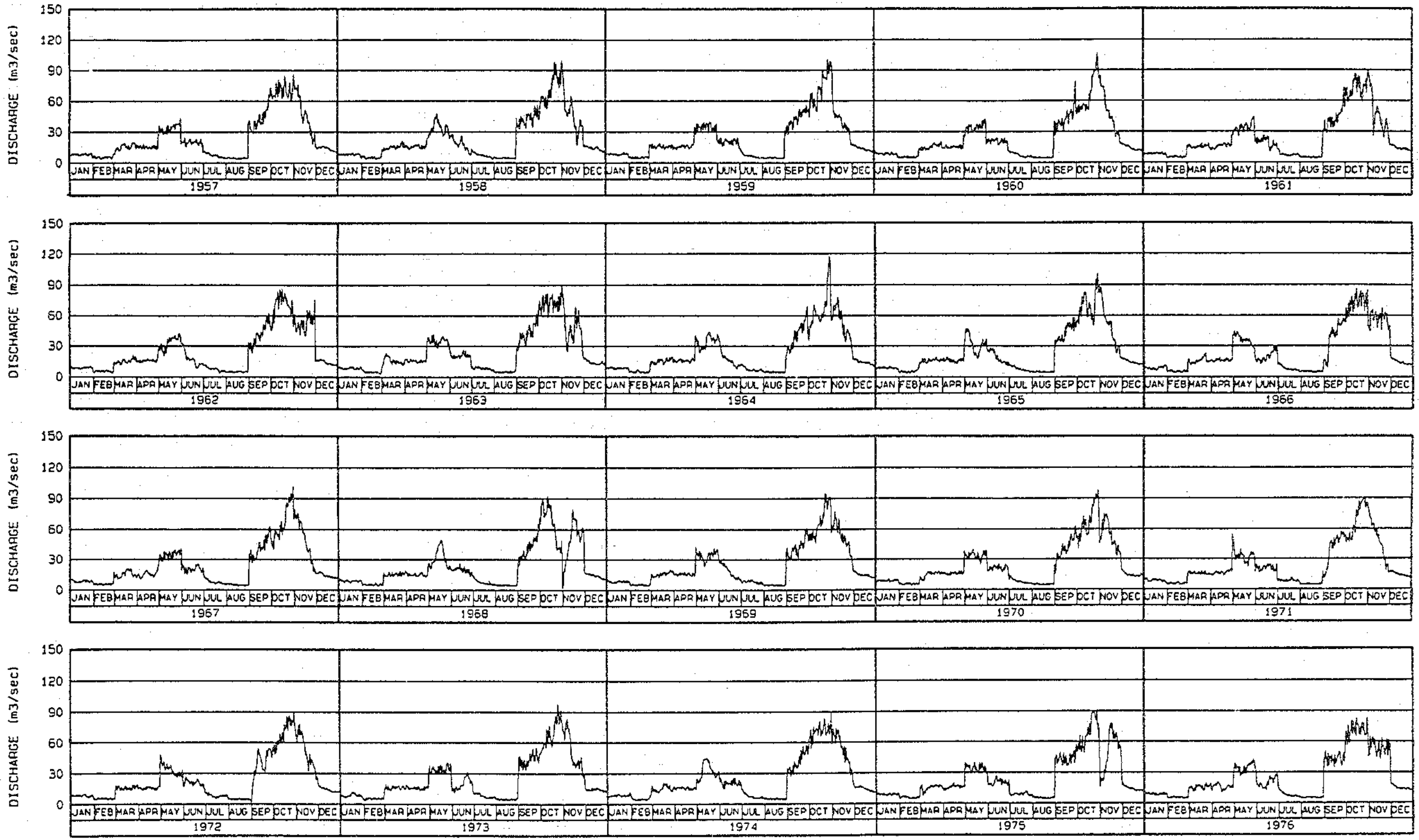


Fig.3.2.15(1) ESTIMATED DAILY DISCHARGE AT NYABESSAN ON THE BIWOME

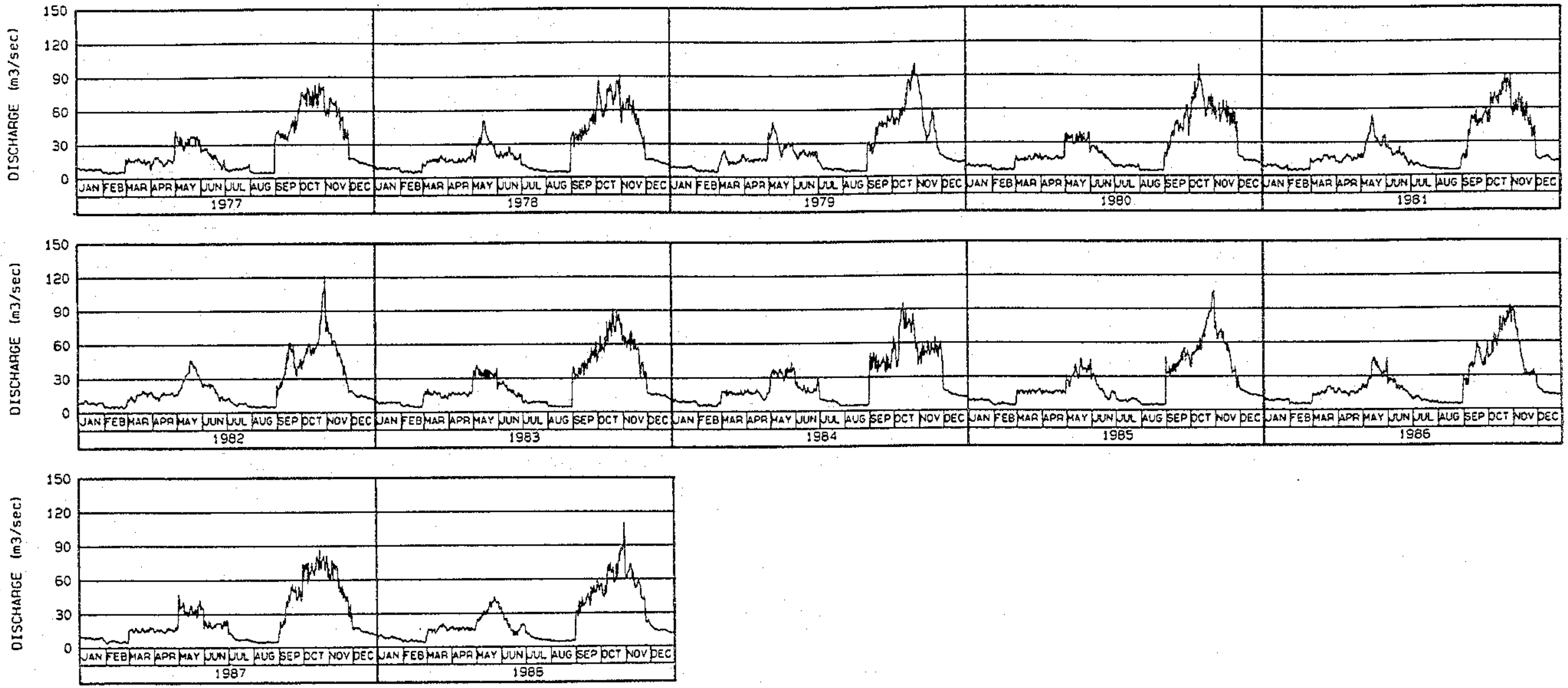


Fig.3.2.15(2) ESTIMATED DAILY DISCHARGE AT NYABESSAN ON THE BIWOME

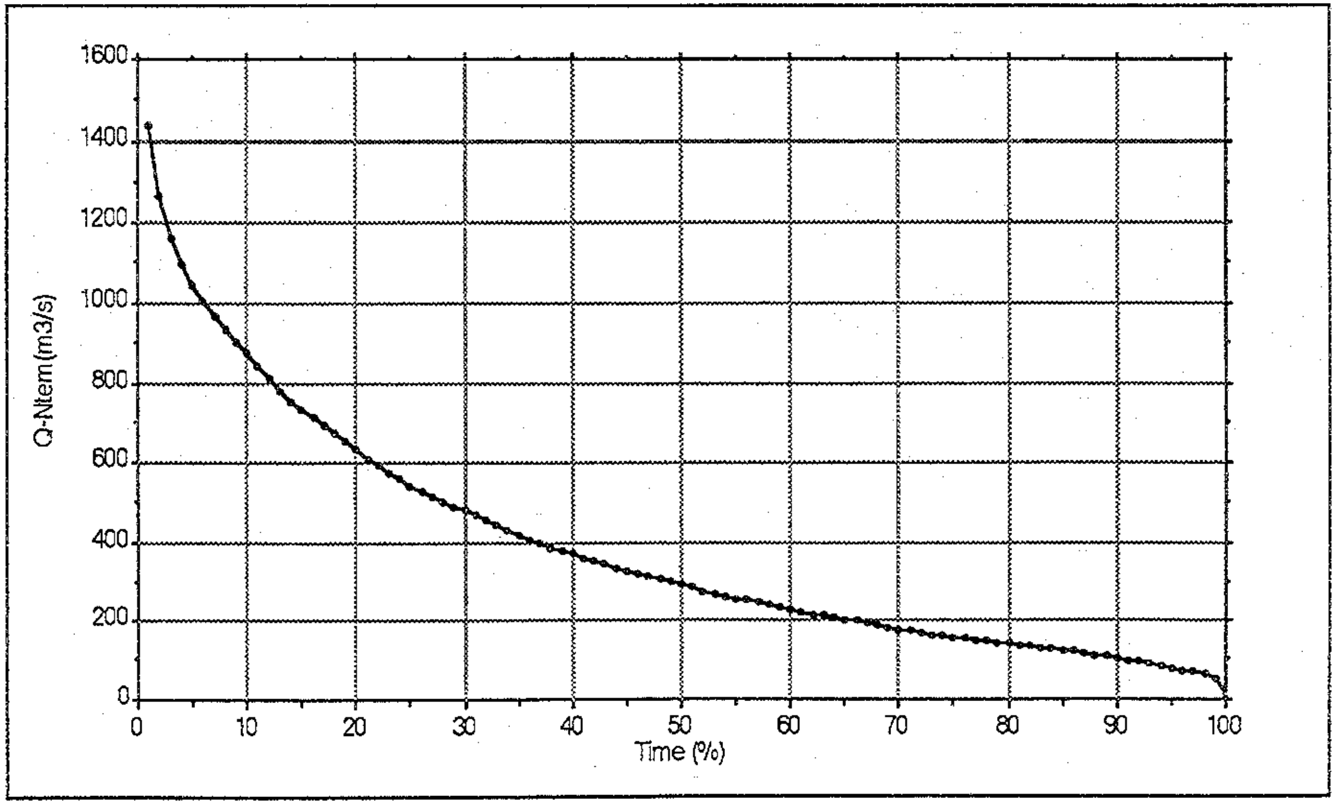


Fig.3.2.16 FLOW DURATION CURVE (NTEM)

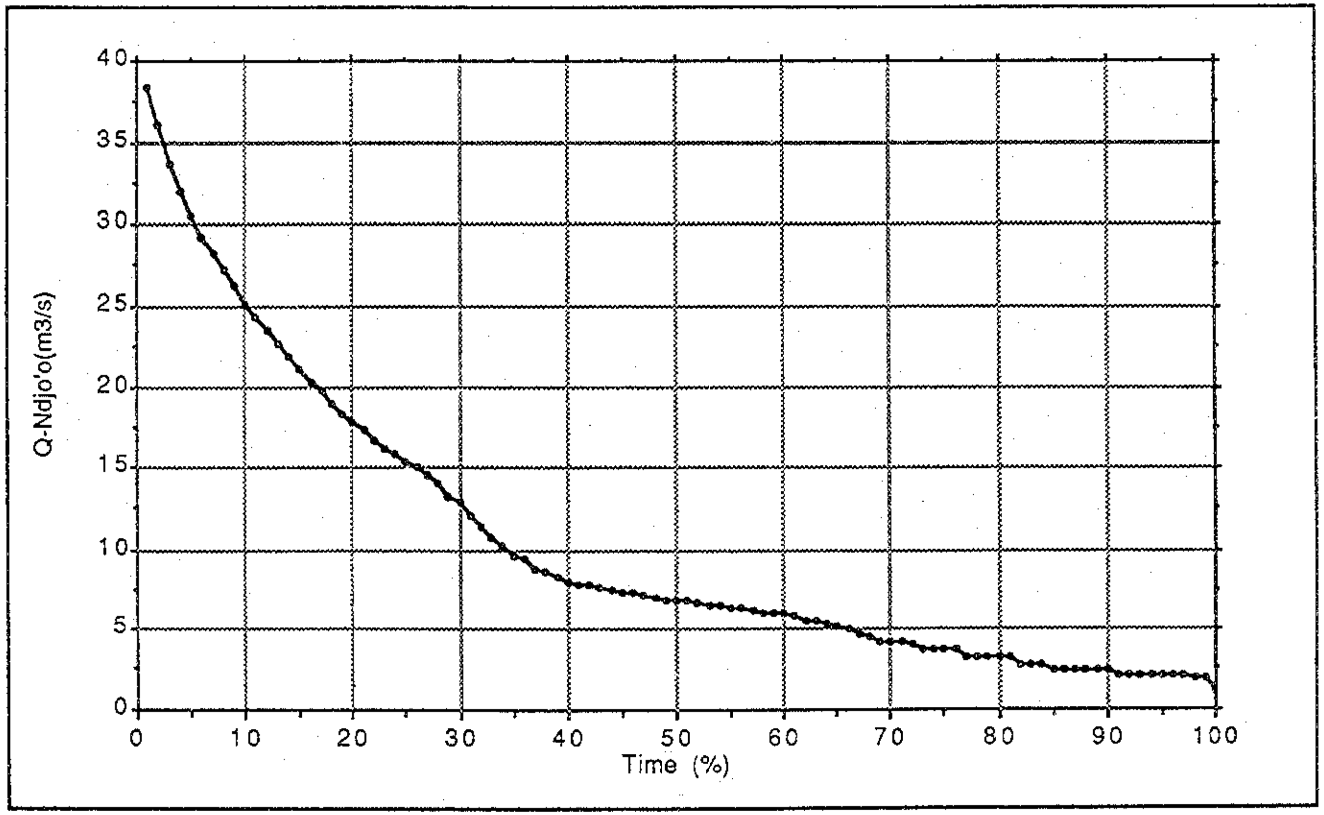


Fig.3.2.17 FLOW DURATION CURVE (NDJO'O)

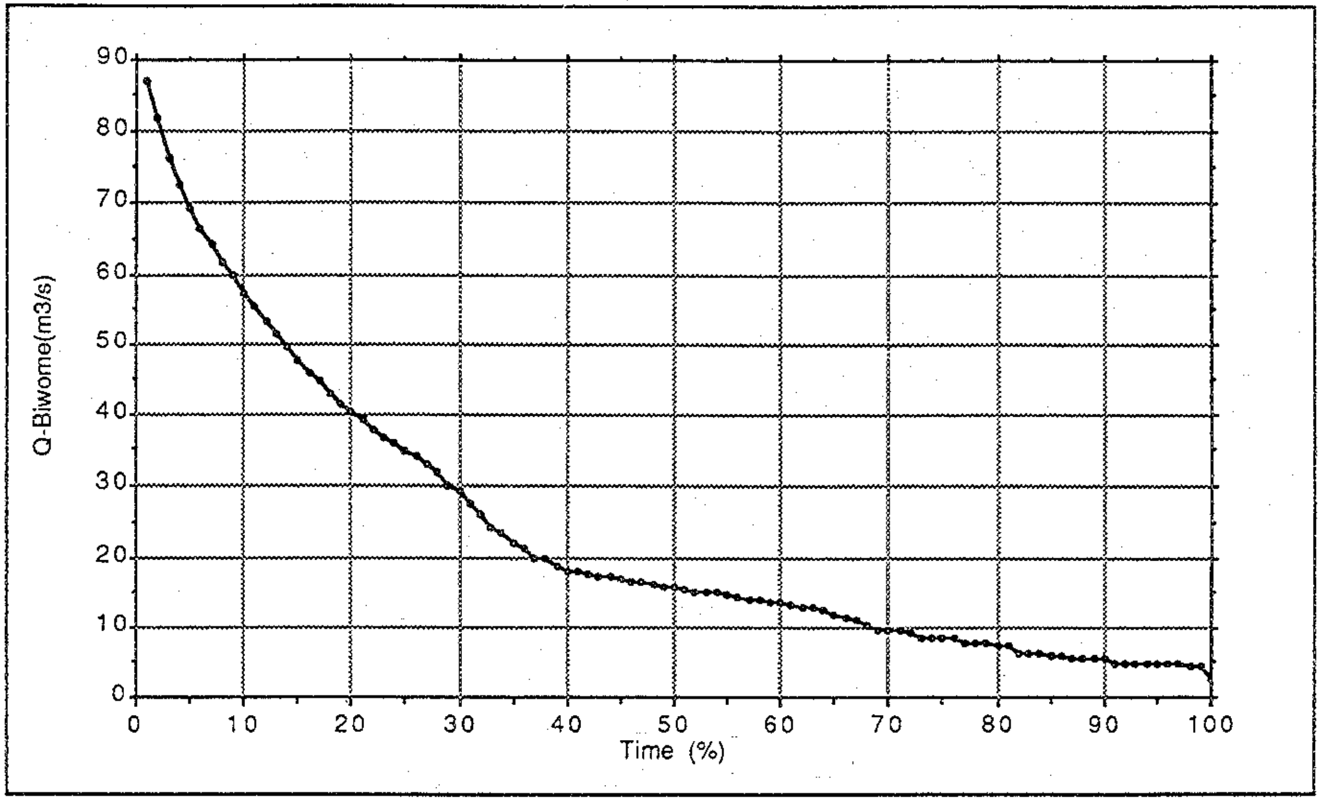


Fig.3.2.18 FLOW DURATION CURVE (BIWOME)

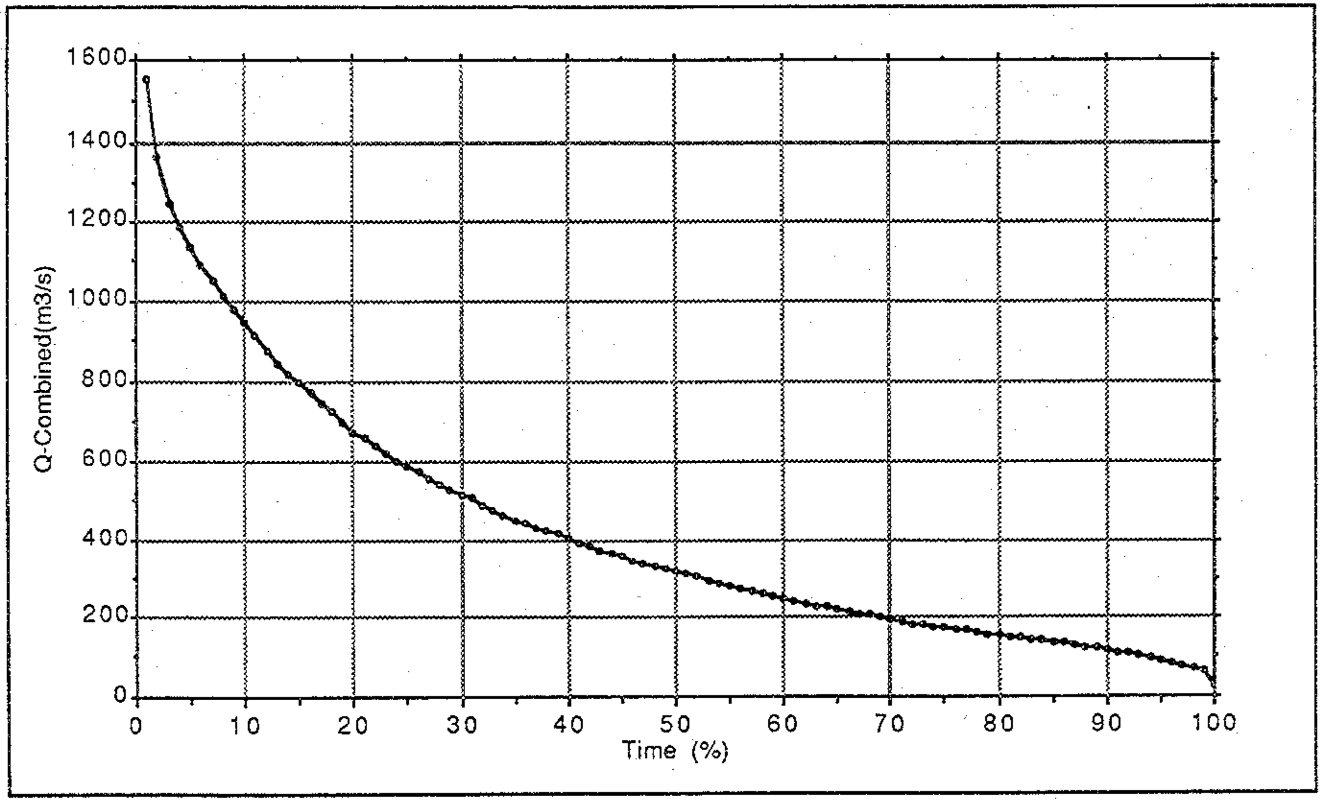
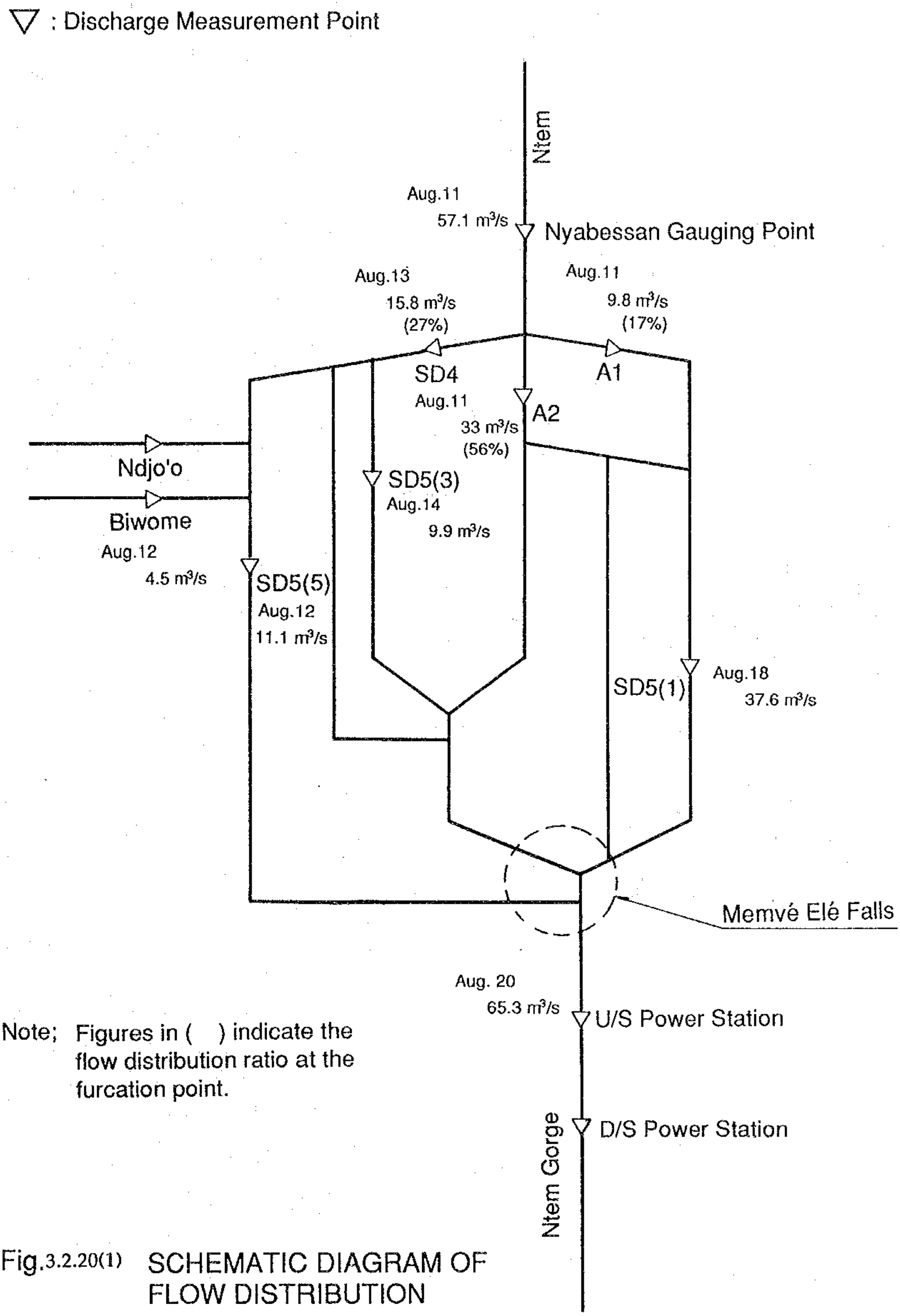


Fig.3.2.19 FLOW DURATION CURVE (COMBINED)

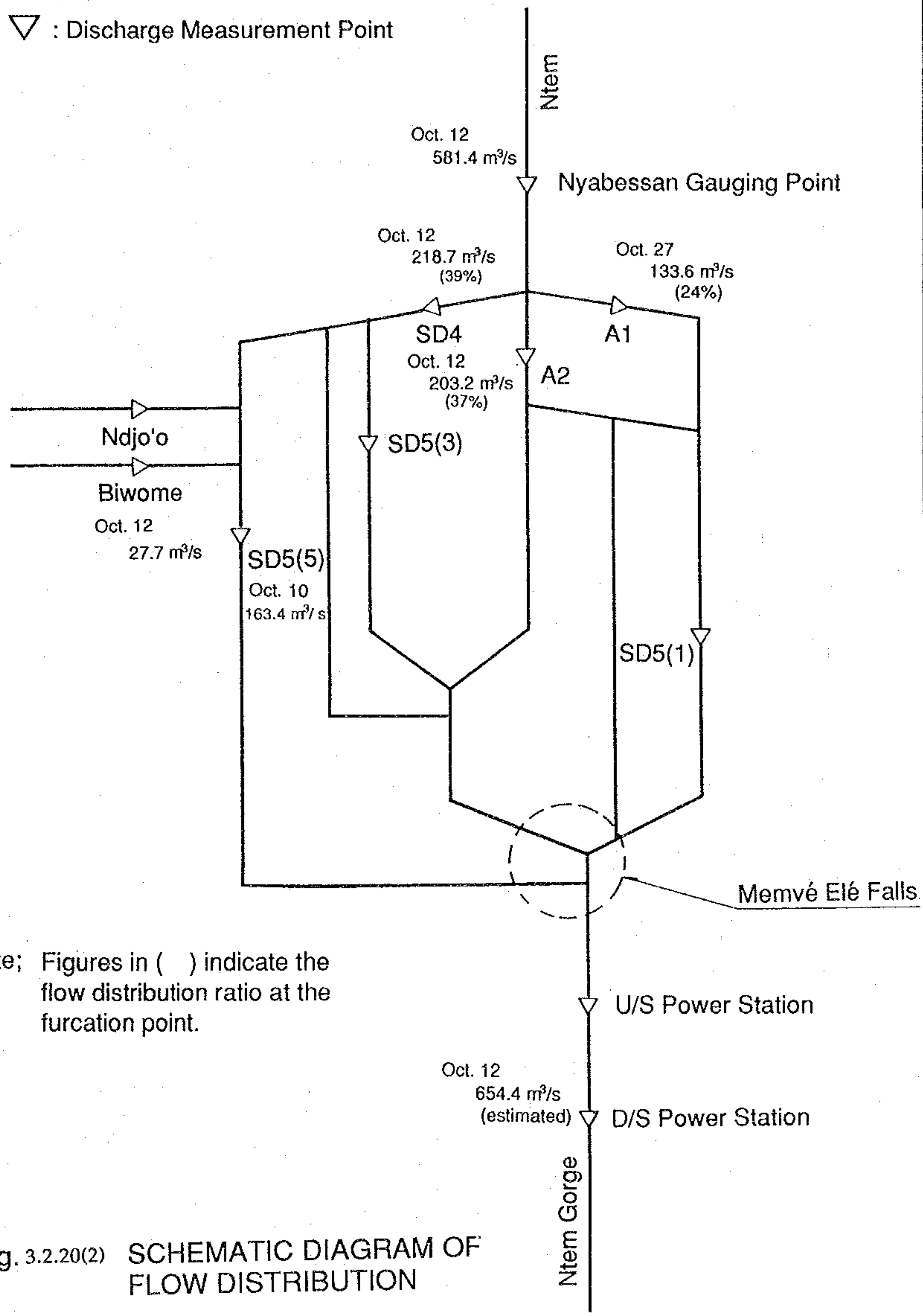
(August, 1992)



Note; Figures in ( ) indicate the flow distribution ratio at the furcation point.

Fig.3.2.20(1) SCHEMATIC DIAGRAM OF FLOW DISTRIBUTION

(October, 1992)



Note; Figures in ( ) indicate the flow distribution ratio at the furcation point.

Fig. 3.2.20(2) SCHEMATIC DIAGRAM OF FLOW DISTRIBUTION

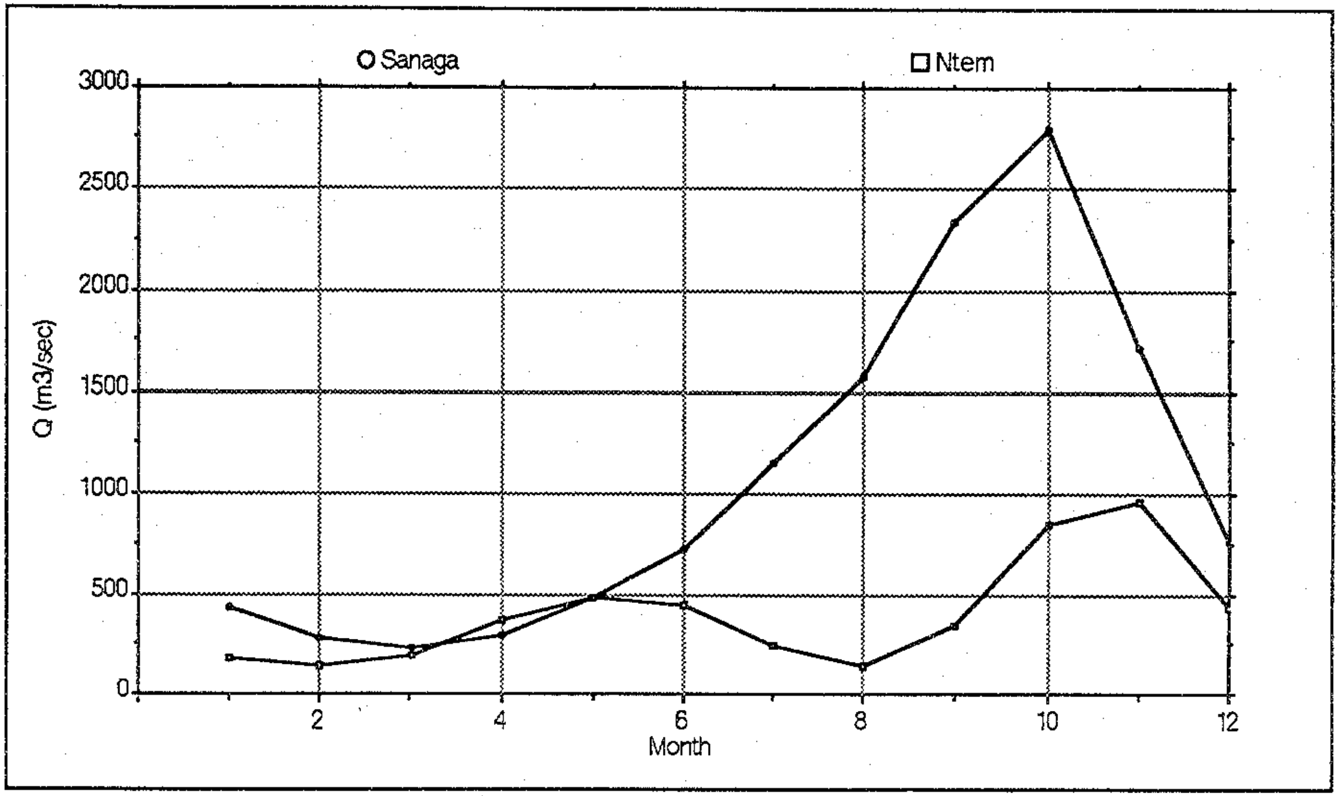


Fig.3.2.21 HYDROGRAPH OF THE SANAGA RIVER

Station ; NTEM RIVER Region : NYABESSAN

Period of Record : 1957-1991

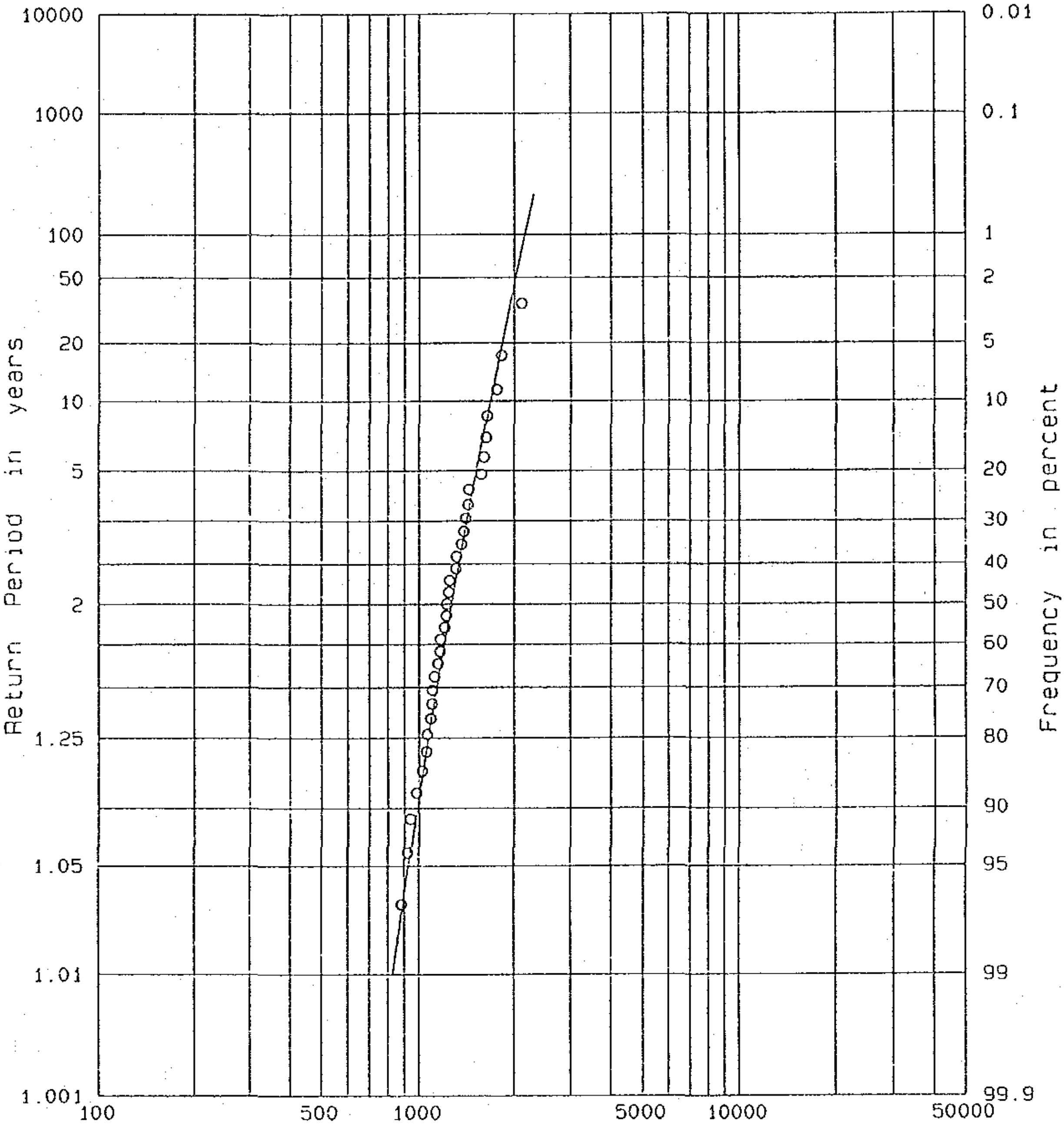


Fig.3.2.22(1) FREQUENCY ANALYSIS ON MAXIMUM FLOOD OF THE NTEM

Iwai's Method

Station :NTEM RIVER Region : NYABESSAN

Period of Record : 1957-1991

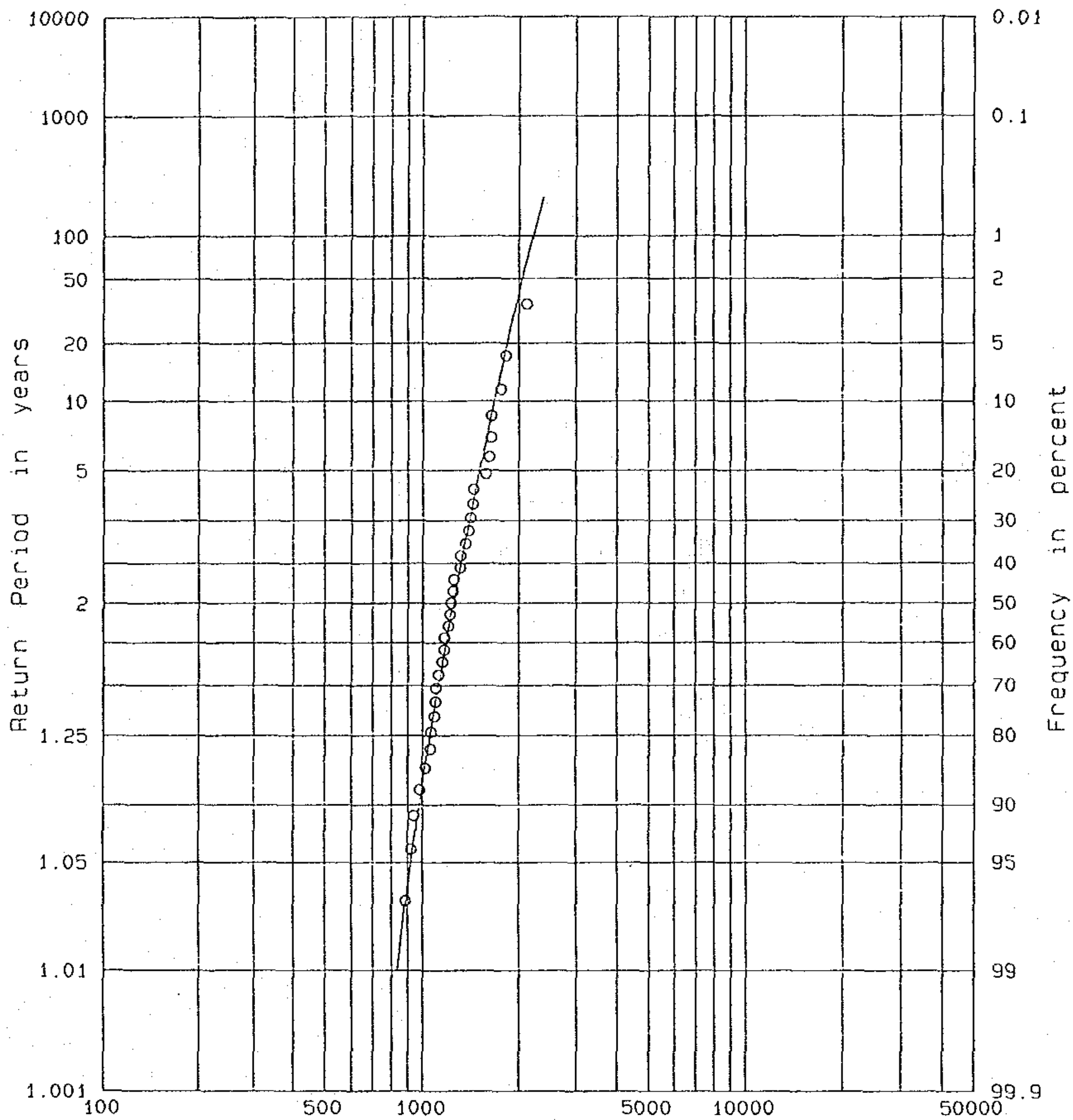


Fig.3.2.22(2) FREQUENCY ANALYSIS ON MAXIMUM FLOOD OF THE NTEM

Log-Pearson III Method

Station ; NTEM RIVER Region ; NYABESSAN

Period of Record ; 1957-1991

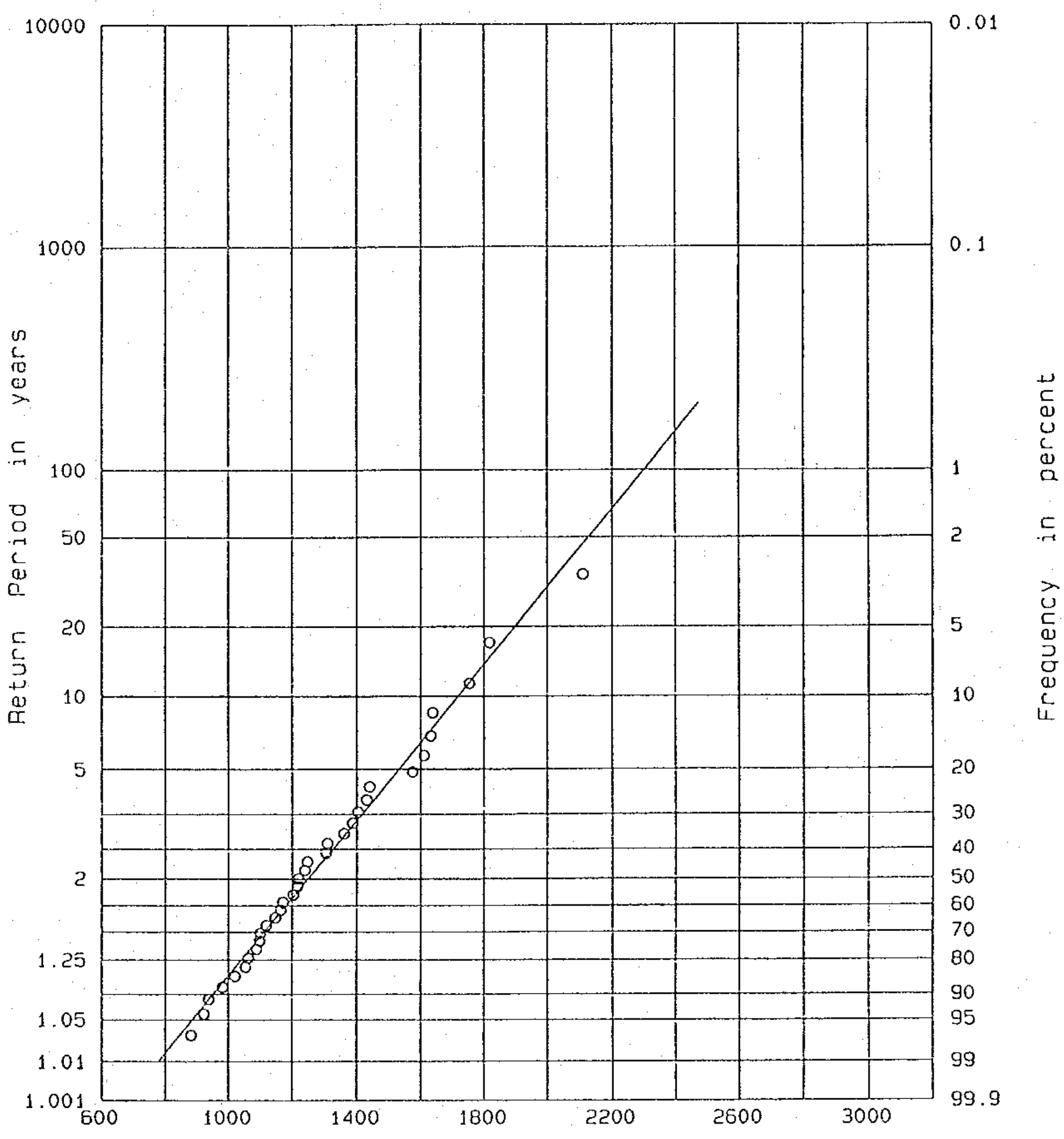


Fig.3.2.22(3) FREQUENCY ANALYSIS ON MAXIMUM FLOOD OF THE NTEM

Gumbel Method

Station NJEM RIVER Region DAMSITE

Period of Record 1958-1988

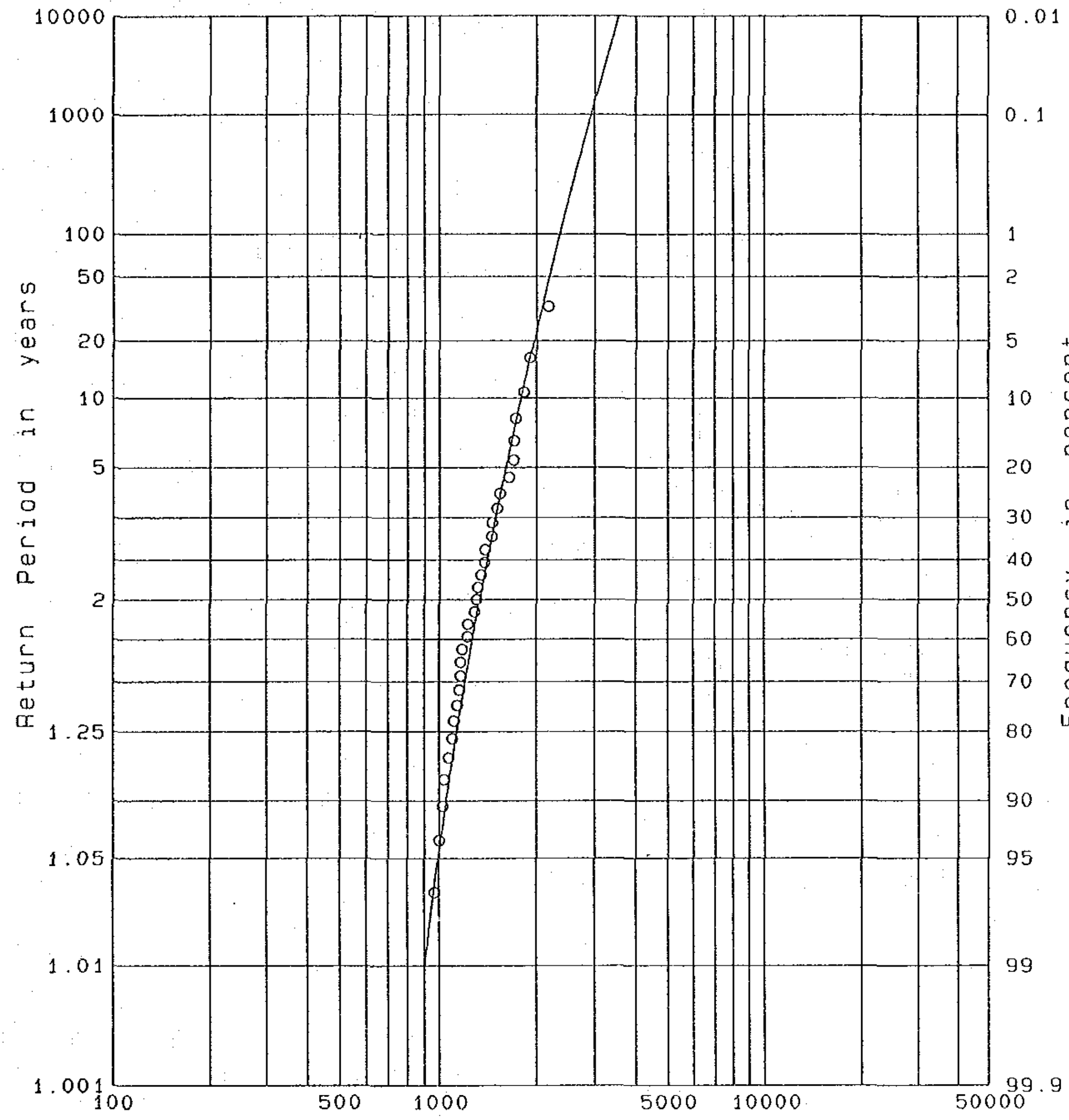


Fig.3.2.23(1) FREQUENCY ANALYSIS ON COMBINED MAXIMUM FLOOD

Iwai's Method

Station NTEM RIVER Region DAMSITE

Period of Record 1958-1988

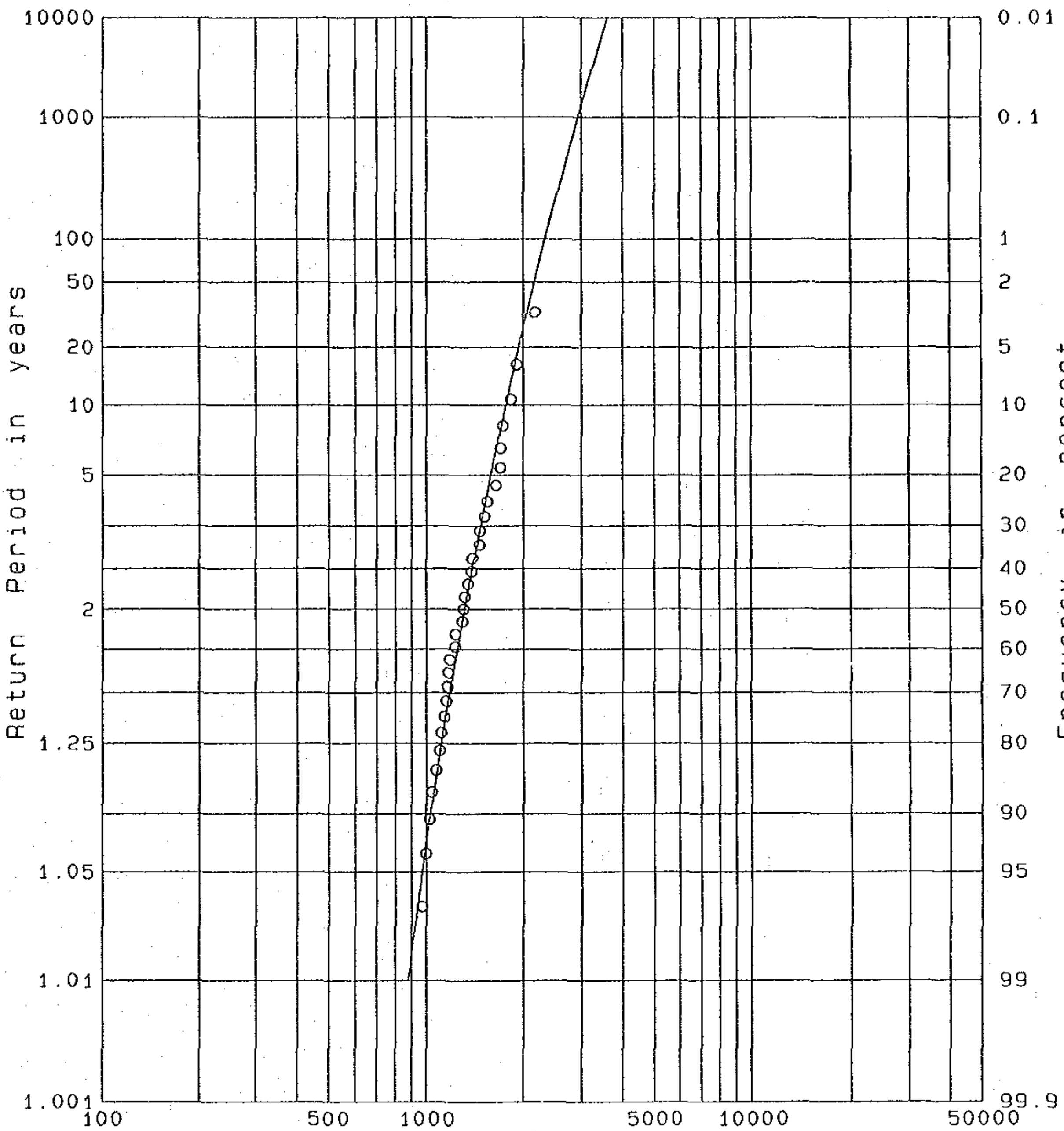


Fig.3.2.23(2) FREQUENCY ANALYSIS ON COMBINED MAXIMUM FLOOD

Log-Pearson III Method

Station NTEM RIVER Region DAMSITE

Period of Record 1958-1988

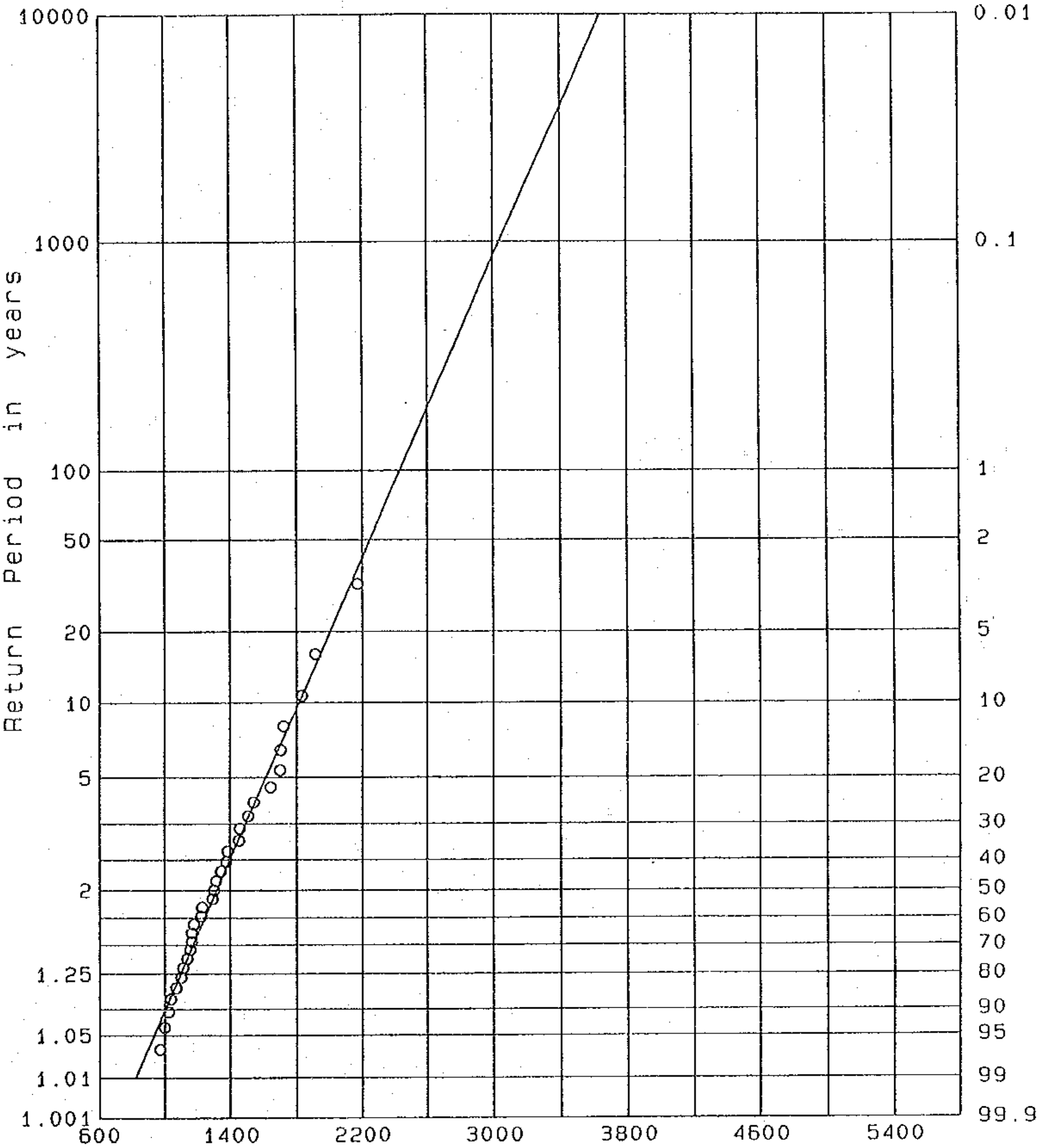
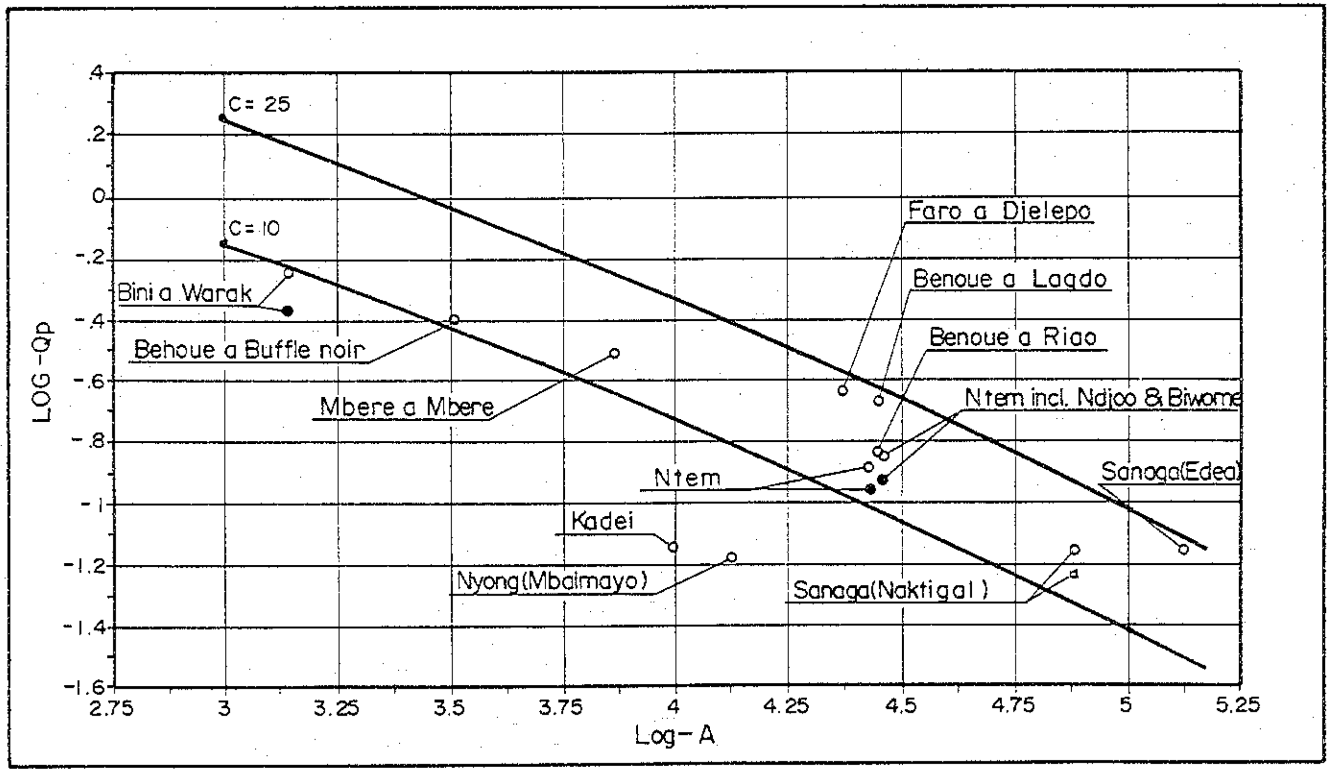


Fig.3.2.23(3) FREQUENCY ANALYSIS ON COMBINED MAXIMUM FLOOD

Gumbel Method



o : 10,000 year probable flood

● : 1,000 year probable flood

□ : 100 year probable flood

Qp : Specific discharge ($ft^3/s/mile^2$)

A : Catchment area ($mile^2$)

Fig.3.2.24 SPECIFIC DISCHARGE OF PROBABLE FLOODS

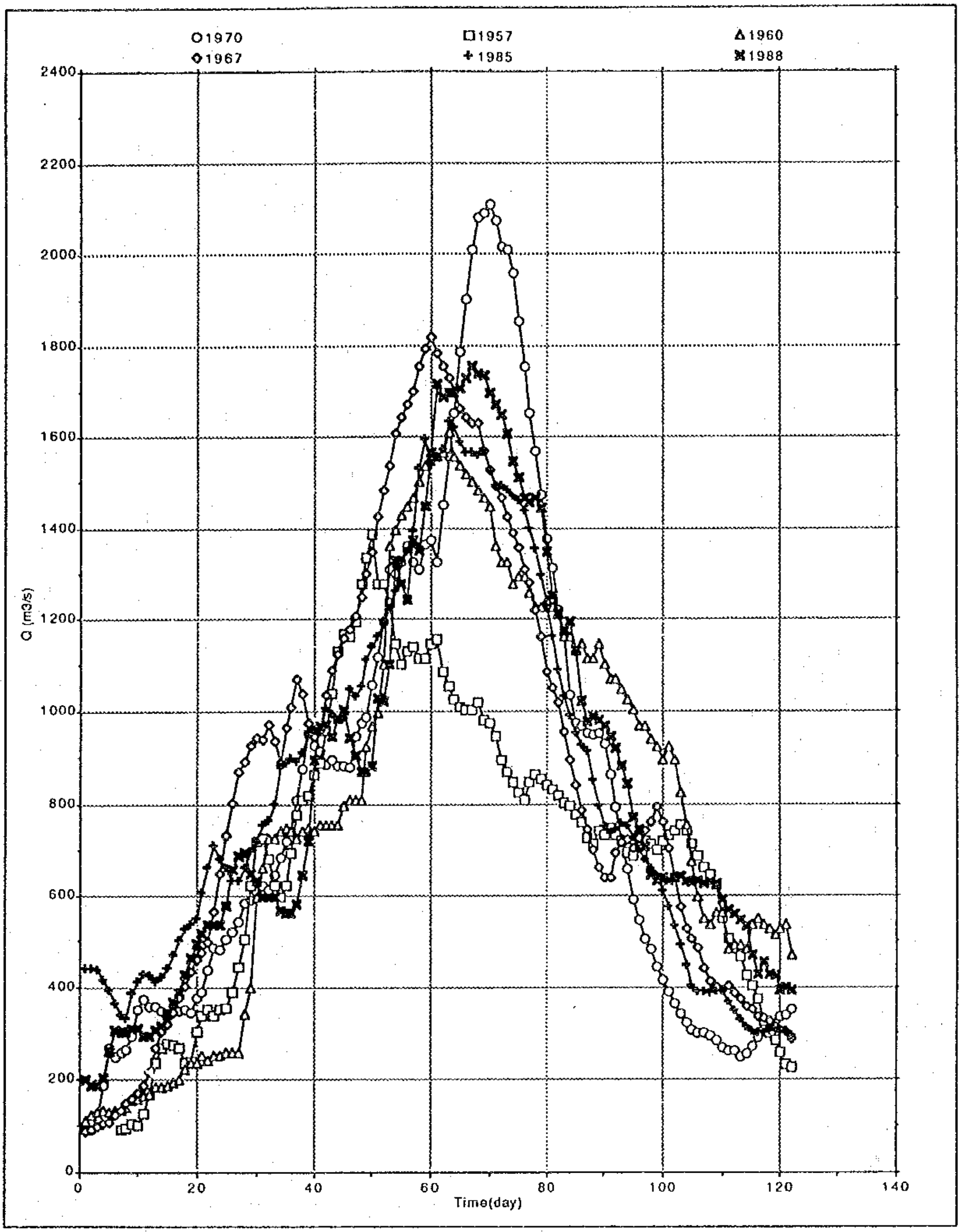


Fig.3.2.25 HYDROGRAPHS OF RECORDED FLOOD AT NYABESSAN ON THE NTEM

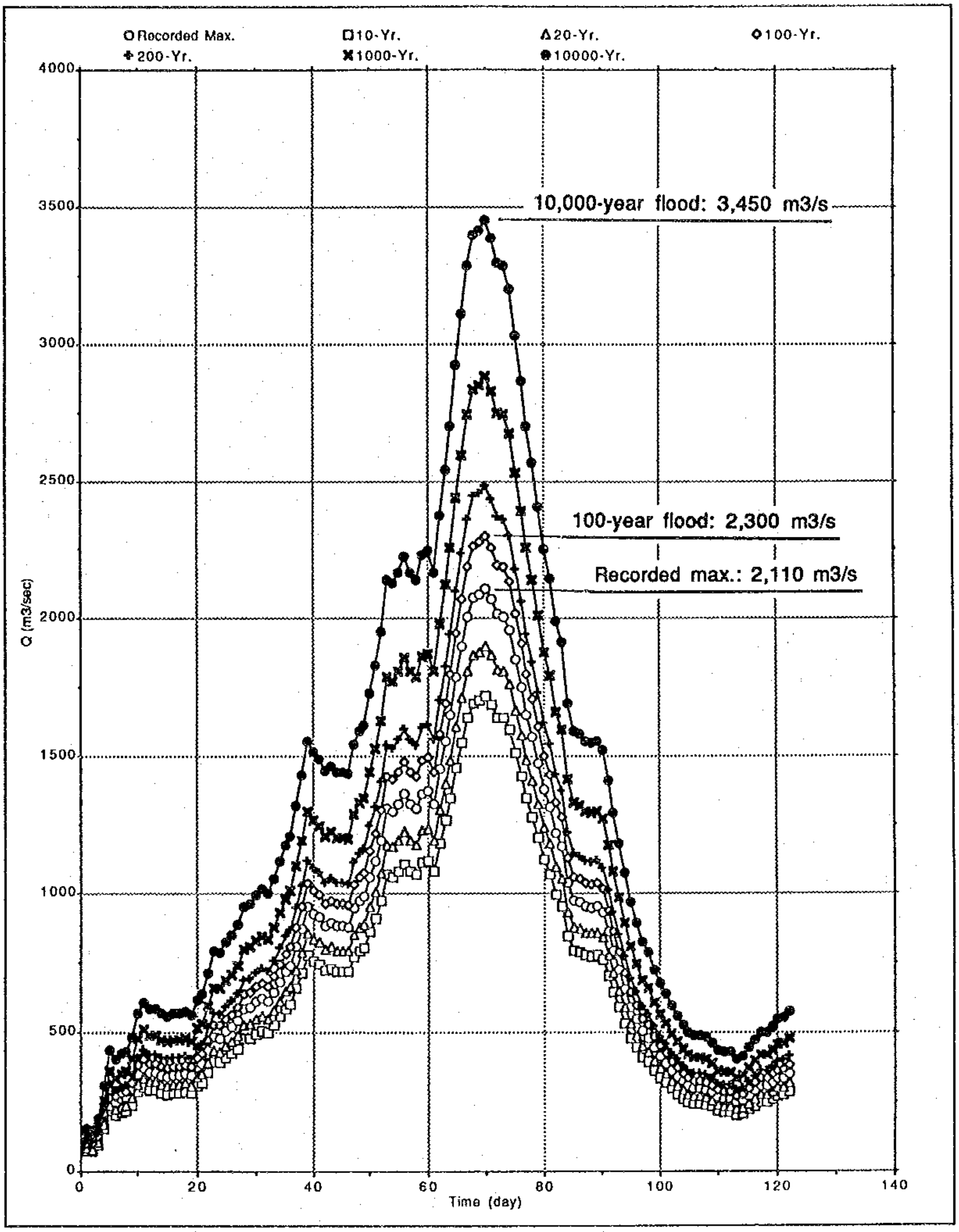
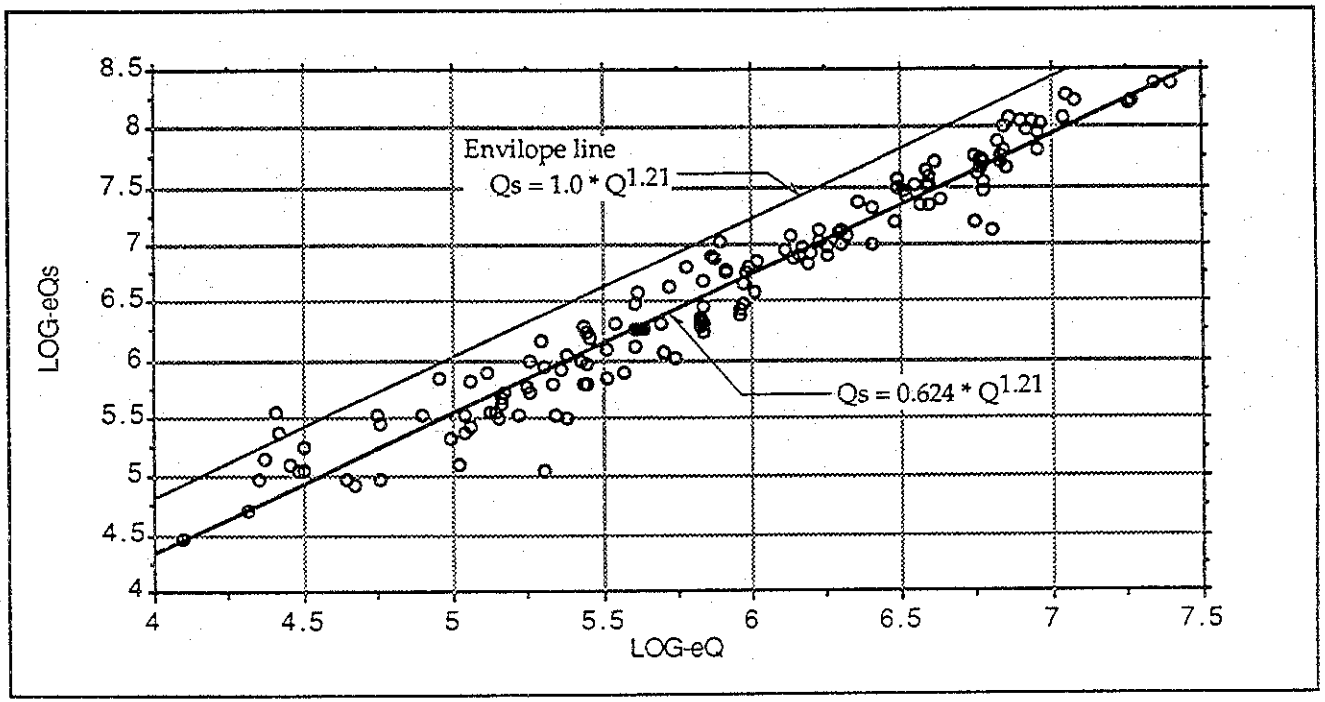
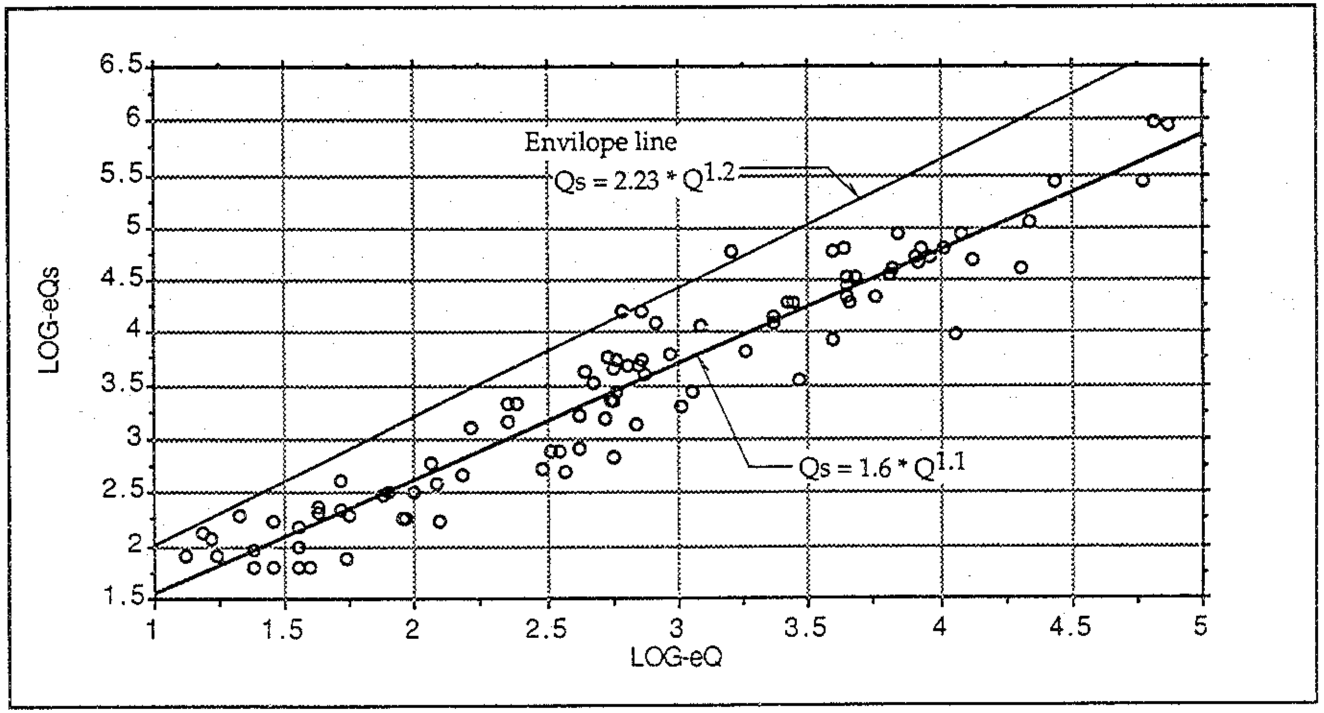


Fig.3.2.26 HYDROGRAPH OF PROBABLE FLOOD AT NYABESSAN ON THE NTEM



Q : flow discharge (m^3/sec)
Qs : suspended load transport (ton/day)

Fig.3.2.27 SUSPENDED LOAD RATING CURVE (NTEM)



Q : flow discharge (m^3/sec)
Qs : suspended load transport (ton/day)

Fig.3.2.28 SUSPENDED LOAD RATING CURVE (NDJO'O)

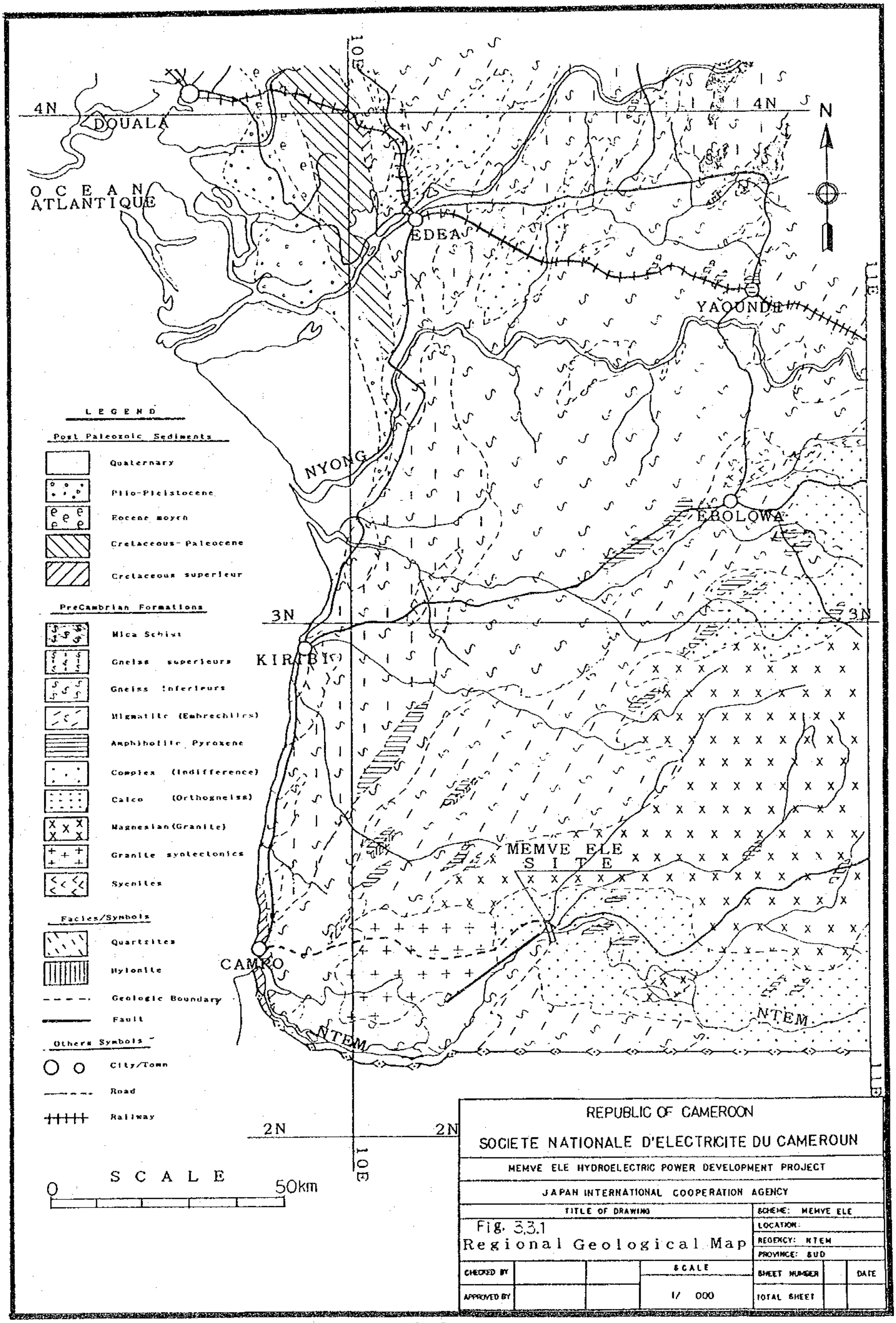
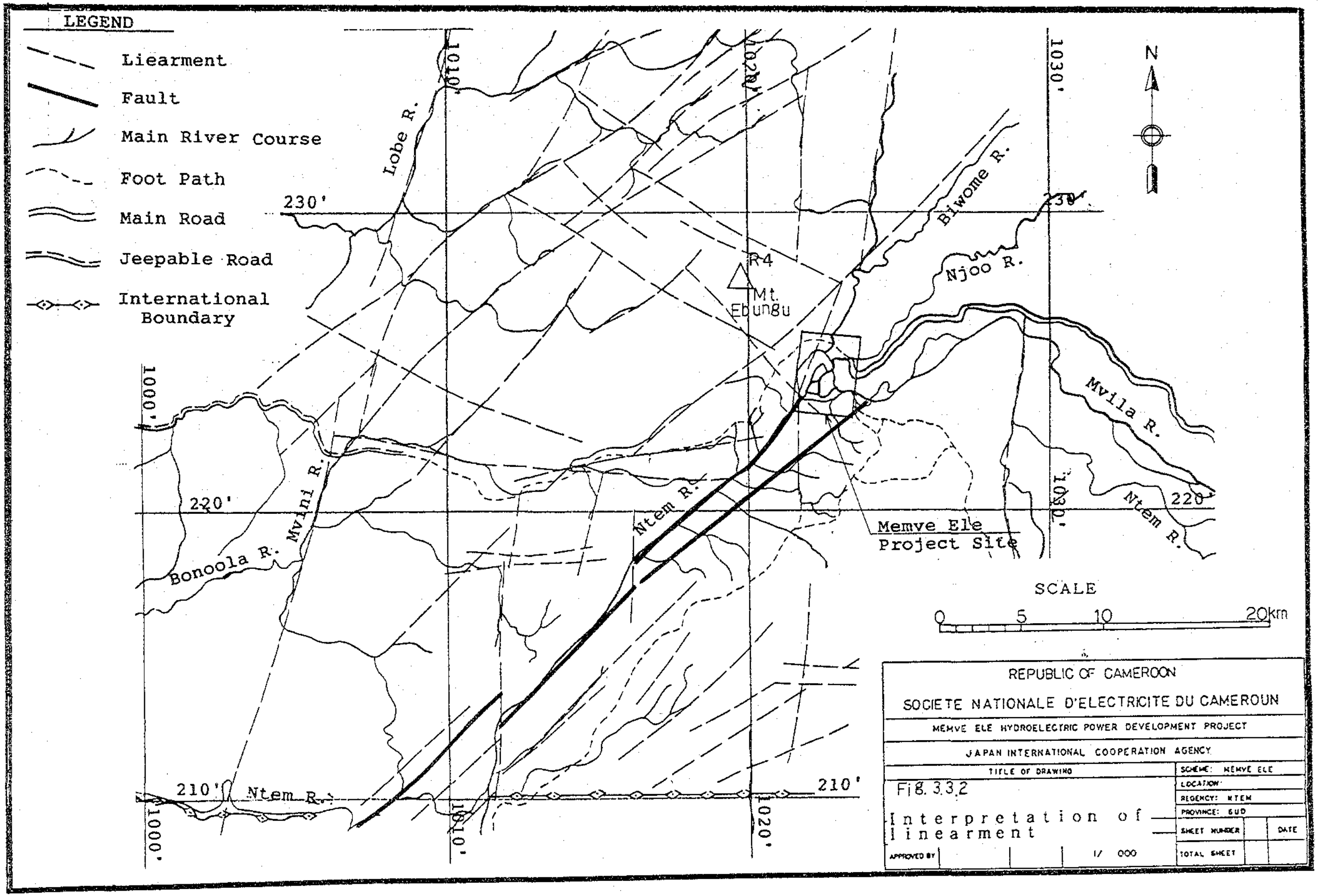
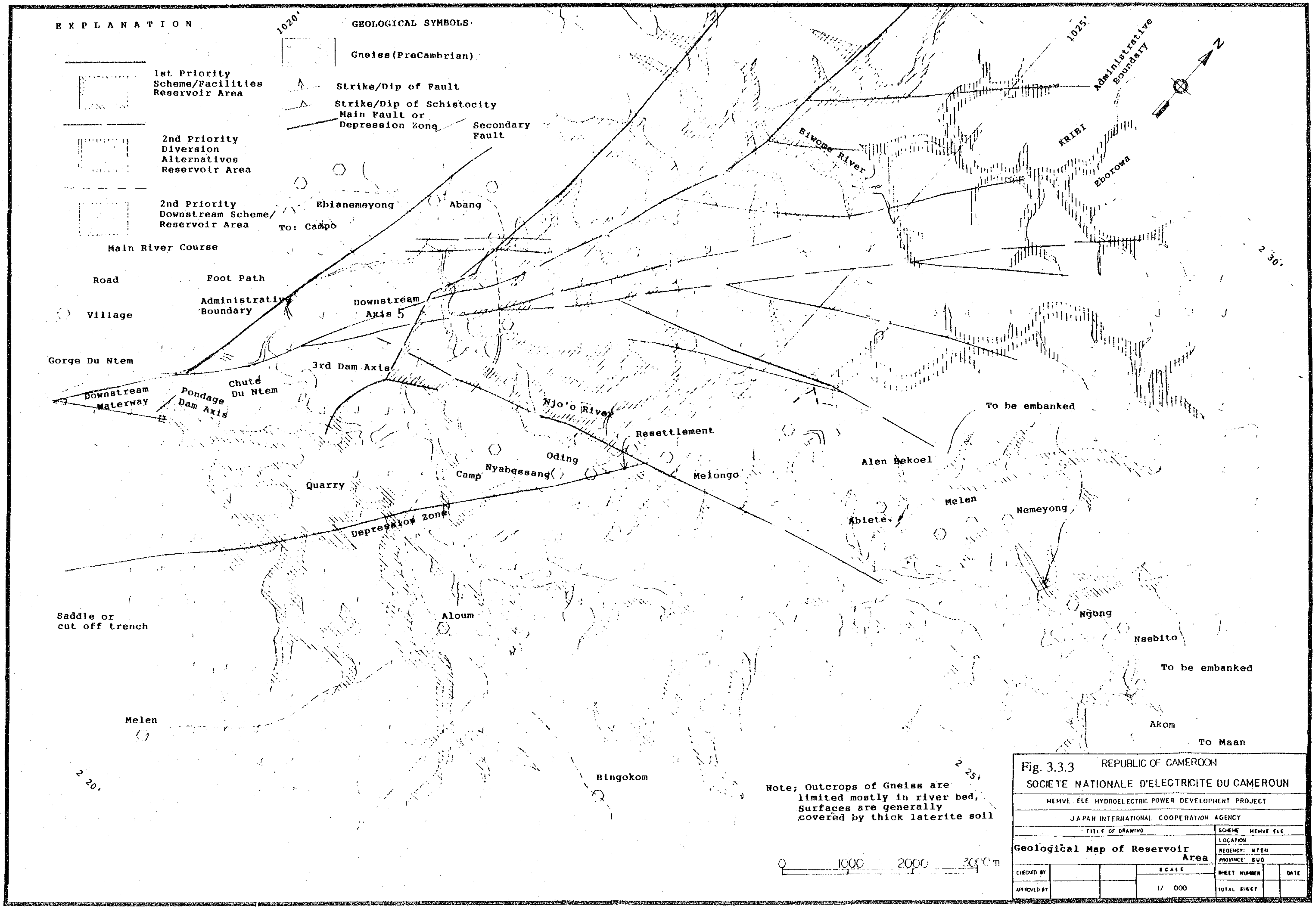
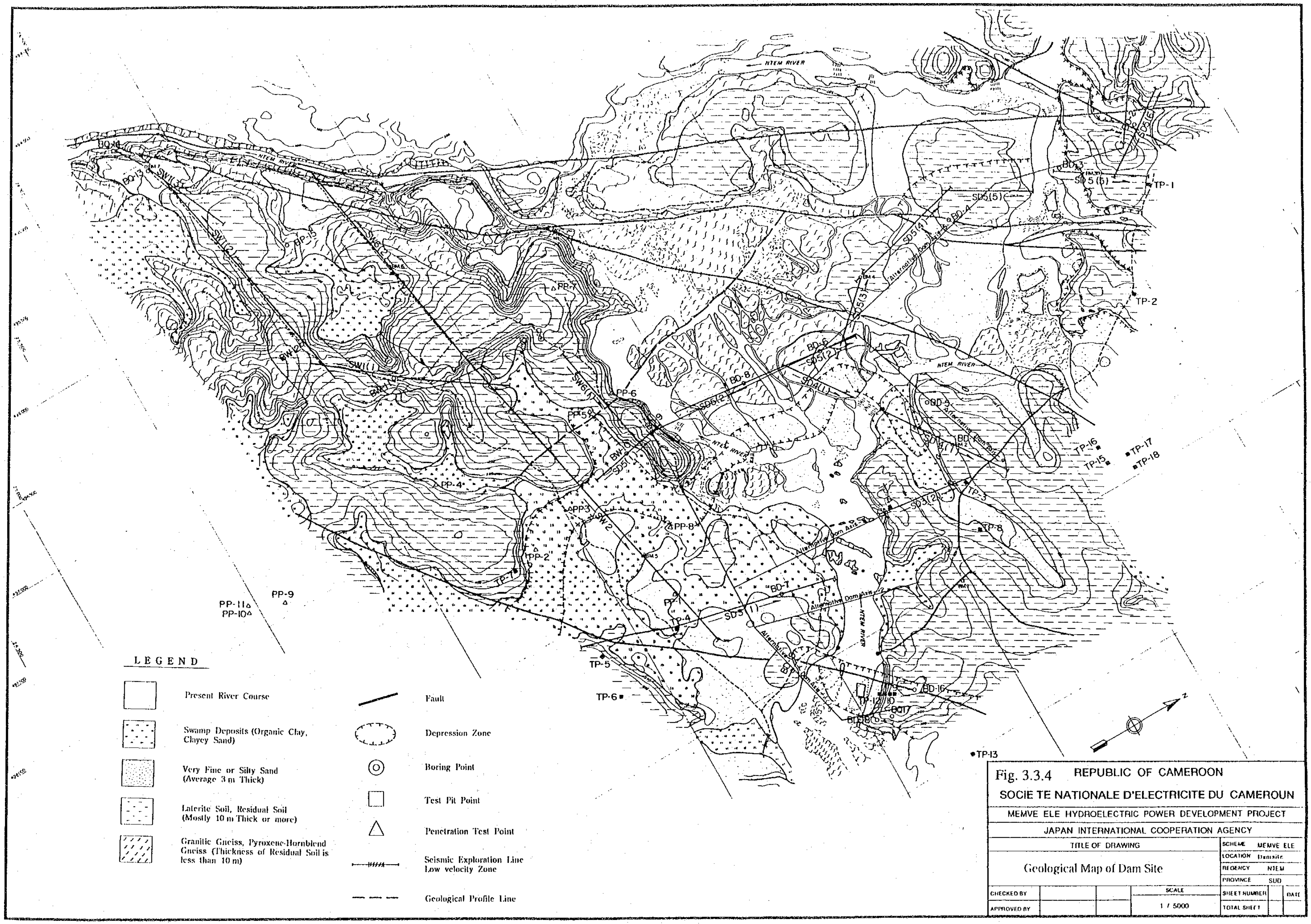


Fig. 3.3.1
Regional Geological Map


LEGEND
Liearment
Fault
Main River Course
Foot Path
Main Road
Jeepable Road
International Boundary
Lobe R.
Biwome R.
Njoo R.
Mvila R.
Ntem R.
Mvini R.
Bonoola R.
R4
Mt. Ebungu
Memve Ele Project Site
230'
220'
210'
1000'
1010'
1020'
1030'
N
SCALE
0 5 10 20km
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Fig. 3.3.2
Interpretation of linearment
SCHEME: MEMVE ELE
LOCATION:
REGENCY: NTEM
PROVINCE: SUD
SHEET NUMBER
DATE
TOTAL SHEET
APPROVED BY
1/ 000


EXPLANATION
1st Priority Scheme/Facilities Reservoir Area
2nd Priority Diversion Alternatives Reservoir Area
2nd Priority Downstream Scheme/ Reservoir Area
Main River Course
Road
Foot Path
Administrative Boundary
Village
Saddle or cut off trench
GEOLOGICAL SYMBOLS
Gneiss(PreCambrian)
Strike/Dip of Fault
Strike/Dip of Schistocity
Main Fault or Depression Zone
Secondary Fault
1020'
1025'
2 30'
2 25'
2 20'
N
Administrative Boundary
KRIBI
Eborowa
Biwome River
Ebianemeyong
Abang
To: Campo
Downstream Axis 5
Gorge Du Ntem
Downstream Waterway
Pondage Dam Axis
Chute Du Ntem
3rd Dam Axis
Njo'o River
Resettlement
To be embanked
Alen Bekoel
Oding
Nyabessang
Camp
Melongo
Quarry
Depression Zone
Melen
Nemeyong
Abiete
Ngong
Nsebito
To be embanked
Aloum
Melen
Akom
To Maan
Bingokom
Note; Outcrops of Gneiss are limited mostly in river bed, Surfaces are generally covered by thick laterite soil
0 1000 2000 3000m
Fig. 3.3.3
REPUBLIC OF CAMEROON
SOCIETE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Geological Map of Reservoir Area
SCHEME MEMVE ELE
LOCATION
REGENCY: NTEM
PROVINCE SUD
CHECKED BY
APPROVED BY
SCALE
1/ 000
SHEET NUMBER
TOTAL SHEET
DATE


NTEM RIVER
TP-1
TP-2
TP-3
TP-4
TP-5
TP-6
TP-8
TP-13
TP-15
TP-16
TP-17
TP-18
PP-2
PP-4
PP-6
PP-7
PP-8
PP-9
PP-10
PP-11
PP-15
BD-5
BD-6
BD-7
BD-8
BD-16
BD-17
Alternative Dam Axis
LEGEND
Present River Course
Swamp Deposits (Organic Clay, Clayey Sand)
Very Fine or Silty Sand (Average 3 m Thick)
Laterite Soil, Residual Soil (Mostly 10 m Thick or more)
Granitic Gneiss, Pyroxene-Hornblend Gneiss (Thickness of Residual Soil is less than 10 m)
Fault
Depression Zone
Boring Point
Test Pit Point
Penetration Test Point
Seismic Exploration Line
Low velocity Zone
Geological Profile Line
Fig. 3.3.4
REPUBLIC OF CAMEROON
SOCIE TE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY
TITLE OF DRAWING
Geological Map of Dam Site
SCHEME MEMVE ELE
LOCATION Damsite
REGENCY NTEM
PROVINCE SUD
CHECKED BY
APPROVED BY
SCALE
1 / 5000
SHEET NUMBER
DATE
TOTAL SHEET

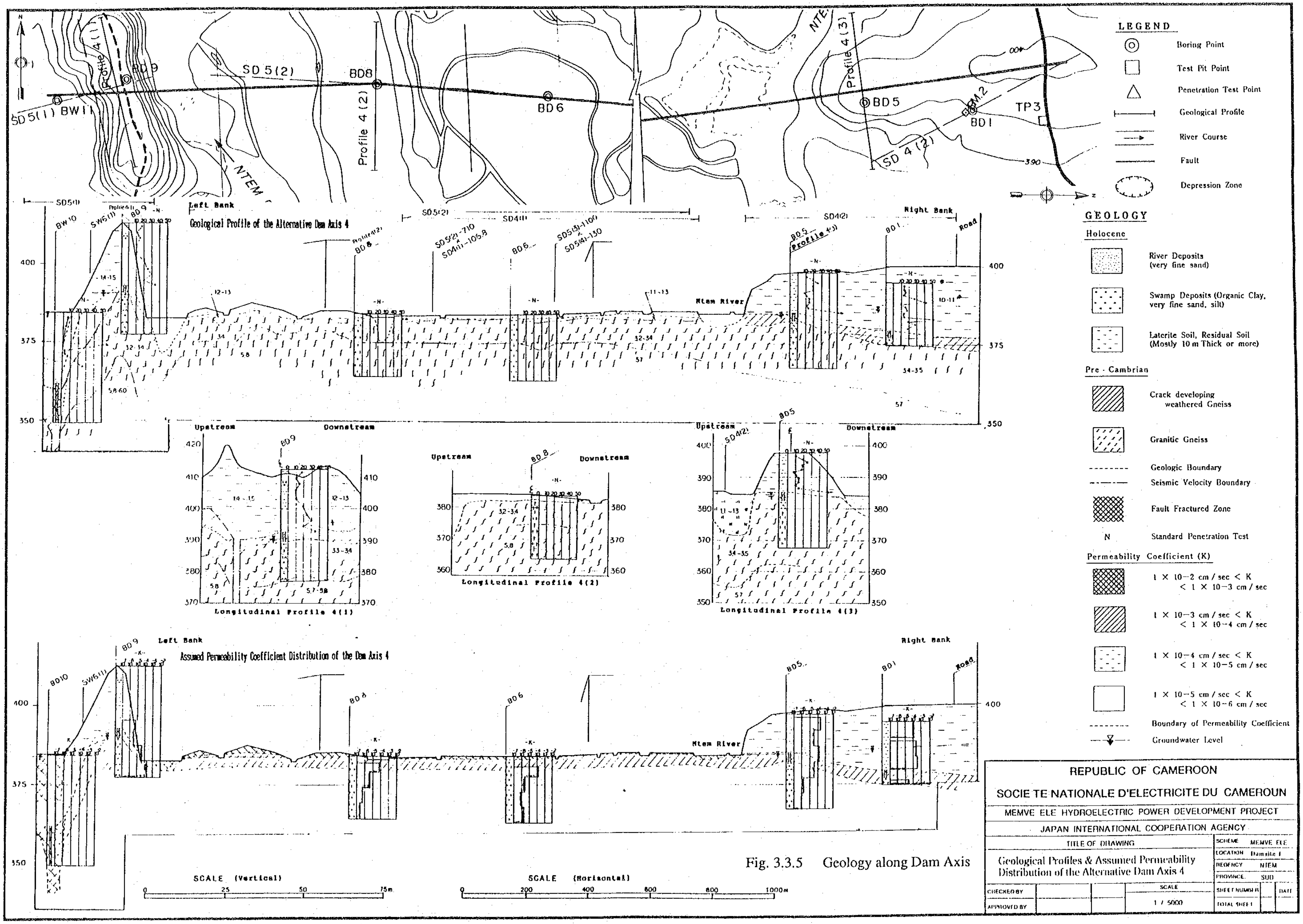


Fig. 3.3.5 Geology along Dam Axis

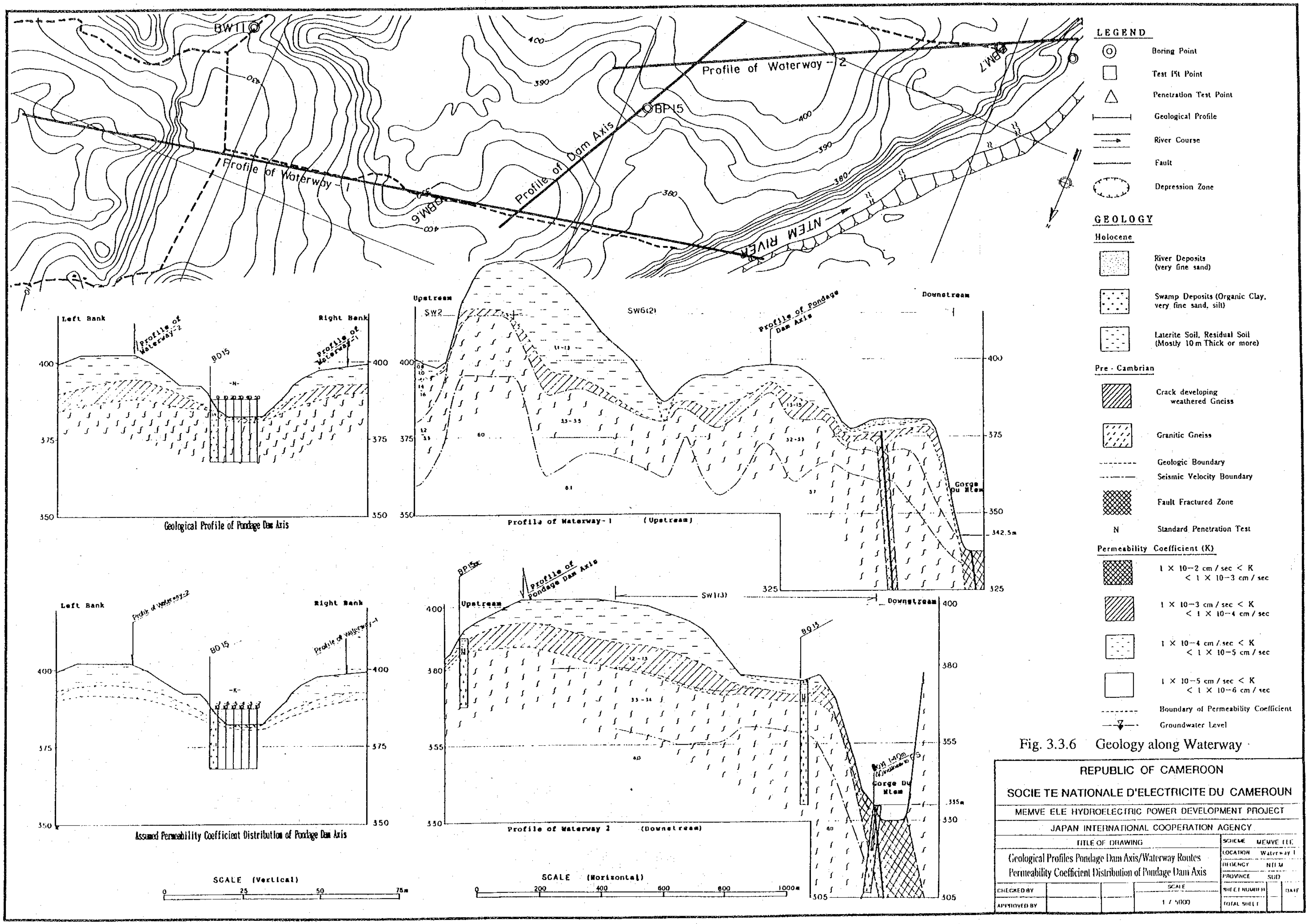


Fig. 3.3.6 Geology along Waterway

REPUBLIC OF CAMEROON
SOCIE TE NATIONALE D'ELECTRICITE DU CAMEROUN
MEMVE ELE HYDROELECTRIC POWER DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE OF DRAWING	SCHEME	MEMVE ELE
Geological Profiles Pondage Dam Axis/Waterway Routes Permeability Coefficient Distribution of Pondage Dam Axis	LOCATION	Waterway 1
	REGENCY	NTEM
	PROVINCE	SUD
CHECKED BY / SCALE 1 / 5000	SHEET NUMBER	DATE
APPROVED BY	TOTAL SHEET	

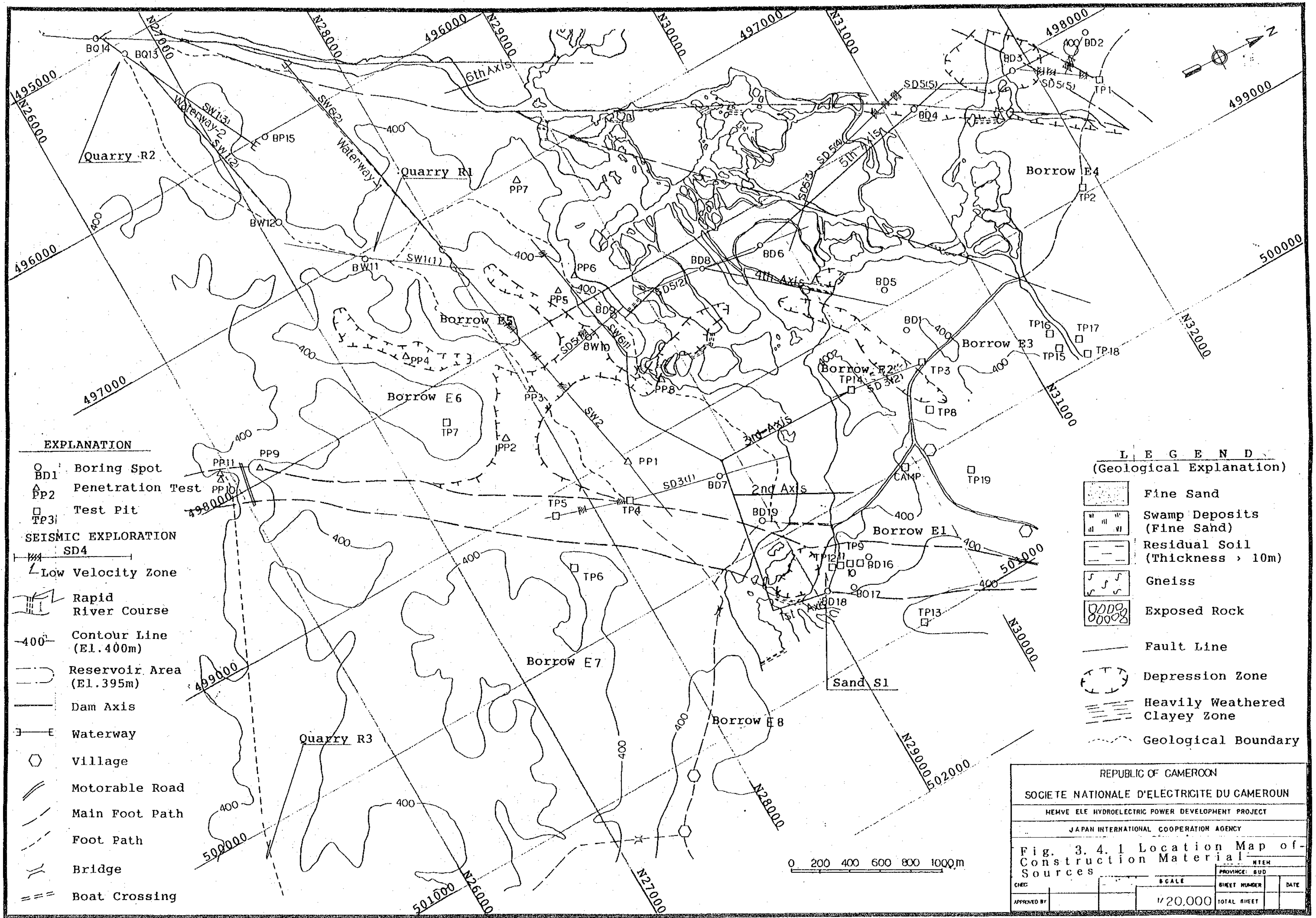


Fig. 3. 4. 1 Location Map of Construction Material Sources

IV POWER MARKET STUDY

4.1 Outline of the Power Sector in Cameroon

Electricity supply in Cameroon is undertaken by SONEL under the supervision of the Ministry of Mines, Water and Energy (MINMEE), as given in Fig. 4.1.1.

The SONEL is the National Company of Electricity in Cameroon which was established in May, 1974 as a joint-stock company of mixed organization. The Cameroon State Interest of the Government hold 93% of its capital that reaches 30 F. CFA billion since September, 1985; the remainder is covered by the Central Economic Cooperation Fund (CFD).

The SONEL is the sole public service responsible for development of power sources, generation, transmission and distribution of electric power to the consumers all over the country. The SONEL are organized by 8 functional directions and 10 electric provinces under the direction of distribution as of June 1990, as given in Fig. 4.1.2.

As of 1991 the Department of Equipment (Direction Equipment) in SONEL is responsible for overall management of generation including designing and construction. In the same sense, Department of Production and Transport (Direction Production and Transport) is responsible for overall management of transmission lines, operation and maintenance of electricity generation by diesel generators. The Department of Distribution (Direction Distribution) and ten Regional Branches (Provincial Delegation) are responsible for management of the electricity distribution. The administrative provinces as of 1991 are shown in Fig. 4.1.3.

Now, there are two (2) major networks as the interconnected power transmission system in Cameroon, i.e., South Interconnection Network (Sanaga system) and North Interconnection Network (Lagdo system). And isolated demand centers which are far from such transmission or sub-transmission line networks are supplied by diesel power plants. The present networks are shown in Figs. 4.1.4 to 4.1.6.

Both the two interconnection networks have thermal units (diesel generators) mainly as standby capacity, there also exist autonomous diesel units to supply the regions which are yet to be connected to the networks respectively.

The load dispatching center (LDC) for the South Interconnection Network has been organized at Mangombe Substation in Edéa, which is responsible for controlling all stations belonging to the South Interconnection Network accordingly. On the other hand, Garoua LDC is responsible in North Interconnection Network.

As to operating pattern of these systems, hydropower plants supply most of the power to meet the demand as can be seen from such composition of power sources as mentioned below. In case of shortage in power supply by the hydro plants or in emergency case, thermal power plants (diesel) will be operated as standby.

Operation schedule of each hydro plant is prepared by the Department of Production and Transportation (Direction Production et Transport), in Head Office based on a yearly forecast of inflow which will be readjusted occasionally by an actual inflow into a regulating pond or reservoir.

4.2 Existing and Committed Generating Plants

4.2.1 Existing Power Plants

The South Interconnection Network which supplies the power to the Provinces of Littoral (Coast), Center ,West, South-west, South and North-west, has two (2) major hydro plants; Edéa (No. I, II and III) and Song Loulou.

When SONEL's operation started in 1974, they took over the operation of Edéa Hydropower Station and other thermal power stations which had been operated by energy d'Eléctrique du Cameroun (ENELCAM), managed and invested by the Eléctricité de France (EDF), and Power of Cameroon (POWERCAM) as both of organizations for power production. SONEL also took over the facilities of distribution system which was formerly managed by Eléctricité de Cameroun (EDC). SONEL started their own commercial operation of the Song-Loulou Hydropower Station from January 1981.

The North Interconnection Network which supplies the power to the Provinces of Adamaoua, North and Extreme-North, has one (1) major hydro plant; Lagdo, which was completed by SONEL and commissioned in May 1983.

While, a new network is foreseen to be established in the future in the East Region; to which the Kadey Hydropower Project has been planned.

Fig. 4.2.1 shows these major hydropower development projects including three upstream regulating reservoirs (Bamendjin, Mapé and Mbakaou), which aim at firming up power/energy production at the downstream plants (Edéa and Song Loulou).

The installed capacity of the power plants in Cameroon is 804 MW as detailed in Table 4.2.1, and their composition is 90 % in hydro and 10 % in diesel plants, of which the South Interconnection Network shares 701 MW or 87.2% and the North Interconnection Network 103 MW or 12.8%.

Edéa hydropower plants of which 2 units were firstly commissioned in 1953 and additional units successively installed up to 1975, are periodically maintained covering all units through the year at present, mainly for replacement of wearing parts and/or runners. Edéa II power station generates the power mainly for ALUCAM (bulk consumer) and Edéa III power station supplements the power for ALUCAM, as the case may demand.

The Song Loulou Hydropower station, located 55 km upstream of the river Sanaga from Edéa, started the first commercial operation in 1981 as the first stage development. The extension work was completed in 1988.

Each network is composed of the following power plants:

(1) South Interconnection Network (Sanaga system)

(a)	2 - hydropower plants	650.835 MW	(92.8 %)
(b)	14 - diesel power plants (stand-by)	43.397 MW	(6.2 %)
(c)	14 - diesel power plants (autonomous)	6.739 MW	(1.0 %)
	Total	700.971 MW	(100 %)

(2) North Interconnection Network (Lagdo system)

(a)	1 - hydropower plant	72.000 MW	(69.8 %)
(b)	4 - diesel power plants (stand-by)	23.242 MW	(22.5 %)
(c)	8 - diesel power plants (autonomous)	7.910 MW	(7.7 %)
	Total	103.152 MW	(100 %)

Most of thermal units seem to be well maintained but some of them also seem to be rather deteriorated due to their life time. As seen in Table 4.2.1, their guaranteed capacity averages only 52 % of standby units and 70 % of autonomous units respectively. These seem to suggest that most of them will retire before long and not be expected to make a big role of the system reserve units other than emergency supply units due to their small unit capacity as compared to that of hydropower plant.

Diesel plants are being relocated to other remote areas or discommissioned according as transmission and distribution lines are expanded.

4.2.2 Planned Power Plants

Other than Memvé Elé project, the following schemes have been planned at the feasibility study level:

(1) South Interconnection Network (Sanaga system)

Nachtigal upstream project in Sanaga river (4 x 66.7 MW) is planned to be connected to the network at Oyomabang substation in Yaoundé through 225 kV transmission line.

Name of project	Type	Installed capacity	Year of commission*	Status
Nachtigal Upstream	Hydro with Regulating dam	I: -2 x 66.7 MW II: -1 x 66.7 MW III:-1 x 66.7 MW	1997/98 2001/02 2002/03	F/S done
Total		266.8 MW		

(* Proposed in the feasibility study)

It is noted that the year of commission has been recommended based on an assumption of annual power demand increase at 8% to 7.2%.

(2) North Interconnection Network (Lagdo system)

Bini a Warak project in Vina river (3 x 25 MW) is planned to be connected to the network at Ngaoundere through 225 kV transmission line.

Name of project	Type	Installed capacity	Year of commission*	Status
Bini a Warak	Hydro with reservoir	75 MW	1995	F/S done

(* Proposed in the previous study)

(3) East Network

In East Province, Kadey hydropower plant of which installed capacity is 12.4 MW, has been planned to construct toward its commissioning in 1995/96. And this Power station is to be connected to the sub-transmission system (30 kV) at Bertoua.

Name of project	Type	Installed capacity	Year of commission*	Status
Kadey	Hydro with Run-of-river	12.4 MW	1995/96	D/D done

(* Scheduled in the previous implementation plan by SONEL)

Location of these schemes is shown in Fig. 4.2.1.

4.3 Existing and Planned Transmission and Distribution Systems

4.3.1 Existing System

As shown in Table 4.3.1 and Fig. 4.3.1, 16 substations are connected with the South Interconnection Network (Sanaga system), excluding four high tension (HT) consumers (bulk consumers of ALUCAM, SOCATRAL, CELLUCAM and CIMENCAM). While, 3 substations are connected with the North Interconnection Network (Lagdo system), excluding one HT consumer (CICAM). The total capacity of substation transformers is 1,086 MVA including some distribution transformers in major substations. Fig. 4.3.1 shows one-line diagram of the interconnection networks.

The particulars of substation transformers (225, 110 and 90 kV class) are shown in the same Table and summarized as under:

(a)	225 kV transformers	420 MVA
(b)	110 kV transformers	40 MVA
(c)	90 kV transformers	604 MVA
	Total	1,064 MVA

Route length of the existing transmission lines as of 1989/1990 is about 1,535 km in total and their line length corresponds to about 1,647 km-circuit as under:

(a)	225 kV transmission line	422 km	(480 km-cct)
(b)	110 kV transmission line	50 km	(100 km-cct)
(c)	90 kV transmission line	1,063 km	(1,067 km-cct)
	Total	1,535 km	(1,647 km-cct)

The particulars of the transmission lines are shown in Table 4.3.2.

Distribution lines, including sub-transmission lines are summarized as follows:

(a) MT lines (33, 30, 15 & 10 kV) 5,182 km

(b) LT lines (220/380 V) 3,880 km

where MT = medium tension, and LT = low tension.

4.3.2 Expansion of Substation and Transmission Facilities

The following facilities are to be installed along with the construction of Kadey Hydropower Project in the East sub-network:

(a) Bertoua substation 110/30 kV, 20 MVA

(b) 110 kV transmission line 100 km (100 km-circuit)

Besides, some expansion of substations and transmission are planned in the South Interconnection Network as below:

(c) Substations

- Bafoussam	225/90 kV	105 MVA
- Makepe	90/30 kV	20 MVA
- Kribi	90/15 kV	20 MVA
- Nkolndongo	90/15 kV	2 x 20 MVA
Total		185 MVA

(d) Transmission line (225 kV)

- Song Loulou - Bafoussam 195 km (195 km-circuit)

While, the following substations equipment and transmission line are expanded in the North Interconnection Network toward commissioning in September, 1992:

(e) Substations

- Ngaoundere 110/15 kV 2 x 20 MVA

(f) Transmission line (110 kV)

- Lagdo -Ngaoundere 238 km (238 km-circuit)

4.3.3 Existing Telecommunication System

In the system networks, power line carrier telephone systems are used among the stations and also utilized for data transmission to or receipt from LDC.

Besides, SONEL Head Office uses wireless communication system among remote areas.

4.4 Electric Power Market

4.4.1 Generation in the Country

(1) Energy production by power source

The energy production by power source in the whole country are shown in Table 4.4 1 and summarized below.

Year	Thermal (GWh)	Hydro (GWh)	Total (GWh)	Increase Rate (%)
1975/76	69.2	1,271.8	1,341.1	-
80/81	94.0	1,561.1	1,655.1	4.3
85/86	40.3	2,456.6	2,496.9	8.6
90/91	38.3	2,669.4	2,707.7	1.6
Annual growth rate: (average for last 10 years)	-8.6%	5.5%	5.0%	(80/81-90/91)

(2) Energy production for public sector by network

The energy production in categories of Public Sector which is composed of MT consumers and LT consumers, and HT consumers are shown in Table 4.4.2, and summarized below.

Energy Production for Public Sector (GWh)				
Year	South Network (GWh)	North Network (GWh)	Total (GWh)	Increase Rate (%)
1975/76	274.6	41.5	316.1	-
80/81	597.7	68.5	666.2	16.1
85/86	1,051.3	125.3	1,176.6	12.0
90/91	1,193.3	116.9	1,310.2	2.2
Annual growth rate: (average for last 10 years)	7.2%	5.5%	7.0%	(80/81-90/91)

(3) Energy production for HT consumers by networks

HT consumers are composed of 5 clients, all of which are connected with the South Interconnection System.

(a) ALUCAM producing aluminum materials

(b) CELLUCAM producing paper pulps

(c) SOCATRAL producing aluminum and zinc products

(d) CIMENCAM producing cement

(e) SONARA refining petroleum (now MT client as from 1989/90)

Table 4.4.3 shows historical energy consumption of these HT consumers, while no accurate record of energy production is available. Hence, the latter was estimated as summarized below.

Energy Production for HT Consumers (GWh)		
Year	South Network (GWh)	Increase Rate (%)
1979/80	793.0	-
80/81	988.9	24.7
82/84	1,397.8	18.9
84/85	1,307.1	-3.3
86/87	1,251.8	-2.1
88/89	1,391.1	5.4
90/91	1,397.5	0.2

In the North Interconnection Network, one HT consumer (CICAM) was connected as from 1989/90 as shown in Table 4.4.3.

4.4.2 Energy Consumption (Sales)

(1) Energy consumption (sales) by consumers

The energy consumption (sales) by consumers in the whole country are shown in Table 4.4.3 and summarized below.

Year	HT consumers (GWh)	MT consumers (GWh)	LT consumers (GWh)	Total (GWh)	Increase Rate (%)
1975/76	985.4	164.4	148.7	1,298.5	-
80/81	952.4	302.7	282.2	1,537.3	3.4
85/86	1,296.5	472.1	478.6	2,247.2	7.9
90/91	1,381.6	396.5	573.5	2,351.6	0.9
Annual growth rate: (average for last 10 years)	3.8%	2.7%	4.3%	4.3%	(80/81-90/91)

where, HT: High tension, MT: Medium tension and, LT: Low tension.

On the other hand, annual growth rate of MT consumers shows somewhat decrease but it seems that this is within an usual fluctuation due to economical tendency.

(2) Loss of Energy

As seen in Table 4.4.4, loss of energy for all consumers in the whole country, including station use, loss in transmission lines and distribution lines varies from 3.3 % to 13.2 % in a duration of 1975/76 to 1990/91 and keeps around 12 to 13 % in these 5 years.

Energy losses for LT and MT consumers (Public Sector) are 20.2 % to 22.8 % in the South Interconnection Network and 5.9 % to 2.9 % in the North Interconnection Network in the last 5 years. This suggests that reinforcement of distribution and/or sub-transmission lines in the South Interconnection Network is desired to reduce the loss to a proper level, e.g., less than 10 to 12 %.

While, energy loss for HT consumers shows decreasing trend from 4.2 % in 1979/80 to 0.9 % in 1990/91. It seems that transmission system network has been reinforced according to development of the power project.

4.4.3 Electrification

To grasp a share of electrification, number of household is very roughly assumed as 7.6 persons per household, referring to Section 2.2. While, historical statistics of population which are quoted from different source of data, are used for this calculation. It is noted that region-wise population increases in the regions of the South Interconnection Network and decreases in that of the North Interconnection Network (Refer to Table 4.4.5).

As shown in Table 4.4.6, share of electrification varies from 8.2 % to 38.3 % among regional provinces as of 1990/91 and increases from 18.0 % in 1986/87 to 19.9 % in 1990/91 in terms of the country total. As summarized below, electrification in the South Interconnection Network is relatively progressing as compared with that in the North Interconnection Network.

		South Network		North Network	
		1986/87	1990/91	1986/87	1990/91
1)	No. of consumers	223,995	290,892	23,774	30,339
2)	No. of household	961,922	1,315,921	418,822	295,092
3)	Share of electrification	23.3 %	22.1 %	5.7 %	10.3 %
4)	- do - in the whole country	18.0 % in 1986/87		19.9 % in 1990/91	

This intimates that electrification for rural areas are required extensively in future.

It is noted that if the above assumption (number of persons per household and population) is to be changed or revised, the ratio of electrification will vary accordingly.

4.4.4 Load Patterns for Public Sector

The typical daily load curves for public sector in the South Interconnection Network (Sanaga system) in 1988/89 shows a night peak pattern and the peaking time starts 18:00 and ends 23:00 as illustrated in Fig. 4.4.1.

The daily load factors (for public sector only) are about 75.6 % in working day, 71.5 % in Saturday and 69.9 % in Sunday and holiday. Respective peak times are 4.4 hours in working day, 4.9 hours in Saturday and 5.1 hours in Sunday and holiday.

Load varies not only on a daily basis but also seasonal one. The highest demand usually occurs in January to March and sometimes in May or June. However, the pattern of the curve seems to be almost similar throughout the seasons as can be seen in Figs. 4.4.2 and 4.4.3.

Annual load factors are around 60 % in the South Interconnection Network and 60 - 65 % in the North Interconnection Network, respectively, as depicted in Table 4.4.2.

4.4.5 Number of Consumers

(1) LT consumers

LT consumers are composed of low consumer (FC), domestic usage (UD), general domestic usage (UDG), small industry (FM), public lighting (EP) and services and agents (SA). According to SONEL, category of FC consumers who use the electricity of less than 5 amperes, exists no more.

The number of consumers in 10 provincial regions are detailed in Table 4.4.7 (1) and summarized below:

	1984/85	1990/91		
Provincial Region	No. of Consumers	No. of Consumers	Per consumer consumption (kWh)	Per capita consumption (kWh)
1) Centre	50,496	85,815.(25.4%)	1,735	50.0
2) South	5,379	9,738 (2.9%)	1,373	29.6
3) East	4,774	6,055 (1.8%)	1,176	13.4
4) Littoral	81,214	121,025 (35.8%)	2,387	128.1
5) West	18,984	39,836 (11.8%)	752	20.1
6) South-west	11,326	22,505 (6.7%)	1,074	25.6
7) North-west	8,945	20,580 (6.1%)	594	9.0
South Network	181,118	305,554 (90.5%)	1,717	52.5
8) North	6,887	11,819 (3.5%)	1,976	34.7
9) Far-north	6,361	12,562 (3.7%)	1,274	14.6
10) Adamaoua	5,026	7,915 (2.3%)	1,201	20.2
North Network	18,274	32,296 (9.5%)	1,513	21.8
TOTAL	326,227	337,850 (100%)	1,697	46.8

As seen above, the South Interconnection Network as of 1990/91 shares about 90 % of the total consumers including East region, and the North Interconnection Network shares 10 %. Among others, Centre and Littoral having urban areas share the major part of all consumers (61 %). Historical statistics of the consumers are shown in Table 4.4.7 (1).

Annual per-consumer consumption in 1990/91 ranges from 594 kWh in North-west region to 2,387 kWh in Littoral region and averages 1,697 kWh in the whole country, as shown above.

Per capita consumption in 1990/91 is 52.5 kWh in the South Interconnection Network, 21.8 kWh in the North Interconnection Network and 46.8 kWh in the whole country.

(2) MT consumers

MT consumers are composed of small industries, etc. which are administrated by the Direction of Distribution (DD) of SONEL. The number of consumers in 10 provincial regions are detailed in Table 4.4.7 (2) and summarized below:

Provincial Region	1984/85 No. of Consumers	1990/91 No. of Consumers	1990/91 Per consumer consumption (MWh)	1990/91 Per capita consumption (kWh)
1) Centre	140	199.(17.5%)	485.5	32.4
2) South	16	36 (3.2%)	289.7	23.1
3) East	12	18 (1.6%)	123.3	4.2
4) Littoral	464	561 (49.4%)	360.8	89.8
5) West	75	100 (8.8%)	181.2	12.2
6) South-west	56	67 (5.9%)	334.5	23.8
7) North-west	19	31 (2.7%)	106.4	2.4
South Network	782	1,012 (89.1%)	351.3	35.5
8) North	42	55 (4.8%)	496.5	40.6
9) Far-north	25	47 (4.1%)	201.3	8.6
10) Adamaoua	19	22 (2.0%)	190.6	8.9
North Network	86	124 (10.9%)	330.3	18.3
TOTAL	868	1,136 (100%)	349.0	32.4

Similarly to the case of LT consumers, the South Interconnection Network as of 1990/91 shares 89.1 % of the total consumers including East region and the North Interconnection Network shares 10.9 %. Historical statistics of the consumers by load centers are also shown in Table 4.4.7 (3) to (4).

Annual per-consumer consumption in 1990/91 ranges from 106.4 MWh in North-west region to 496.5 MWh in North region and averages 349.0 MWh in the whole country, as shown above.

(3) HT consumers

At present, 5 HT consumers which are composed of bulk industrial consumers and administrated by Direction of Production and Transport (DPT) of SONEL, is outlined in Table 4.4.7 (5). Among others, ALUCAM usually consumes largely the energy produced in the country, i.e., 95.4 % in 1990/91, as shown in the same table. Historical peak power recorded for ALUCAM is also shown in the same table.

Most of HT consumers except CICAM, are supplied from the South Interconnection Network.

4.4.6 Power Tariff

The energy consumption shown in Table 4.4.3 is indicated by three categories (HT, MT and LT). And, Table 4.4.8 shows the income of SONEL by the categories and number of customers. Table 4.4.9 shows the tariff system of SONEL which has been revised in September, 1989.

Historical per consumption revenues are as shown below:

(unit: F. CFA/kWh/Year)

Year	South Network				North Network				Whole Networks
	LT	MT	HT	Total	LT	MT	HT	Total	Total
1980/81	36.7	19.8	2.7	11.7	49.6	25.6	-	33.0	12.6
85/86	47.6	25.5	4.1	16.9	53.2	28.8	-	37.0	18.6
90/91	56.5	39.9	5.2	22.7	56.8	36.3	24.7	42.9	23.7
Growth rate for last 10 years (1980/81-90/91)	4.4%	7.3%	6.8%	6.9%	1.4%	3.6%	-	2.7%	6.5%

As shown above, average power charge in the whole network increases from 12.6 F. CFA/kWh in 1980/81 to 23.7 F. CFA/kWh in 1990/91 with average growth rate of 6.5 %. The above Table also indicates that the high tension category consumers are treated quite favorably in terms of power tariff charged.

According to the available data, the energy consumption by the high tension category consumers was 1,382 GWh in 1990/91, and income from 5 HT consumers amounted F. CFA 7,624 million. On the other hand, the energy consumption by the medium and the low tension category consumers was 397 GWh and 574 GWh each and SONEL received the power income as sum of F. CFA 15,679 million and F. CFA 32,393 million respectively. This indicates that average revenue per kWh was F. CFA 5.52 for HT consumers and F. CFA 49.50 for MT/LT consumers combined as of 1991. Note that F. CFA 49.50/kWh for the MT and LT consumers are used for computing the project's benefit in the view of financial evaluation; see Chapter 8.

4.5 Power Demand Forecast

4.5.1 Introduction

Historical energy production and consumption in the whole country for the period of 1975/1976 to 1990/91, are shown in Tables 4.4.1 through 4.4.3.

As summarized in Table 4.4.2, the energy produced for the public sector which is composed of both LT and MT consumers, was recorded at 1310 GWh, of which 1193 GWh or 91 % is produced in the South Interconnection Network (Sanaga system) in 1990/91 and the remaining 117 GWh or 9 % in the North Interconnection Network (Lagdo system). The respective annual growth rate of energy production in the South Interconnection Network were 2.6 % for the last 5 years and 7.2 % for the last 10 years. While, the same rate of energy production in the North Interconnection Network were -1.4 % for the last 5 years and 5.5 % for the last 10 years. Such growth rates are relatively low compared with the growth in the preceding period, presumably due to socioeconomic regression effected in the world.

The SONEL has estimated future power demand by trend method in 1989/90, based on actual annual growth rate for public sector as 3.8 % in average recorded for the last 3 years (1985/86 - 1988/90) in the South Interconnection Network and 1.6 % in average for the last 4 years (1984/85 - 1988/90) in the North Interconnection Network, as shown in Table 4.5.1. While, SONEL has made another forecast for the public sector by micro method with some due assumption. The projection by this method is shown in Table 4.5.2.