TABLE 3.3-4 UNIT GRAPH AT TALAWAKELLE AND CALEDONIA

Unit Rainfall: 10mm

Time (hr)	Unit Graph at Talawakelle Qu (m^3/s)	Unit Graph at Caledonia Qu (m^3/s)	Time (hr)	Unit Graph at Talawakelle Qu (m^3/s)	Unit Graph at Caledonia Qu (m^3/s)
0	0.0	0.0	15	12.3	4.6
1	5.7	8.9	16	10.6	3.7
2	30.1	47.2	17	9.1	3.0
3	79.6	124.8	18	7.8	2.5
4	158.8	92.4	19	6.7	2.0
5	117.5	55.9	20	5.8	1.7
6	87.0	37.4	21	5.0	1.4
7	64.4	28.7	22	4.3	1.1
8	47.6	21.9	23	3.7	0.9
9	39.0	16.8	24	3.2	0.7
10	31.9	12.8	25	2.7	
11	26.1	10.2	26	2.3	
12	21.3	8.3	27	2.0	
13	17.5	6.8	28	1.7	
14	14.3	5.6	29		

II.9 Probable Flood Hydrograph

Design Rainfall

The hydrograph has been applied for estimation of the probable hydrograph. Probable Maximum Precipitation (PMP) was considered in obtaining Probable Maximum Flood at the proposed Caledonia reservoir.

Rainfall-depth-duration relationship for Nuwara Eliya is given as follows:

TABLE II.9-1 RAINFALL-DEPTH-DURATION RELATIONSHIP FOR NUWARA ELIYA

Duration (hrs)	Return Period (Years)											
	50		100		200		500		1,000		10,000 1/	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1	1.3	33.0	1.4	35.6	1.6	40.6	1.7	43.2	1.9	48.3	2.3	58.4
2	2.3	58.4	3.2	81.3	3.4	86.4	3.5	88.9	3.8	96.5	5.2	132.1
4	4.4	111.8	4.8	121.9	5.4	137.2	6.3	160.0	6.8	172.7	8.9	226.1
6	5.6	142.2	6.2	157.5	6.6	167.6	7.9	200.7	8.4	213.4	11.0	279.4
8	6.5	165.1	7.2	182.9	7.9	200.7	9.1	231.1	9.7	246.4	12.5	317.5
10	7.2	182.9	8.0	203.2	8.8	223.5	10.0	254.0	10.7	271.8	13.7	348.0
12	7.7	195.6	8.6	218.4	9.6	243.8	10.8	274.3	11.6	294.6	15.0	381.0
14	8.1	205.7	9.2	233.7	10.0	254.0	11.4	289.6	12.3	312.4	15.9	403.9
16	8.5	215.9	9.4	238.8	10.5	266.7	12.0	304.8	12.9	327.7	16.9	429.3
18	8.8	223.5	9.9	251.5	11.0	279.4	12.5	317.5	13.5	342.9	17.7	449.6
20	9.2	233.7	10.3	261.6	11.4	289.6	13.0	330.2	14.1	358.1	18.5	469.9
22	9.5	241.3	10.7	271.8	11.8	299.7	13.5	342.9	14.6	370.8	19.1	485.1
24	9.9	251.5	11.0	279.4	12.3	312.4	14.0	355.6	15.1	383.5	19.9	505.5

1/: Value estimated from the other data
Source: Development of Unit Hydrographs for Ungauged Catchments Using Snyders Technique; A.A.Jayaratna, Hydrology Division

Various studies were made for Probable Maximum Precipitation(PMP) in the upstream portion of Mahaweli Ganga basin. According to the study report for the existing Kotmale Dam, PMP for the Kotmale Dam catchment is estimated on the basis of the observed daily rainfall at Watawala.

Namely, PMP for the Kotmale Dam catchment was obtained at 711mm (28") based on a observed 1-day rainfall of 525mm (20.65") on October 5th, 1913, with application of a moisture maximization factor of 20% and a conversion factor of 13% to obtain 24-hour rainfall.

As mentioned earlier, Watawala is located in the South-western end of the Kotmale dam catchment where rainfall is abundant compared to the other areas. Annual average rainfall at Watawala is also high at 5,236mm compared to the catchment average of 2,847mm. 1000-year probable daily rainfalls at various stations are presented below; Watawala and Hatton have very high values compared to the other stations.

1000-YEAR PROBABLE DAILY RAINFALL

Unit: mm

Watawala	: 746	New Forest	: 406
Watagoda	: 426	Nuwara Eliya	: 371
Labookelle	: 428	Caledonia	: 358
Hatton	: 636		

Source: An Analysis of the Rainstorms in the Upper Mahaweli Catchment; KDN Silva and P Sumanasekera; Journal of Sri Lanka Meteorological Society - April 1974.

Application of PMP obtained based on Watawala rainfall to the Caledonia dam catchment seems too conservative. In view of the many uncertainties in the hydrometeorological phenomena and behaviour, and particularly due to orographic influence, however, spillway discharge capacity will be checked against PMF. Area reduction factor in the case of PMP was set at 0.80.

Based on the above assumptions, probable floods have been developed as presented in FIG.II.9-1. The obtained peak discharges for various probability are presented below, while developed hydrographs are presented in TABLE II.9-2 and II.9-3.

PROBABLE FLOOD PEAK DISCHARGES AT CALEDONIA

Catchment Area: 175.2km2

Return Period (Year)	50	100	200	500	1,000	10,000	PMF
Peak Discharge (m^3/s)	933	1,108	1,202	1,330	1,429	1,913	2,527
Specific Peak Discharge ($m^3/s/km^2$)	5.3	6.3	6.9	7.6	8.2	10.9	14.4

Probable peak discharges at the Talawakelle diversion dam site have also been developed in the same manner, at 1,363m^3/s for 50-year return period probability and at 1,584m^3/s for 100-year return period.

Probable Flood Hydrograph at Caledonia

Unit: m3/s

Hrs.	Return Period (years)					
	Unigraph	50	100	200	1,000	PMF
1	0.890	14.875	13.967	15.858	16.842	19.565
2	4.720	30.120	25.306	36.319	42.518	62.355
3	12.480	71.414	58.685	90.420	111.317	182.595
4	9.240	106.475	97.050	131.459	166.397	298.575
5	5.590	138.321	133.603	160.907	209.612	375.056
6	3.740	160.611	163.904	190.911	240.692	431.470
7	2.870	177.042	198.918	216.437	269.773	493.746
8	2.190	195.355	236.051	248.261	310.030	566.313
9	1.680	229.740	273.752	307.676	366.606	653.306
10	1.280	286.255	331.743	375.276	433.444	747.809
11	1.020	367.359	413.128	462.182	536.202	895.324
12	0.830	489.042	530.301	576.919	709.130	1183.170
13	0.680	663.081	693.538	781.684	1003.520	1665.910
14	0.560	814.583	941.223	1049.760	1286.520	2171.640
15	0.460	932.966	1108.490	1201.900	1428.940	2527.440
16	0.370	925.946	1009.770	1108.870	1376.680	2396.850
17	0.300	812.537	883.150	955.853	1185.320	2035.320
18	0.250	695.309	765.711	840.242	1013.220	1713.250
19	0.200	595.112	664.741	737.265	874.865	1486.070
20	0.170	506.061	575.915	643.477	764.160	1313.070
21	0.140	434.476	508.870	549.510	664.310	1159.180
22	0.110	385.176	449.267	481.996	584.068	1030.090
23	0.090	350.177	396.003	432.668	526.496	927.422
24	0.070	320.209	352.230	387.493	481.959	851.936
25	0.000	284.492	304.950	349.062	434.328	776.766
26	0.000	244.156	251.365	303.492	375.743	657.875
27	0.000	185.800	192.106	230.152	283.365	491.108
28	0.000	142.234	148.921	174.761	214.256	369.305
29	0.000	113.168	119.330	138.358	168.785	289.258

Probable Flood Hydrograph at Caledonia

Unit: m^3/s

Hrs.	Return Period (years)					
	Unigraph	50	100	200	1,000	PMF
30	0.000	92.384	97.445	112.388	136.403	231.873
31	0.000	76.031	80.217	91.881	111.002	186.837
32	0.000	63.127	66.730	75.808	91.031	151.663
33	0.000	52.836	55.747	62.831	75.098	123.757
34	0.000	44.440	46.685	52.458	62.247	101.030
35	0.000	37.157	39.239	43.692	51.013	81.411
36	0.000	31.157	32.387	35.785	41.395	64.677

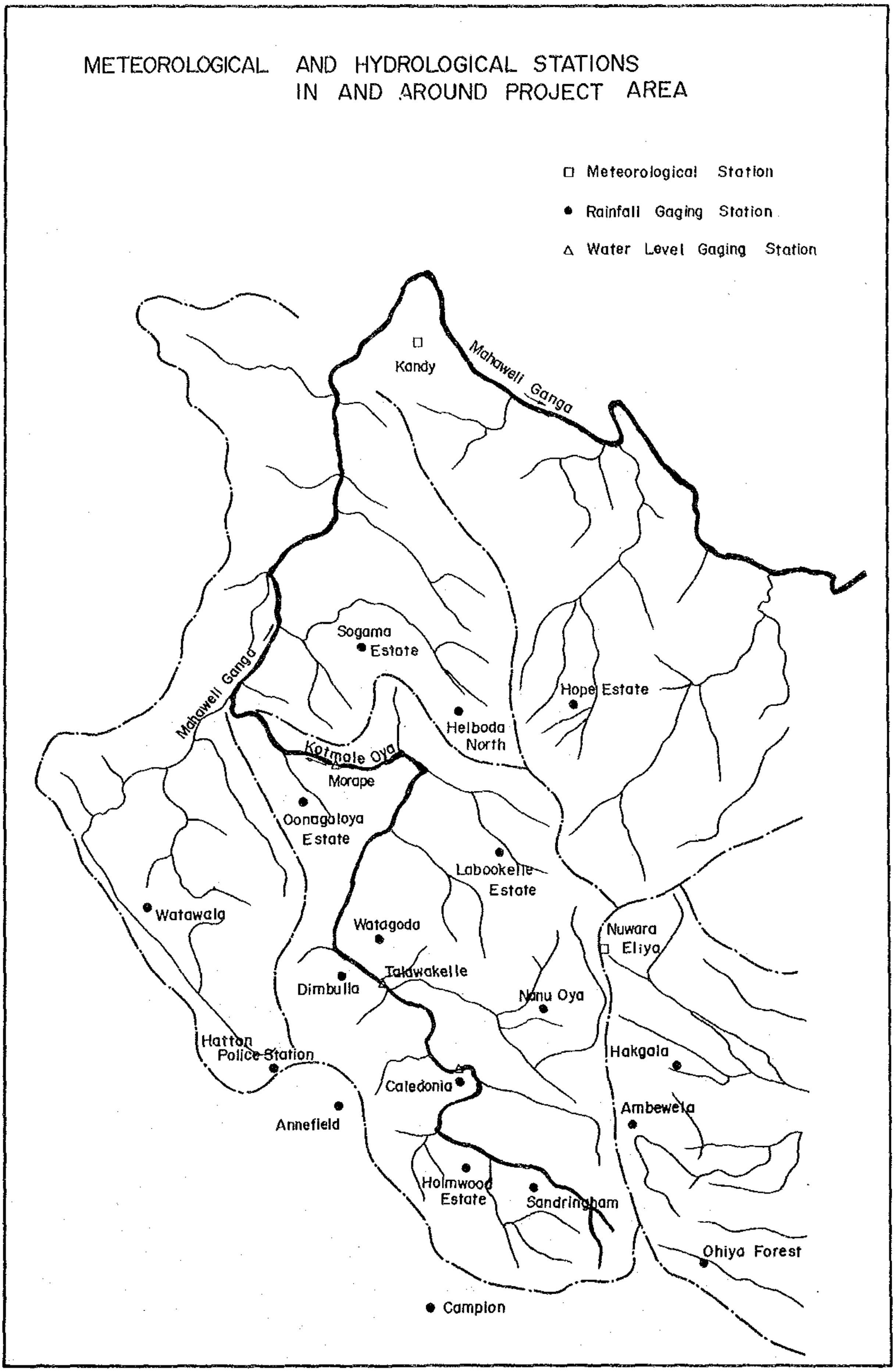
Probable Flood Hydrograph at Talawakelle

Unit: m^3/s

Hrs.	Return Period (years)			Hrs.	Return Period (years)		
	Unigraph	50	100		Unigraph	50	100
1	0.570	21.841	21.260	19	0.670	1093.530	1208.040
2	3.010	31.563	28.493	20	0.580	960.121	1071.380
3	7.960	57.904	49.785	21	0.500	840.168	955.251
4	15.880	112.522	96.325	22	0.430	743.670	859.842
5	11.750	159.271	147.916	23	0.370	670.886	771.567
6	8.700	204.919	200.583	24	0.320	612.571	690.104
7	6.440	239.334	248.587	25	0.270	559.771	617.763
8	4.760	268.860	302.423	26	0.230	499.458	539.891
9	3.900	305.025	360.479	27	0.200	434.755	458.846
10	3.190	363.495	425.497	28	0.170	353.176	374.783
11	2.610	454.964	520.737	29	0.000	290.649	310.018
12	2.130	586.806	651.229	30	0.000	242.749	259.860
13	1.750	772.248	843.114	31	0.000	205.254	220.402
14	1.430	1013.890	1092.230	32	0.000	175.829	188.850
15	1.230	1216.170	1399.950	33	0.000	151.290	162.394
16	1.060	1363.370	1583.640	34	0.000	130.806	140.162
17	0.910	1355.710	1481.800	35	0.000	113.486	121.523
18	0.780	1230.550	1357.410	36	0.000	98.713	105.535

FIGURES

ILLUSTRATIONS

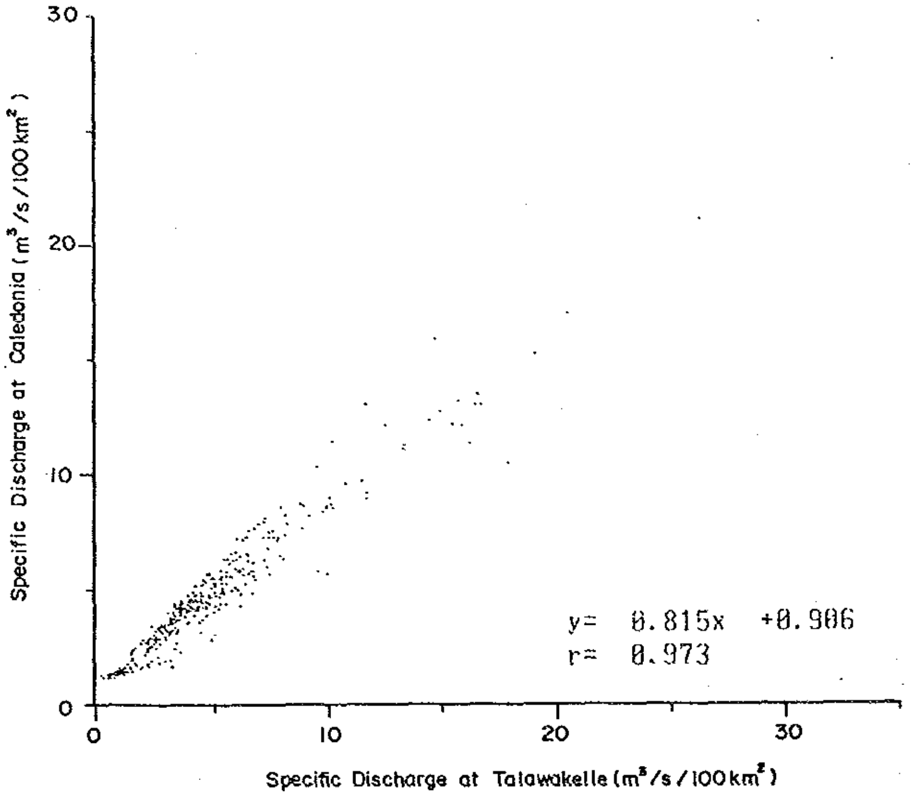

METEOROLOGICAL AND HYDROLOGICAL STATIONS
IN AND AROUND PROJECT AREA
Meteorological Station
Rainfall Gaging Station
Water Level Gaging Station
Kandy
Mahaweli Ganga
Mahaweli Ganga
Sogama Estate
Hope Estate
Helboda North
Kotmale Oya
Morape
Oonagaloya Estate
Labookelle Estate
Watawala
Watagoda
Nuwara Eliya
Dimbulla
Talawakelle
Nanu Oya
Hatton Police Station
Hakgala
Caledonia
Annefield
Ambewela
Holmwood Estate
Sandringham
Ohiya Forest
Campion

COLLECTED METEOR-HYDROLOGICAL DATA AND PERIOD

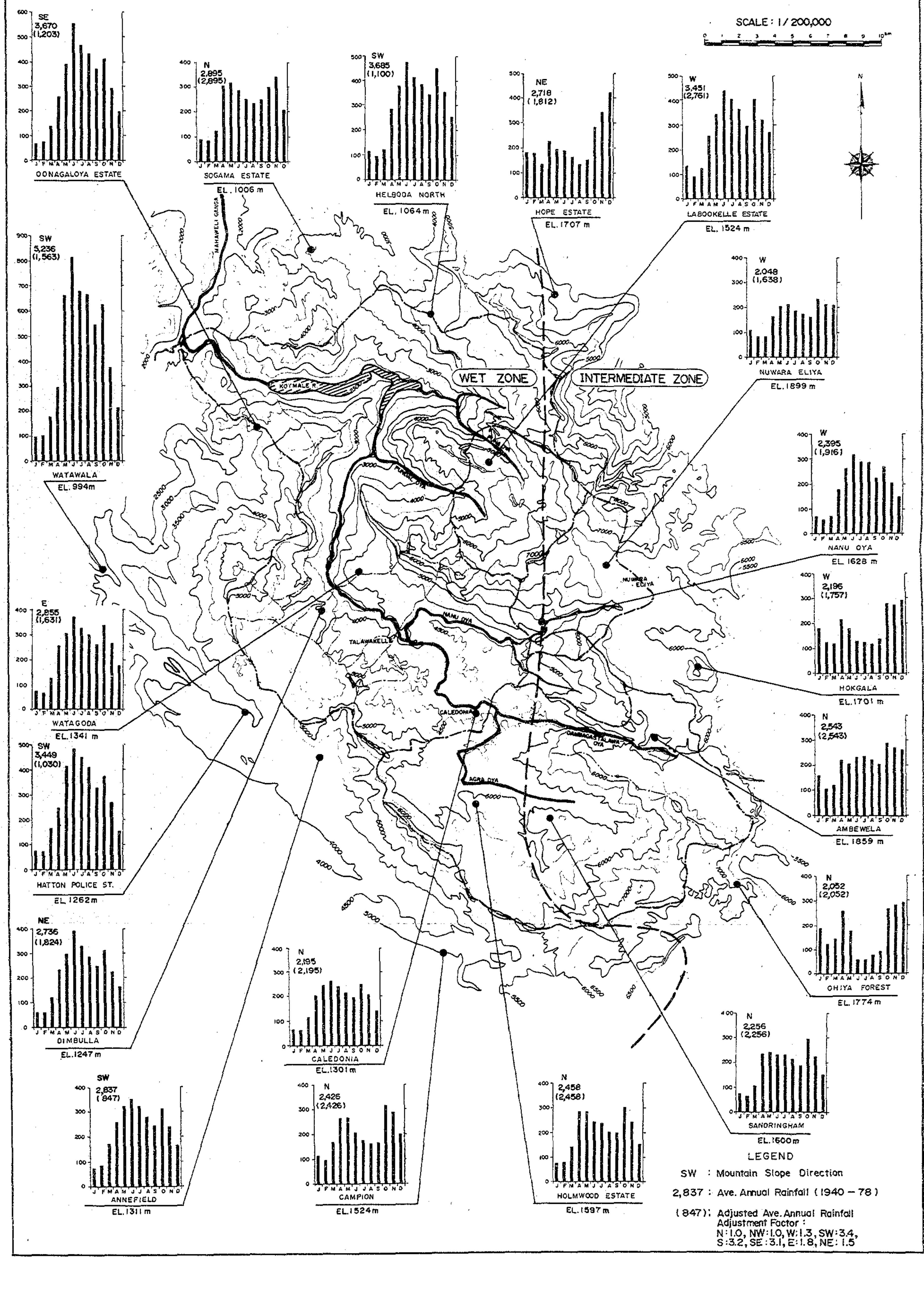
Years: 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985

Station	Long : Tude	Lat : Tude	Elev. (EL.m) /C.A.(km²)	
Meteorology				
Nuwara Eliya	6°58'25" N	80°43'37"E	EL. 1,899 m	1955 - 60; Oct.
Kandy	7° 20' N	80° 38' E	EL. 477	
Montly Rainfall				
Caledonia	6°54'00" N	80° 42'39"E	EL. 1,301	1940
Nuwara Eliya	6°58'25" N	80° 43'37"E	EL. 1,899	1940
Ambewela	6°53'23" N	80° 48'02"E	EL. 1,859	1940; Aug.
Campion	6°46'41" N	80° 42'00"E	EL. 1,524	1940; Feb.
Sandringham	6°50'54" N	80° 45'02"E	EL. 1,600	1940
Annefield	6°52'23" N	80° 38'07"E	EL. 1,311	1940; Feb.
Holmwood Estate	6°51'10" N	80° 42'52"E	EL. 1,597	1940; Feb.
Nanu Oya	6°56'35" N	80° 43'37"E	EL. 1,628	1940
Ohiya Forest	6°58'06" N	80° 50'37"E	EL. 1,774	1940
Dimbulla	6°56'48" N	80° 38'04"E	EL. 1,247	1940
Hakgala	6°55'29" N	80° 49' 12"E	EL. 1,701	1940
Hatton Police Station	6°53'41" N	80° 36'00"E	EL. 1,262	1940
Helboda North	7°05'10" N	80° 39'48"E	EL. 1,064	1940
Hope Estate	7°06'23" N	80° 43'33"E	EL. 1,707	1940
Labookelle Estate	7°01'23" N	80° 42'46"E	EL. 1,524	1940
Donagaloya Estate	7°02'12" N	80° 36'00"E	EL. 1,067	1940
Sogama Estate	7°07'27" N	80° 37'29"E	EL. 1,006	1940
Watagodo	6° 57'54" N	80° 39'08"E	EL. 1,341	1940
Watawala	6° 57'33" N	80° 31'52"E	EL. 994	1940
Daily Rainfall				
Nuwara Eliya	6°58'25" N	80°43'37"E	EL. 1,899	1955 - 60; Oct.
Ambewela Cattle Farm	6°53'23" N	80°48'02"E	EL. 1,859	(May); (Jan) Sep.
Campion State Plantation	6°46'41" N	80°42'00"E	EL. 1,524	(Jan) Sep.
Sandringham Estate	6°50'54" N	80°45'02"E	EL. 1,600	(Nov.); (Jan) Sep.
Annefield	6°52'23" N	80°38'07"E	EL. 1,311	(Jan) Sep.
Holmwood Estate	6°51'10" N	80°42'52"E	EL. 1,597	(Jan) Sep.
Monthly Discharge				
Talawakelle (I.D. Flow)	6°56'25" N	80°39'45"E	EL. 1,219	1954 Oct.; Jul.; Apr.; Jul.
Talawakelle (Corrected)	6°56'25" N	80°39'45"E	EL. 1,219	1954. Jul.
Morape (acc. I.D. records)	7°03'40" N	80°37'20"E	EL. 762	1949. Oct.; Apr.
Daily Discharge				
Talawakelle (HCP-1-19)	6° 56'25" N	80°39'45"E	EL. 1,219	1954 Jul.; Aug.; Aug.; Aug.
Morape (HCP-1-5)	7°03'40" N	80°37'20"E	EL. 762	1946 Nov.; Sep.; Feb.; Jun.
Caledonia (HCP-3-5)	6°54' N	80°42' E	EL. 1,372	Aug.; Sep.
Talawakelle (Original)	6°56'25" N	80°39'45"E	EL. 1,219	1954. Oct.; Jul.; Apr.; Apr. May
Caledonia (Original)				Oct.; Sep.

SPECIFIC DISCHARGE CORRELATION BETWEEN CALEDONIA AND TALAWAKELLE



MONTHIY RAINFALL DISTRIBUTION IN AND AROUND KOTMALE RIVER BASIN



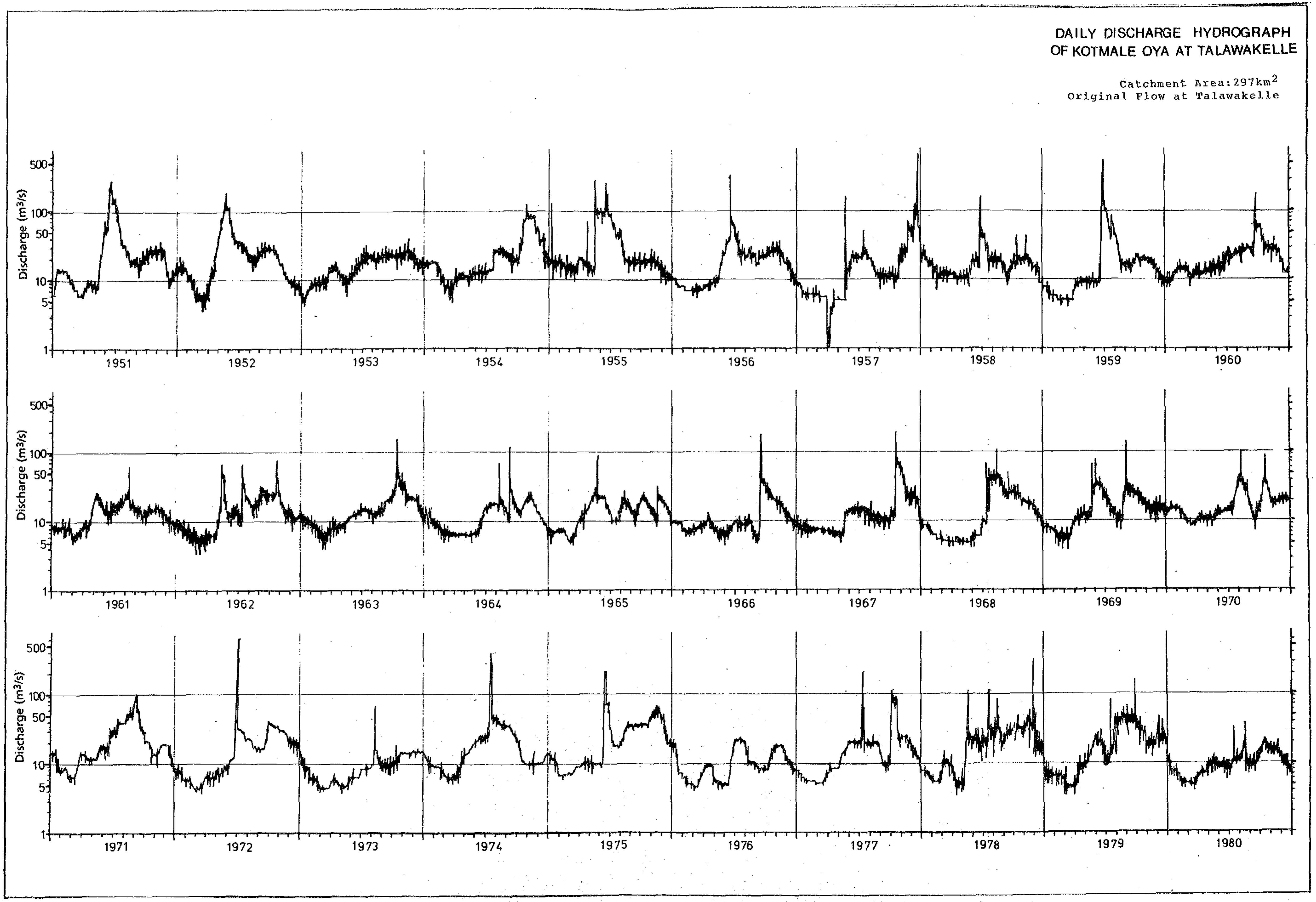

DAILY DISCHARGE HYDROGRAPH
OF KOTMALE OYA AT TALAWAKELLE
Catchment Area:297km2
Original Flow at Talawakelle
Discharge (m³/s)
500
100
50
10
5
1
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980

FIG.II.6-1

AVERAGE FLOW DURATION OF KOTMALE OYA AT TALAWAKELLE

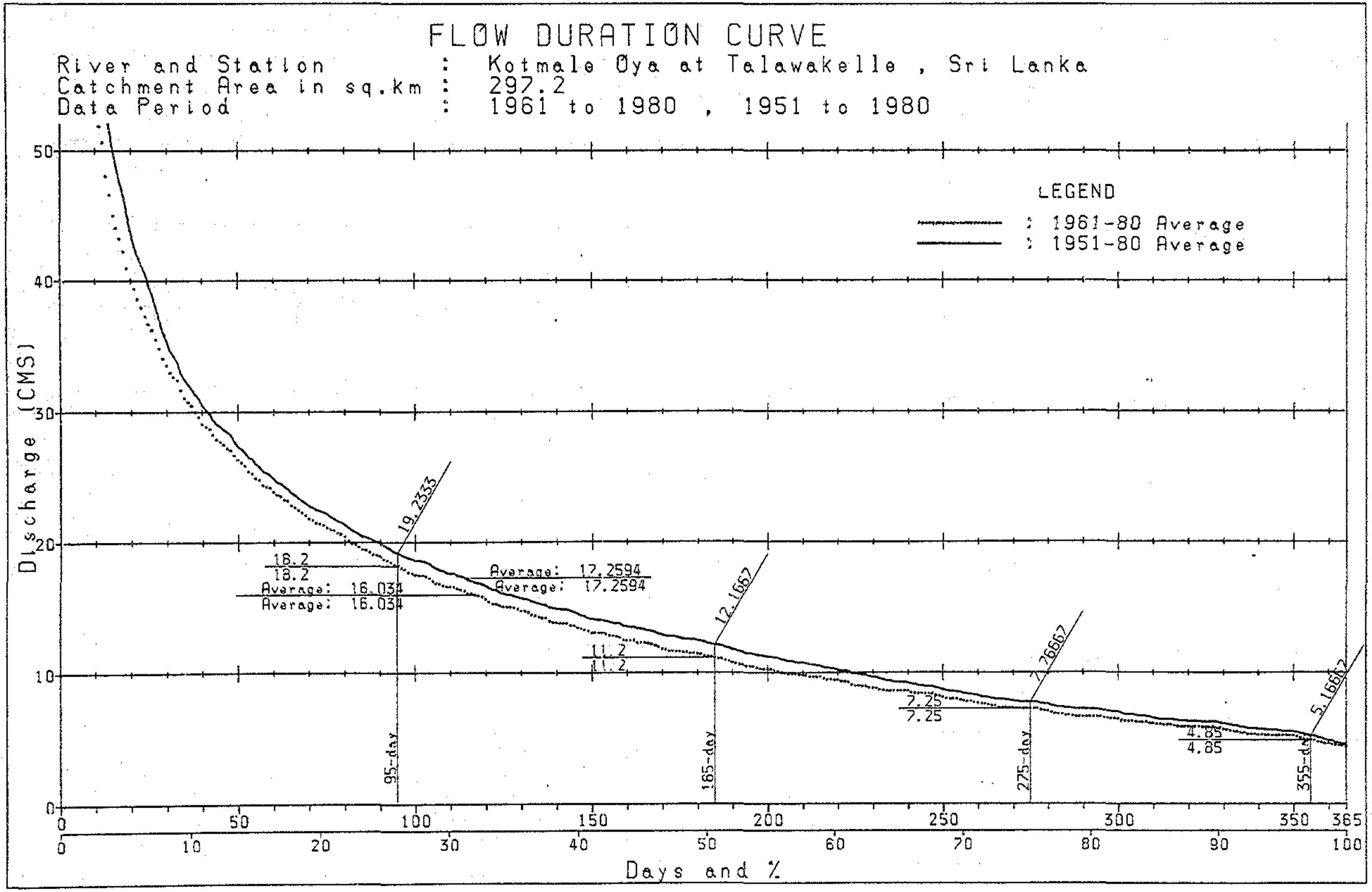
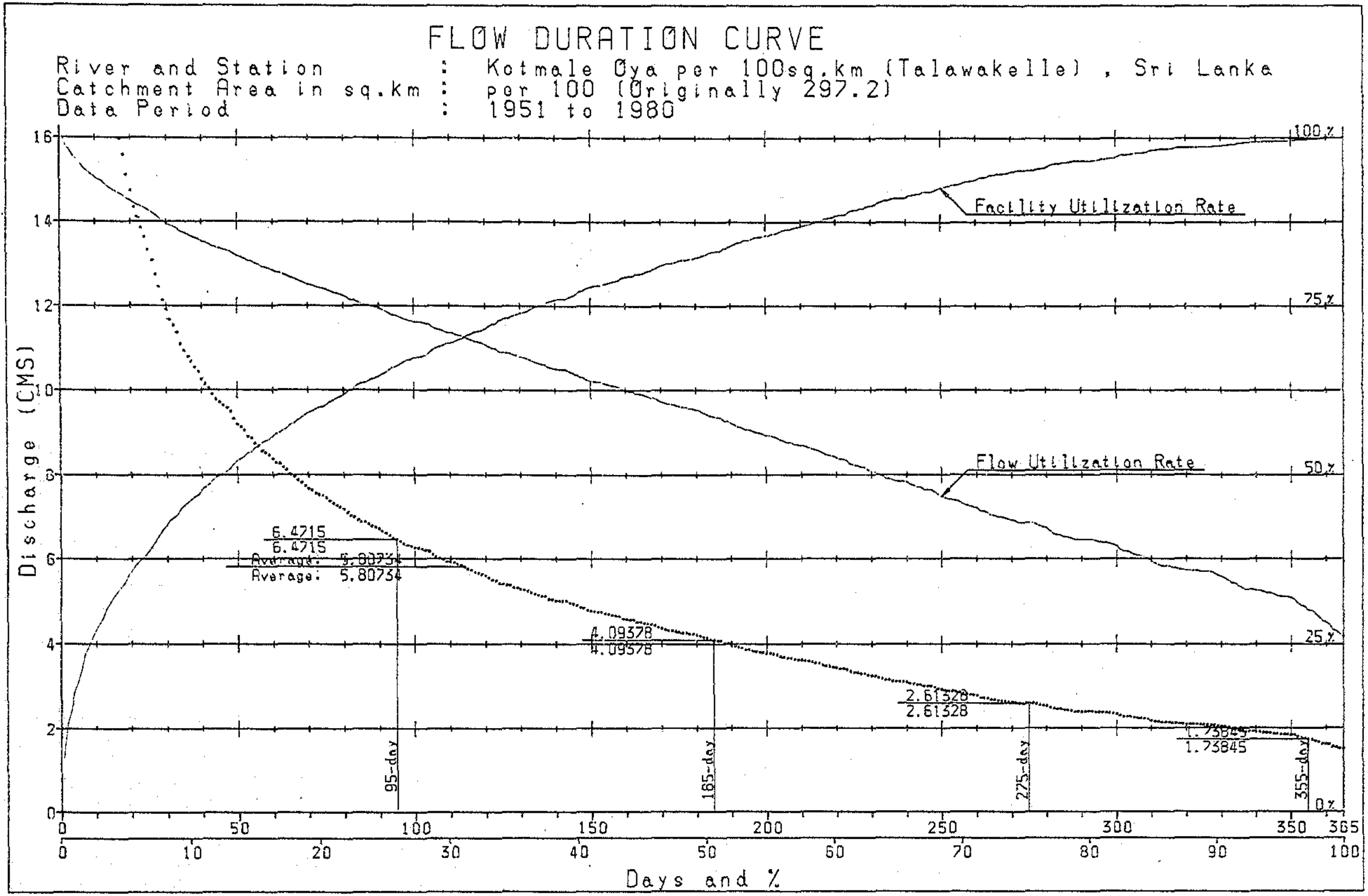
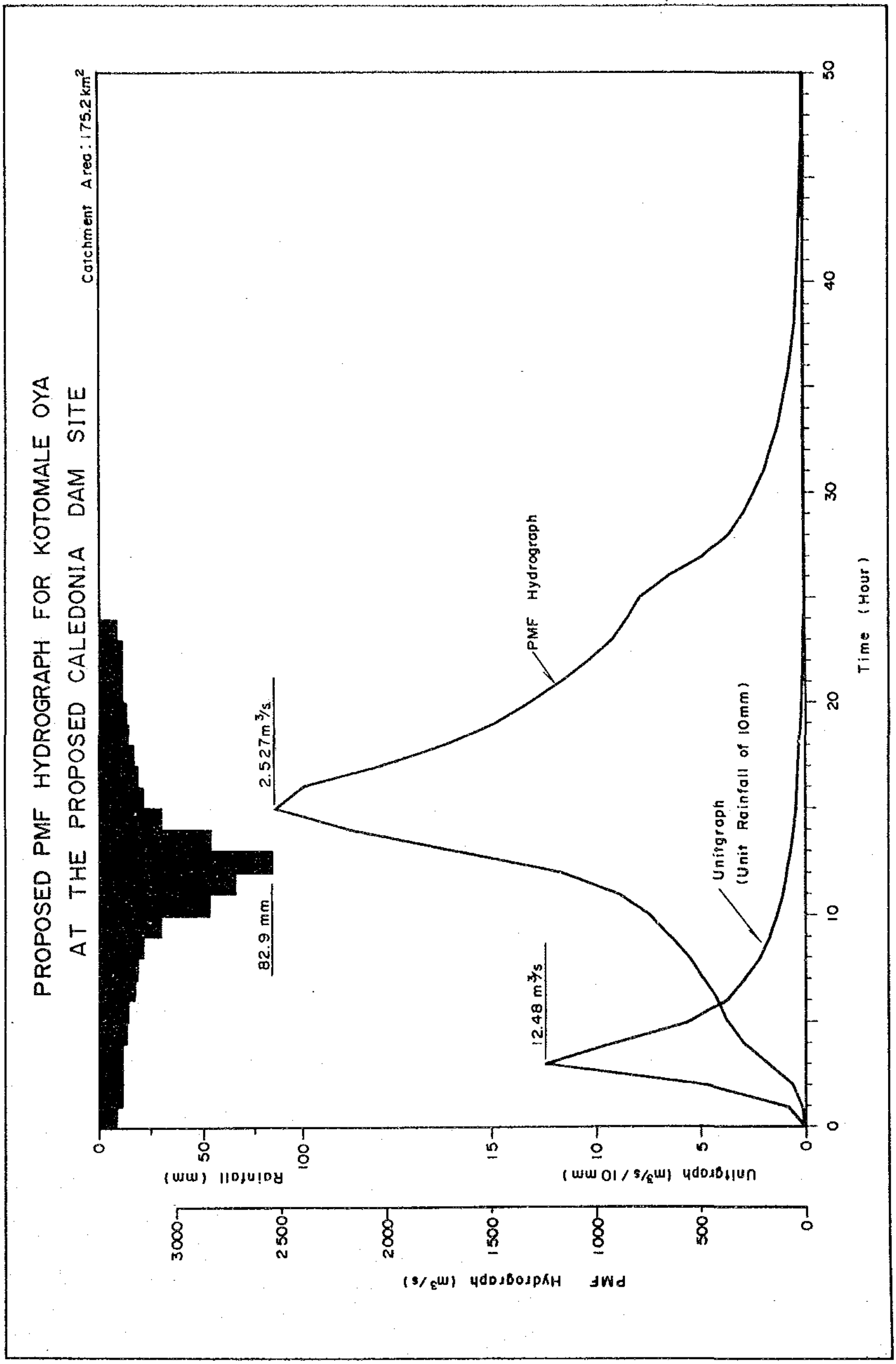


FIG.II.6-2

AVERAGE PER 100km2 FLOW DURATION OF KOTMALE OYA AT TALAWAKELLE




PROPOSED PMF HYDROGRAPH FOR KOTOMALE OYA
AT THE PROPOSED CALEDONIA DAM SITE
Catchment Area: 175.2 km²
82.9 mm
2,527 m³/s
12.48 m³/s
PMF Hydrograph
Unitgraph
(Unit Rainfall of 10mm)
Time (Hour)
0
10
20
30
40
50
Rainfall (mm)
0
50
100
Unitgraph (m³/s/10mm)
0
5
10
15
PMF Hydrograph (m³/s)
0
500
1000
1500
2000
2500
3000

APPENDIX III

HYDROPOWER PLANNING

APPENDIX III HYDROPOWER PLANNING

List of Illustrations

APPENDIX III

HYDROPOWER PLANNING

III.1 Review of Long Range Generation Plan

III.1.1 Long Range Power Demand and Supply Plan

In January 1987, CEB announced its "Long Range Generation and Transmission Plan, 1986". According to this report, power demand growth is anticipated as follows:

1987: 16%

1988-2001: 9%

2002-2006: 8%

The exceptionally high rate for 1987 is explained as due to consideration of recovery of lost loads.

Past power demand in Sri Lanka is shown in TABLE III.1-1. The average growth rate during the 20 year period 1965-1985 was 9.2% for both energy demand and peak demand. FIG. III.1-1 shows future trends for energy demand and peak demand based on past performance. As it is concluded that a reasonable long-term forecast can be made from this data, it has been used as a basis for the planning discussed below.

TABLE III.1-1 PAST POWER DEMAND

Period	Maximum Demand (MW)	Average Annual Growth Rate (%)	Generated Energy (GWh)	Average Annual Growth Rate (%)
1965	89		427.7	
1970	163	12.9	785.8	12.9
1975	219	6.1	1,078.8	6.5
1980	368.5	11.0	1,668.3	9.1
1985	514.9	6.9	2,464.1	8.1
Average		9.2		9.2

Long term energy demand is presented in TABLE III.1-2 and long term peak demand is shown in TABLE III.1-3. If no additional capacity is realized beyond the power development projects already in progress, energy demand will exceed supply capacity from 1991, and peak demand will experience shortfall in supply from 1995. Consequently, there is obviously a need to expand power generating capacity.

III.1.2 Introduction of New Power Generating Facilities

The Long Range Generation and Transmission Plan, 1986, envisages operation of the Upper Kotmale power generating facilities from the year 2000. However, as study has revealed the extremely good economic viability of the Upper Kotmale Hydropower Project and its obvious advantageousness compared to planned introduction of oil-fired plants (2 units of 120MW and 4 units of 200MW) in 1993-2001, CEB and the Study Team agreed that the commencement of operation of the Project should be moved forward tentatively to January 1997. The Alternate Generation Expansion Planning to the year 2001 is presented in TABLE III.1-4.

In the year 2000, an installed capacity of 2,323MW is anticipated. Peak demand is estimated at 1,945MW. If both the largest hydropower facility (70MW) and largest thermal facility (200MW) were to simultaneously shut down, effective output would be 2,053MW, or 5% surplus over peak demand. If plant factors for thermal facilities are considered at 0.77 for diesel, 0.75 for 120MW oil steam, and 0.74 for 200MW oil steam total generated energy is 6,275GWh. On the other hand, considering firm energy plus 1/4 secondary energy, generated energy for hydropower is 3,956 GWh. The total for both thermal and hydropower is thus 10,231GWh, or a 9% surplus over demand of 9,375GWh.

III.1.3 Fluctuation in Daily Demand

Power generation performance from 18 June (Tuesday) to 24 June (Monday)1985 is shown in TABLE III.1-5. As can be seen from the table, there exists a sharp fluctuation between weekdays and the weekend. If the peak generation of 510MW occurring on Tuesday is designated as 100%, average generation on Saturday is 53% and that on Sunday is 45%.

The one week peak value of 510MW and the annual energy (6,822MWh x 365) derived from the daily average are similar to the 514.9MW and 2,464

GWh values for the same for annual data from 1985. This data can thus be considered as the annual mode.

FIG.III.1-2 shows load conditions for 18 June (Tuesday) when maximum power generation occurred, and average load conditions for the week. As can be seen from the figure, maximum peak occurs between 19:00 and 20:00, with generated energy sharply less both before and after this period. This is considered as due to concentrated power use for illumination during the said period. The load pattern depicted in the figure is anticipated to continue to prevail in Sri Lanka for the foreseeable future.

Available power stations as of 2000 are shown in TABLE III.1-6. Performance at hydropower stations by the year 2000 is presented in TABLE III.1-7. Facilities capable of responding to relatively short period peak load are few. Facilities which may be considered for peak load operation are Kotmale, Upper Kotmale and diesel plants.

In the case of the most typical week day load assumed for the year 2000, supply will be such as presented in FIG. III.1-3, if firm + $\frac{1}{4}$ secondary is counted for energy of hydropower stations. As can be seen from the figure, Kotmale and Upper Kotmale can be used effectively for peak generation. Development of Upper Kotmale as peak facilities is accordingly appropriate.

The figure further shows that energy demand and peak demand cannot be considered separately. As there is little surplus over demand in both cases, implementation of an appropriate power generating plan is important.

LONG RANGE ENERGY DEMAND FORECAST AND SUPPLY BALANCE BY STATIONS EITHER EXISTING OR UNDER CONSTRUCTION

Year	Peak Demand (MW)	available Hydro (MW)	available Thermal (MW)	Total available (MW)	Deficit (MW)
1987	635	715	200	915	-
88	692	946	200	1,146	-
89	754	946	250	1,196	-
90	822	995	250	1,245	-
91	896	995	250	1,245	-
1992	976	1,115	250	1,365	-
93	1,064	1,115	250	1,365	-
94	1,160	1,115	250	1,365	-
95	1,265	"	"	"	-
96	1,378	"	"	"	13
1997	1,502	"	"	"	137
98	1,637	"	"	"	272
99	1,785	"	"	"	420
2000	1,945	"	"	"	580
1	2,121	"	"	"	756
2002	2,291	"	"	"	926
3	2,474	"	"	"	1,109
4	2,672	"	"	"	1,307
5	2,886	"	"	"	1,521
6	3,116	"	"	"	1,751

Source: Long Range Generation and Transmission Plan, 1986, CEB

Note: 1. Peak Demand is at Generator Terminal

2. The units of maximum capacity for both hydro and thermal are considered non-effective for Available Energy

LONG RANGE PEAK DEMAND FORECAST AND SUPPLY BALANCE
BY STATIONS EITHER EXISTING OR UNDER CONSTRUCTION

Year	Peak Demand (MW)	available Hydro (MW)	available Thermal (MW)	Total available (MW)	Deficit (MW)
1987	3,058	2,267	1,050	3,317	-
88	3,333	2,537	1,050	3,587	-
89	3,633	2,537	1,230	3,787	-
90	3,960	2,711	1,250	3,961	-
91	4,316	2,711	1,250	3,961	355
1992	4,705	3,161	1,250	4,411	294
93	5,128	3,161	1,250	4,411	717
94	5,590	3,161	1,250	4,411	1,179
95	6,093	"	"	"	1,682
96	6,641	"	"	"	2,230
1997	7,239	3,161	1,250	4,411	2,828
98	7,890	"	"	"	3,479
99	8,600	"	"	"	4,189
2000	9,375	"	"	"	4,964
1	10,218	"	"	"	5,807
2002	11,035	3,161	1,250	4,411	6,624
3	11,918	"	"	"	7,507
4	12,872	"	"	"	8,461
5	13,901	"	"	"	9,490
6	15,014	"	"	"	10,603

Source: Long Range Generation and Transmission Plan, 1986, CEB
Note: Demand is at Generator Terminal

TABLE III.1-4 FUTURE ALTERNATE GENERATION EXPANSION PLAN

Year	Installed Capacity (MW)			Eff. Capacity (MW) 1/	Peak Demand (MW) 2/	Reserve Margin (%) 3/	Planned Projects (MW) 4/	Energy (GWh)		
	Hydro	Thermal	Total					Demand	Hydro 5/	Thermal 6/
1987	715	200	915	825	635	29.9	Randenigala:122	3,058	2,497	561
1988	946	"	1,146	1,056	692	52.6	Kotmale:67×3, Canyon II:30	3,333	2,825	508
1989	"	250	1,196	1,101	754	46.0	KPS oil steam:25×2	3,633	"	808
1990	995	"	1,245	1,150	822	39.9	Rantambe:49	3,960	3,017	943
1991	"	290	1,285	1,190	896	32.8	Diesel:20×2	4,316	"	1,299
1992	1,115	"	1,405	1,310	976	34.2	Samanalawewa:120	4,705	3,448	1,257
1993	"	410	1,525	1,335	1,064	25.5	Oil Steam I:120	5,128	"	1,680
1994	"	"	"	"	1,160	15.1		5,590	"	2,142
1995	"	530	1,645	1,455	1,265	15.0	Oil Steam II:120	6,093	"	2,645
1996	"	"	"	"	1,378	5.6		6,641	"	3,193
1997	1,363	"	1,893	1,703	1,502	13.4	Upper Kotmale:248	7,239	3,956	3,283
1998	"	610	1,973	"	1,637	4.0	Oil Steam III:200, KPS Gas:-120	7,890	"	3,934
1999	"	760	2,123	1,853	1,785	3.8	Oil Steam IV:200, KPS Steam:-50	8,600	"	4,644
2000	"	960	2,323	2,053	1,945	5.6	Oil Steam V:200	9,375	"	5,419
2001	"	1,160	2,523	2,253	2,121	6.2	Oil Steam VI:200	10,218	"	6,262

Note: 1/ Effective Capacity : The units of maximum capacity for both hydro and thermal are considered as non-effective
2/ Peak Demand : Peak demand at generation site (capacities also at generation site)
3/ Reserve Margin : (Eff. Capacity - Peak Demand)/(Peak Demand)
4/ Minus values indicate obsolescence beginning in the designated year.
5/ Generated Energy : (Firm) + (1/4 Secondary)
6/ Obtained by subtracting Hydro from Demand, the value is required thermal generation.

TABLE III.1-5 HOURLY ENERGY FLUCTUATION

Date Time	Mon., Jun. 24	Tue., Jun. 18	Wed., Jun. 19	Thu., Jun. 20	Fri., Jun. 21	Weekday mean	Sat., Jun 22	Sun., Jun 23	Weekly Mean
0	194	252	240	232	228	229	231	222	228
1	178	236	230	220	218	216	214	193	213
2	178	221	214	210	210	207	204	186	203
3	163	215	211	295	210	201	202	181	198
4	170	232	234	205	212	211	205	182	206
5	206	263	266	243	244	244	213	198	233
6	273	333	337	307	320	314	279	252	300
7	253	259	292	294	288	277	271	262	274
8	258	303	310	296	298	293	266	214	278
9	278	341	319	300	328	313	288	203	294
10	302	343	338	323	330	327	228	200	295
11	253	347	342	328	339	322	234	213	294
12	315	334	332	318	316	323	214	208	291
13	227	258	305	284	300	275	255	208	262
14	274	251	305	289	310	286	243	188	266
15	260	304	313	293	310	296	244	201	275
16	297	329	313	297	316	310	263	196	287
17	295	324	305	300	305	306	271	230	289
18	302	344	320	319	321	321	288	266	309
19	423	499	470	467	458	463	410	381	444
20	453	430	467	470	462	456	425	381	441
21	373	343	403	430	415	393	391	332	384
22	273	278	330	345	330	311	364	257	311
23	217	264	272	264	255	254	238	218	247
Total	6,415	7,303	7,468	7,239	7,323	7,150	6,441	5,562	6,822
Mean/ Peak	52%	60%	61%	59%	60%	58%	53%	45%	56%

Note: Peak = 510MW
Source: CEB

TABLE III.1-6 POWER GENERATION STATIONS AS OF 2000 (PEAK BALANCE)

Category	Type	Installed Capacity (MW)
1. Peak Load	Diesel Hydro -Kotmale -Upper Kotmale	120 201 248
2. Middle Peak	Other Existing Hydro	825
3. Base Load	Thermal	840
Total		2,323

TABLE III.1-7 HYDROPOWER STATIONS AS OF 2000 (ENERGY BALANCE)

Station Name	Inst. Capa. (MW)	Firm (GWh)	Equiv. Peak Time (hr)	Firm + 1/4 Sec.	
				Energy (GWh)	Equiv.peak time (hr)
K-M Complex	335	1,304	10.7	1,371	11.2
Ukuwela & Bowatenna	78	213	7.5	217	7.6
Victoria	210	447	5.8	557	7.2
Kotmale	201	270	3.7	328	44.5
Randenigala	122	304	6.8	352	7.9
Rantambe	50	174	9.5	192	10.5
Samanalawewa	120	420	9.6	431	9.8
Upper Kotmale	248	407	4.5	508	5.6

Source: Long Range Generation & Transmission Plan, 1986 by CEB

1/

III.2 Determination of Development Mode

III.2.1 Development Approach

A number of proposals have been preliminarily formulated to the present for the Upper Kotmale Hydropower Development Project. Under the subject Study, these proposals were examined and used as reference in determining the optimum development project based on the fundamental approach set out as follows.

In general, once the catchment has been determined, development approach for a hydropower project is studied from the stand point of either large-scale development mode, or step-wise development mode.

In the case of large-scale development, the optimally cost-effective canal connecting point of intake and tailrace outlet is designed, and generating facilites are minimized in number and maximized in scale. However, discharge from tributaries downstream of the intake site can be utilized only for independent small-medium scale hydropower development.

In step-wise development, discharge is maximally utilized, and total available head is divided into several steps, with each steps developed with separate power generating facilities. This approach has the advantage of utilizing almost all of the natural discharge of the main flow, as well as allowing phased development in response to demand growth. However, increase in number of steps results in increase in construction cost, and the optimum number of steps must be carefully selected,

In studying the best development mode for the Upper Kotmale, selection of dam site is extremely important. The optimum upstream dam site is considered to be the Caledonia site (maximum high water level: EL. 1,365m). As discussed in section 4.5.1 of the main report, the site is ideal for creating a reservior. Between the Caledonia site and existing Kotmale reservoir, there are good dam sites at Talawakelle, Lindura, Yoxford, and Wavahena. Talawakelle is appropriate for construction of a 20m high dam; however, the fact that highway A7 passes near the site as well as the site's proximity to the town of Talawakelle must be taken into consideration when determining high water level.

Topographically, large dam construction is also possible at Lindura, Yoxford, and Wavahena; however dam scale will be geologically limited for Lindura as discussed in the main report.

In order to conduct an overall evaluation of these cases, the development potential index was adopted. Under this method, the product of catchment area and total head is designated as the development potential index, and cases are evaluated on the basis of size of index value. In general, the said index value increases with stepped development; however, construction and O&M costs for facilities also increase as number of facilities is larger and canal length is greater. Potential indices of possible cases for power development of the area with the Caledonia and Talawakella schemes as main components are presented for comparison in TABLE III.2-1.

As shown in TABLE III.2-1, the development index for 2 stage development rises markedly over that for 1 stage, and the index for 3 stage development subsequently decreases. The reason for this is that diversion from the Pundal and Puna rivers can be performed comparatively easily in the case of 2 stage development; whereas in the case of 3-4 stage development, diversion from both rivers is not realistic due to extremely excessive canal length. Furthermore, as the facilities cost can naturally be expected to be greater in the case of 3-4 stage development, such was eliminated from consideration. Consequently, further comparative study focused on 1 stage and 2 stage developments only.

For 1-step development the Team compared five cases, three cases each with a daily regulation pond and two cases each with a reservoir. Of the three cases with a daily regulation pond, Case No.3 with the intake at Talawakelle presents the highest index value and the lowest cost with the shortest tunnel length. Accordingly, for 1-step development with a daily regulation pond, Case No.3 (referred to as the Talawakelle run-of-river scheme) is selected for further comparison.

Of the two cases with reservoir for 1-step development, case No.4 with a reservoir at Caledonia presents a higher development potential index. Construction costs for cases No.4 and No.5 are almost the same. In case No.5, a reservoir must be constructed around Lindula, although the site exhibits distinct lineaments identified by photogeological interpretation running along the Kotmale Oya and is not suited for dam construction. Accordingly, Case No.4 referred to as the Upper Kotmale Power Station Scheme has been selected for detailed comparison.

Of the possible 1 stage development approaches, that proposed with the regulating pond is a run-of-river type with a firm discharge of $1.68m^3/s/100km^2$ which is 48% of the $3.52m^3/s/100km^2$ in the case with the reservoir. Consequently, both firm output and firm energy are less in the case of the former, although it has the advantage of more inexpensive dam construction.

III.2.2 Description of Alternative Proposals

Talawakelle Run-of-river Scheme

Canal is the same as for the Talawakelle power station under two stage development. Diversion points and discharges from tributaries (Puna, Pundal and Devon) are also the same.

Intake is from the right bank upstream of Talawakelle dam, and canal passes through the diversion point on the Pundal Oya. Power station is underground, and tailrace outlet is at the upstream extremity of the existing Kotmale dam. Discharge from the Puna Oya is diverted to the Pundal Oya. Full water level at the Talawakelle regulating pond is the same as that for the regulating pond under 2 stage development, in other words, EL. 1,200m. Maximum turbine discharge is $30m^3/s$.

Caledonia Single Step Scheme (with Reservoir)

Intake is from the right bank, roughly 1.5km above the Caledonia dam site. The shortest possible canal is designed to connect with the upstream extremity of the Kotmale reservoir. Diversion from the various tributaries along the route is performed to the degree economically viable, i.e. Nanu Oya No.1 (43.3km2; 8.5m3/s), No.2 (16.5km2; 3.4m3/s), Puna Oya (16.6km2; 3.4m3/s), and Pundal Oya (17.2km2; 3.4m3/s). Discharge from the Puna Oya is to be diverted to the Pundal Oya; while in the case of the other tributaries diversion to the headrace canal is to be direct by vertical shaft. When the power station is not operating, discharge is diverted to Calaedonia reservoir for storage.

The special feature of this proposal is that head is extremely high at over 600m (other examples of hydropower projects worldwide where head of this size is utilized are few, lists of existing high head power stations in the world are presented in TABLEs III.2-2 and III.2-3). The envisaged canal tunnel route cuts across the mountain divide of the island, and features an extremely long 9,200m between work access shafts. By selecting a more round-about tunnel route, the distance between work shafts could be reduced to 7,100m, however tunnel length would increase by 920m.

Optimum full water level at the dam is determined at EL.1,360, which yields a turbine discharge of $40m^3/s$.

Caledonia/Talawakelle (Two Step) Scheme (Final Proposal)

Intake is from the right bank of the Kotmale Oya directly above Caledonia dam. The tunnel route from Caledonia reservoir to Talawakelle regulating pond is essentially straight. An underground power station is planned at Caledonia. The tailrace from Caledonia power station subsequently crosses the Kotmale Oya, and empties into the upstream portion of Talawakelle regulating pond. For the remaining portion of the scheme at Talawakelle, water is conveyed by headrace from the pond to the power station located at the same point as that for the described single step development.

The normal high water levels at Caledonia reservoir and Talawakelle regulating pond are determined at EL. 1360 and EL. 1200m respectively. Maximum turbine discharge are $35m^3/s$ at the Caledonia power station, and $50m^3/s$ at the downstream Talawakelle power station.

III.2.3 Comparison of Development Proposals

The above three alternative proposals are compared in TABLE III. 2-4.

The output and annual generated energy of the Talawakelle run-of-river scheme are small at 123MW and 610GWh, respectively compared to the other plans and hence not preferable from the viewpoint of effective utilization of water resources and hydropower potential. Accordingly, this scheme was eliminated from further study even though it presents better cost effectiveness than the other two plans.

Comparing the remaining two alternatives i.e. 1-step development (Caledonia Single Step Scheme) and 2-step development (Caledonia/Talawakelle Scheme), 2-step development presents higher effectiveness in water resources utilization while economically the 1-step development is better as presented in TABLE III.2-2.

As a result of consultation and discussions with concerned agencies within the Sri Lankan government, it was determined that focus should be placed on effective maximum development of hydropower potential and consequently the 2 stage development mode was selected.

Detailed comparison of the two alternatives are presented hereafter, while determination of the optimum development scale for each schemes are presented in section III.3.3.

(1) With regard to effectiveness of water resources utilization and hydropower potential development, 2-step development is more advantageous than 1-step development.

	1-step Development	2-step Development
Output (MW)	214	248
Annual Firm Energy (GWh)	346	407
Annual Total Energy (GWh)	664	809

(2) 1-step development is more viable as follows:

	1-step Development	2-step Development
B/C	1.45	1.39
B-C	309	337
Energy Cost (RS/kWh)	1.22	1.24
Construction Cost (Rs million)	7,920	9,800

(3) Construction period is shorter in the case of 2-step development. In both cases, the construction of the headrace tunnel is the critical pass in overall construction works. The

construction period of the headrace tunnel in each case is as follows:

	1-step Development	2-step Development
Tunnel Length (m)	17,900	13,240
Longest Segment (m)	8,410	7,400
Construction Period for the Longest Segment		
Preparatory Works	6 months	6 months
Excavation (from both sides with 110m/month)	38.2 months	33.6 months
Lining (from both sides with 200m/month)	21.0 months	18.5 months
Total	65 months (5 year 5 months)	58 mnnths (4 year 10 months)

As presented above, a difference of 7 months occurs in the construction period for the two cases. For reference, 8,409m of the longest interval of the tunnel for the 1-step development case can be shortened to 6,256m by bending the alignment and adding an approach tunnel but the total length will increase by 920m. Also in 2-step development, the longest interval of 7,380 can be shortened to 5,440m by adding a 200m deep vertical shaft.

(4) In the case of 2-step development, the staged implementation approach can be selected considering actual electric demand increase and also funding scale for implementation. In other words, in the case of 2-step development, both simultaneous development of the upper and lower schemes and stage development are applicable. On the other hand in the case of 1-step development, major facilities such as the dam, headrace tunnel, penstock and tailrace as well as the underground powerhouse must be constructed at the same time. Staged development is possible only by means of step-wise installation of turbines and generators. 1-step development gives only a small selection margin for staged development.

(5) The Talawakelle regulation pond will not be required in the case of 1-step development. On the other hand, from the viewpoint of social impact, over 100 houses, temples, bus terminal, a bank, a school, etc. will be inundated by the Talawakelle regulation pond in the case of 2-step development, and compensation for the same is required.

(6) Two major falls i.e. St. Clair Falls and Devon Falls exist in the Project area and provide tourism attraction. In the case of 1-step development, diversion of water from the Devon Oya is not economical due to required long diversion facilities and hence the Devon Oya will not be included in the Project. Devon Falls remains in this case. In the case of 2-step development, diversion of water from the Devon Oya is very economical and 2/3 of the volume will be used for power generation while one third will be kept to maintain the falls. With regard to the St. Clair Falls, it will disappear in the case of 2-step development because water will be diverted by the Talawakelle diversion dam which is located just upstream of the Falls. In the case of 1-step development, however, the remaining catchment upstream of the falls and downstream of the Caledonia dam is approximately $120km^2$. Although discharge will be 1/3 of that of the present, the falls will remain and in the rainy season, water supply to the falls will be ample. Thus from the viewpoint of tourism, 1-step development is superior to 2-step development.

TABLE III.2-1 COMPARISON OF DEVELOPMENT POTENTIAL INDEX

No. of P/S	Intake Site	Type	Catchment Area (km^2)								Head (m)			Development Potential Index ($m \cdot km^2$)
			Kotmale	Nanu 1	Nanu 2	Devon	Pundal	Puna 1	Puna 2	Total	Intake W.L.	Tailrace W.L.	G. Head	
1	Regulating Pond													
	Case No.1 Caledonia	P	175.2	64.0	-	-	18.0	8.2	17.2	282.6	1,310	703	607	171,538
	Case No.2 Lindula	P	190.0	79.2	-	-	19.6	8.9	17.5	315.2	1,255	703	552	173,990
	Case No.3 Talawakelle	P	297.2	-	-	16.3	21.3	10.1	18.5	363.4	1,200	703	497	180,610
	Reservoir													
	Case No.4 Caledonia	R	175.2	16.5	43.3	-	17.2	-	16.6	268.8	1,365	703	662	177,946
	Case No.5 Lindula	R	190.0	64.0	-	-	18.0	-	17.2	289.2	1,310	703	607	175,544
2	Caledonia	R	175.2	16.5	43.3		-	-	-	235.0	1,360	1,200	160	37,600
	Talawakelle	P	297.2	-	-	16.3	21.3	10.1	18.5	363.4	1,200	703	497	180,610
	Total													218,210 1/
3	Caledonia	R	175.2	16.5	43.3	-				235.0	1,360	1,200	160	37,600
	Talawakelle	P	297.2	-	-	16.3				313.5	1,200	960	240	75,240
	Yoxford	P	365.0	-	-	-				365.0	960	703	257	93,805
	Total													206,645
4	Caledonia	R	175.2	16.5	43.3	-				235.0	1,360	1,200	160	37,600
	Talawakelle	P	297.2	-	-	16.3				313.5	1,200	960	240	75,240
	Yoxford	P	365.0	-	-	-				365.0	960	800	160	58,400
	Wevahena	P	398.0	-	-	-				398.0	800	703	97	38,606
	Total													209,846

Note: R: Reservoir, P: Daily Regulation Pond
1/ Development Potential Index for 2-Step Development is the highest value

WORLD HIGH HEAD FRANCIS TURBINE

Plant	Country	Head (m)	Output (MW)	rpm.
Horn Bert	F.R. Germany	652	262	600
Hemsil I	Norway	543	37	
Murray I	Australia	521	119	
Kvilldal	Norway	520	350	333
Ferera	Switzerland	520	74	
Praoella	Switzerland	494	75	750
Oriichella	Italy	474	75	600
Mihoro II	Japan	465	66	600
Grimsel II		458	106	750
Fionnay	Switzerland	455	47	
Le Pouget	France	440	257	333
Limberg	Austria	436	58	
Oksla	Norway	435	206	375
Tonstad	Norway	430	165	
Arimine	Japan	411	266	300

FECTURES OF HIGH HEAD PUMP TURBINES MANUFACTURED IN JAPAN

Hydropower station	Country	Head (m)	Output (MW)
Chaira	Bulgaria	677	216
Bajinabasta	Yugoslavia	600	315
Honkawa	Japan	550	306
Tenzan	Japan	560	308
Imaichi	Japan	540	360
Helms	U. S. A.	532	414
Matanogawa	Japan	529	309
Oku-Yoshino	Japan	526	207
Tamahara	Japan	524	309
Oohira	Japan	512	256
Okumino	Japan	506	270
Numappara	Japan	500	230
Chompion	Korea	498	206
Okukiyotu	Japan	490	260
Drakensberg	South Africa	451	300

COMPARISON OF DEVELOPMENT SCHEMES
1/2 : 1-STEP DEVELOPMENT

Item	Unit	Talawa. Run-of River Scheme	Caledonia Single Step scheme
Catchment Area			
Total	km^2	363.4	235.8
Main River	km^2	297.2	175.2
Tributaries	km^2	66.2	59.8
Dam			
Type		C.Gravity	C.Gavity
Height	m	20	70
Reservoir/Pond			
N.H.W.L.	EL.m	1,200	1,360
L.W.L.	EL.m	1,193	1,341
Storage Capacity			
-Gross	MCM	2.6	45.1
-Effective	MCM	2.0	30.0
Tunnel			
Headrace	m	13,066	17,860
Branch	m	9,420	3,200
Tailrace	m	406	770
Power Generation			
Rated Head	m	468	614
Max. Turbine Discharge	m^3/s	30	40
Installed Capacity	MW	123	214
Annual Generated Energy 1/	GWh	610	664
-Firm Energy	GWh	207	346
-Secondary Energy	GWh	403	318
Construction Cost 2/	$Rs.10^6$	4,380	7,920
Evaluation			
B (Annual Benefit) 3/ 4/	$Rs.10^6$	762	999
C (Annual Cost) 3/	$Rs.10^6$	382	690
B/C		1.99	1.45
B-C	$Rs.10^6$	380	309
Construction Unit Cost	Rs./kWh	7.18	11.93
Energy Cost	Rs./kWh	0.74	1.22

Note: 1/ Effective value considering 5% of loss in generation
2/ Construction cost is based on price levels as of December '86
3/ Discount rate at 10%oil-thermal
4/ Benefit from Output and Firm Energy is based on diesel, the same from Secondary Energy is based on oil-thermal

COMPARISON OF DEVELOPMENT SCHEMES
2/2 : 2-STEP DEVELOPMENT

Item	Unit	Caledonia/Talawakelle Scheme		
		Caledonia	Talawa-kelle	Total
Catchment Area				
Total	km^2	235.8	363.4	
Main River	km^2	175.2	297.2	
Tributaries	km^2	59.8	66.2	
Dam				
Type		C.Gravity	C.Gravity	
Height	m	70	20	
Reservoir/Pond				
N.H.W.L.	EL.m	1,360	1,200	
L.W.L.	EL.m	1,341	1,193	
Storage Capacity				
-Gross	MCM	45.7	2.6	
-Effective	MCM	30.0	2.0	
Tunnel				
Headrace	m	2,982	13,066	
Branch	m	4,130	9,420	
Tailrace	m	3,168	406	
Power Generation				
Rated Head	m	144	468	
Max. Turbine Discharge	m^3/s	35	50	
Installed Capacity	MW	44	204	248
Annual Generated Energy 1/	GWh	135	674	809
-Firm Energy	GWh	76	331	407
-Secondary Energy	GWh	59	343	402
Construction Cost 2/	Rs. 10^6	4,160	5,640	9,800
Evaluation				
B (Annual Benefit) 3/ 4/	Rs.10^6			1,191
C (Annual Cost) 3/	Rs.10^6			854
B/C				1.39
B-C	Rs.10^6			337
Construction Unit Cost	Rs./kWh			1.39
Energy Cost	Rs./kWh			1.24

Note: 1/ Effective value considering 5% of loss in generation
2/ Construction cost is based on price levels as of December '86
3/ Discount rate at 10%
4/ Benefit from Output and Firm Energy is based on diesel, the same from Secondary Energy is based on oil-thermal

III.3 Determination of Optimum Development Scale

III.3.1 Basic Concept

The Upper Kotmale Hydropower Development Project is formulated on the basic premise that river discharge is to be seasonally regulated at the Caledonia reservoir. As a result, the discharge regulating capacity at Caledonia reservoir will effect selection of power generating scale.

With regard to topography at the dam site, the maximum full supply level will be at EL.1,365m which is determined from the shape of the valley and the left bank saddle topography.

Geological conditions at the site are explained in detail in the Main Report. Major geological characteristics concerning dam construction at the site are weathering conditions and existence of shear zone. The right bank at the site presents a relatively thick weathered zone of 20~30m depth and, in addition, existence of a relatively large shear zone is assumed. Accordingly, sufficient foundation treatment must be undertaken for the right bank. The saddle portion on the left bank, approximately 500m from the dam site, has an elevation of EL.1,350m at the lowest point and a highly weathered portion 20~30m deep.

Accordingly if the full supply level is determined above EL.1,350m, a saddle dam with foundation treatment is required. In addition two shear zones are confirmed from the investigations, and treatment will be required in the case of a higher full supply level.

From the above topographical and geological conditions, it is concluded that a dam with a full supply level of below EL.1,360m presents no major engineering problems; however, above this elevation, the main dam body as well as the saddle dam become much larger and foundation treatment is required in accordance with the increase in water pressure due to a higher full supply level.

Sedimentation volume is an important factor in determining the reservoir scale. The catchment upstream of the Caledonia reservoir consists of highland plains and mountains extend up to elevations of more than 7,700ft (EL.2,350m). Tea plantation fields are widely distributed in the basin up to an elevation of EL.5,500ft (EL.1,676m). These tea plantation lands are usually stable with a history of more than 50 years and in addition soil erosion prevension measures are relatively well developed. Areas above elevations of 5,500ft are covered by dense forests.

In due consideration of the natural conditions of the catchment, sediment inflow to the Caledonia reservoir is assumed to be relatively low and a sediment inflow of $500m^3/km^2/year$ was conservatively adopted. The design sediment volume is thus determined at 8.75 million m^3 ($500m^3/km^2/year \times 175km^2 \times 100$ year) considering 100-year sedimentation.

On the basis of the sedimentation volume, Low Water Level of the Caledonia reservoir is set at EL.1,341m considering intake water depth. In this case the dead storage volume is 15.7MCM. The relation of Normal High Water Level to the effective storage capacity is as follows:

RELATION OF N.H.W.L. AND STORAGE CAPACITY OF CALEDONIA RESERVOIR

N.H.W.L. (EL.m)	Effective Storage Capacity (MCM)
1,350	11.0
1,355	18.0
1,360	30.0
1,365	44.5

Effective storage capacity varies depending on dam height. Maximum turbine discharge, in turn, fluctuates in response to effective storage capacity. Thus dam height controls scale of generating output.

Furthermore, as a large portion of the maximum turbine discharge at Talawakelle is composed of tailwater from the Caledonia power station, generating scale at Talawakelle as well is greatly dependent on Caledonia dam height.

III.3.2 Simulation of Optimum Reservoir Operation

Output and generated energy in the case of generation with a reservoir for each study case were calculated on the basis of differential mass curve and optimum reservoir operation for a 30 year simulation period from 1951~80. The procedures are as follows (refer to FIG.III.3-1):

(1) Preparation of a daily discharge data file at the Caledonia dam site as presented in a monthly summary in TABLE III.3-1 for the 30-year period from 1951~80 based on the Talawakelle daily discharge data file considering diversion from tributaries.

(2) Development of a differential mass curve from the daily discharge at the dam site obtained above as shown in FIG.III.3-1.

(3) Fixation of Normal High Water Level of the reservoir and subsequent determination of effective storage volume for a calculation case.

(4) Determination of an optimum release curve on the differential mass curve based on the given effective storage capacity.

(5) Calculation of monthly average release value from the optimum release curve, an example of which is tabulated in TABLE III.3-2. From a monthly average release of 360 months (30 year × 12 month), the value which is 8th from the smallest will be selected as a firm discharge with 98% dependability. In the case presented in TABLE III.3-2, the 8th (360 × 2%) from the smallest is the value 8.2965m^3/s of February, 1976. Thus firm discharge is obtained once storage capacity is fixed.

(6) Assumption of maximum turbine discharge and determination of the release restricted by the same value. In other words, any release value of optimum operation exceeding the maximum turbine discharge will be amended to the maximum value and the exceeded values will be recorded as spillout discharges.

(7) Based on the restricted release curve, calculation of the monthly average release value as presented in TABLE III.3-3. At the same time through this reservoir operation simulation, the monthly average reservoir water levels and spillout discharge volume will be recorded as presented in TABLE III.3-4 and III.3-5 respectively. Daily value of the release, reservoir water level and spillout discharge will be stored in the Data File Disk.

(8) Calculation of generation for 30 years based on the daily value of the release and reservoir water level as follows:

$$Pmax = 9.8 \times \eta \times Qmax \times He$$

$He = HeadEL. - TailEL. - Hloss$

where,

Pmax: Maximum Output (kW)

η: Turbine and generator efficiency (0.89)

Qmax: Maximum turbine discharge (m^3/sec)

He: Effective head (m)

Head EL.: Reservoir water level (EL.m)

Tail EL.: Tailrace water level (EL.703m for Upper Kotmale P/S, EL.1,193m for Caledonia P/S)

Hloss: Head loss (m)

$Td = Qd/Qmax \times 24$

where,

Td: Daily operation time (hour)

Qd: Daily average release (m3/sec)

$Ed = Pd \times Td$

where,

Pd: Daily Average Output (= Pmax) (kW)

Ed: Daily generated energy (kWh)

TABLE III.3-1

Discharge Data for 1951-1980

Unit : m^3/s

** DMDS0024:1951-80 Kotmale Oya Daily Q at Caledoina(175.2km2) with Nanu1/Nanu2(Total 59.8km2) for Caledonia/Talawakelle Scheme. Data from DMDS0024 **

Main Catchment:175.20km2, Trib.Catchment(km2)/Max.Div.(m3/s) 59.800/ 6.400

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1951	11.4184	9.5000	5.1269	7.4327	6.1217	64.5579	24.5692	14.1053	13.9926	19.4390	21.5222	8.1877	17.1210
1952	12.3081	7.4709	4.9228	10.5478	32.3712	26.3502	18.7454	14.9198	21.1411	19.9245	9.3831	7.0909	15.4593
1953	6.5298	3.7559	7.3970	13.1786	7.6266	12.9266	19.4168	15.5700	17.2510	17.4618	20.9593	13.9013	13.0401
1954	14.6410	11.6913	5.5860	8.7242	8.2565	9.7521	11.3929	21.8969	15.2384	24.7557	13.6003	18.3782	13.6957
1955	17.8883	13.5178	11.0700	13.6200	29.6083	52.0698	29.7824	15.7875	14.5535	15.2072	16.4818	9.6671	19.9441
1956	7.8561	5.8077	6.6573	6.3521	7.3205	35.4337	18.6521	17.4880	15.9550	18.6434	21.5876	12.1668	14.4825
1957	7.0399	5.4503	4.7188	3.6109	7.4257	16.0269	19.3271	10.1997	8.8560	8.6468	19.9915	46.7777	13.2476
1958	19.6824	7.9354	8.9529	7.8017	8.7999	14.5809	15.3804	15.2086	8.4343	18.2703	17.3452	9.7947	12.7283
1959	6.3512	4.7443	3.8515	7.2219	7.8816	33.4329	29.1661	13.2381	11.8388	16.2777	15.1393	9.7946	13.2746
1960	7.9071	11.6528	7.0144	10.2767	9.9732	13.7539	17.7106	19.8611	29.1718	23.5351	24.6809	10.7129	15.4988
1961	6.8359	6.1280	5.0249	6.2730	16.3409	11.4494	12.2415	20.2745	10.9118	10.1007	11.7553	9.2590	10.5909
1962	6.7083	5.2808	4.4637	5.1133	15.3364	9.0669	16.7963	12.2421	20.2023	18.4013	11.8343	8.3663	11.1948
1963	9.1570	6.8905	4.9738	8.2498	6.8869	9.2812	11.0190	9.7691	11.4086	21.0112	15.9576	16.5212	10.9571
1964	10.1262	6.9256	5.7135	5.0079	4.9228	5.1660	12.1699	16.6439	18.6961	9.9987	18.0569	8.1622	10.1325
1965	5.1779	5.5350	4.3617	10.0274	24.3493	16.1569	8.0857	14.7200	10.0858	15.8406	15.1737	12.9243	11.9111
1966	7.9824	5.2808	6.0451	7.5645	5.7646	5.7459	6.9379	7.7286	17.9562	20.0899	14.7694	8.3663	9.5323
1967	6.3257	5.9021	5.5095	5.4032	4.7188	7.3193	11.5979	8.5703	7.4327	22.8652	19.0763	16.9665	10.1791
1968	7.2695	4.7716	4.7188	4.3489	7.5013	9.6658	28.4069	25.9355	21.9368	19.9474	14.9119	9.5651	13.3004
1969	6.5808	4.7725	4.2342	7.8017	11.6842	19.7177	11.9117	8.0857	17.0270	16.9854	10.7801	13.8682	11.1432
1970	12.4189	11.6233	6.5043	9.0141	8.2132	10.0684	12.0903	22.6475	9.9630	16.9733	13.8853	16.1004	12.4843
1971	11.0955	6.1563	5.1269	10.8887	9.1486	13.3386	18.7598	20.2840	32.9908	21.3137	10.8064	15.1013	14.6269
1972	6.1727	4.4716	3.5710	5.2714	17.3985	6.2203	28.8129	17.0418	12.9610	29.3832	25.8127	16.1048	14.5100
1973	7.0144	4.9984	3.7240	4.5334	3.5710	5.0342	6.6063	22.7357	7.6436	7.8051	11.0963	11.7553	8.0788
1974	7.3460	5.5350	4.8208	6.3521	10.6092	17.1984	37.3971	31.0133	25.5147	18.1639	7.9335	8.0027	15.0764
1975	9.6404	5.1114	6.8103	8.3025	7.4735	39.4960	13.7482	23.3239	24.7823	26.8010	34.2987	14.9981	17.9073
1976	8.7999	4.6080	3.6475	7.4854	4.4127	3.8745	8.8635	8.4428	6.3521	9.2845	15.1817	8.0347	7.4221
1977	5.2034	4.4901	4.1321	6.8001	10.1517	16.0569	26.2788	15.1734	7.7490	27.0581	18.1159	9.5906	12.6373
1978	6.0196	4.6313	8.5674	3.8218	27.5256	16.8418	27.5803	35.0937	16.0209	20.7124	35.6688	14.4788	18.1907
1979	5.6625	5.2244	3.6475	7.4327	10.7274	15.5000	24.1459	16.6412	22.0828	27.2826	27.3982	20.2384	15.5545
1980	6.8359	4.0081	3.7240	5.2714	6.5808	7.3009	11.6653	13.8624	8.0389	15.5855	12.7305	8.8764	8.7364
Ave./T	8.7998	6.4600	5.4873	7.4577	11.2901	17.4461	17.9753	16.9501	15.5396	18.5922	17.5312	13.1251	13.0881

TABLE III.3-2

Optimum Water Release for 1951-1980

Unit : m^3/s

** OPTQ0324:1951-80 Optimum Water Release simulated on Mass Curve DMAS0024 for Caledonia/Talawakelle Scheme ** Eff.Strg.Capacity:30.00MCM , Firm Discharge (98% Probable Monthly Ave.) = 6.69606m3/s

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1951	11.8427	10.5049	9.4443	9.4443	9.7263	52.9838	24.7137	17.5588	17.3344	17.3344	16.6371	11.0354	17.3629
1952	10.5529	10.1784	10.1784	11.5603	22.5695	28.2652	21.7242	18.5705	18.5705	14.5206	9.1106	8.9211	15.4058
1953	8.9211	8.9211	8.9211	9.7015	9.7882	13.6373	15.8898	16.0946	16.0946	16.0946	16.0946	14.7230	12.9288
1954	14.2157	12.0841	10.3936	10.3936	10.3936	10.3936	12.4053	17.0910	17.1658	17.1658	17.1658	17.1658	13.8512
1955	16.0393	15.5028	15.5028	15.5195	25.2694	47.3057	29.7828	17.1495	15.1586	15.1586	14.5195	9.7923	19.7225
1956	8.9576	8.9576	8.9576	8.9576	8.9576	24.4472	20.4568	17.9623	17.9623	17.9623	17.9623	12.1338	14.4718
1957	7.5684	7.2396	7.2396	7.2396	7.6356	14.1028	13.5717	12.6663	12.6663	12.6663	18.7248	37.0598	13.2476
1958	19.8905	10.5875	10.4080	10.4080	10.4080	11.0137	14.0424	14.0424	14.0424	14.0424	13.7977	9.8528	12.7331
1959	8.2417	8.2417	8.2417	8.2417	8.2417	22.7902	28.6209	14.4731	14.3577	14.3577	13.4573	11.2724	13.4057
1960	11.2111	11.2111	11.2111	11.2111	11.2586	13.5999	16.9422	18.7758	21.7573	23.9292	22.5592	11.0882	15.3985
1961	8.7838	8.7838	8.7838	8.8880	10.5964	12.9447	12.9447	12.9447	11.4270	10.8095	10.8095	9.1576	10.5826
1962	7.9066	7.9066	7.9066	7.9066	10.9362	13.7765	14.2655	14.4656	14.4656	14.4656	11.7586	9.2962	11.2743
1963	9.1991	9.1452	9.1452	9.1452	9.1452	9.5332	9.9224	9.9224	11.7739	14.5174	15.0341	13.8690	10.8712
1964	9.9275	7.7642	7.7642	7.7642	7.7642	7.7642	12.3292	13.2827	13.2827	13.2827	12.1038	8.6186	10.1493
1965	8.3578	8.3578	8.3578	11.0585	14.8150	14.5326	12.9883	12.9883	12.9883	12.9883	12.9883	11.8168	11.8705
1966	8.4146	7.7832	7.7832	7.7832	7.7832	7.7832	7.7832	7.7832	10.7948	17.7825	14.4961	8.3276	9.5316
1967	7.4830	7.4744	7.4744	7.4744	7.4744	7.9598	9.2947	9.2947	9.2947	14.2380	19.4640	15.0592	10.1779
1968	7.9039	7.6396	7.6396	7.6396	7.6396	10.3700	22.7275	22.4300	21.2973	20.1678	14.6972	9.1694	13.3051
1969	8.4234	8.4234	8.4234	8.4234	9.7474	13.1236	13.1236	13.1236	13.1236	13.1236	12.8954	12.8701	11.2513
1970	11.8043	10.9789	10.9213	10.9213	10.9213	10.9213	12.6998	13.9258	13.9258	13.9258	13.9258	13.8584	12.4055
1971	11.5285	9.7236	9.7236	10.0426	10.4073	12.2779	18.2217	18.8268	27.0389	20.9934	13.9242	12.0840	14.5921
1972	7.7395	7.7395	7.7395	7.7717	11.1718	11.2014	21.0563	19.3970	19.2624	23.2143	21.3661	16.1093	14.5130
1973	7.4310	6.5621	6.5621	6.5621	6.5621	6.5926	6.6757	11.7025	9.8386	9.5799	9.5799	9.5799	8.1146
1974	8.8424	8.5887	8.5887	8.5887	10.7586	13.8178	29.9240	32.1090	25.4255	17.4951	9.1914	9.1914	15.2750
1975	9.1914	9.1914	9.1914	9.1914	9.1914	28.2087	21.5624	21.5223	24.1742	27.8714	27.5986	14.9900	17.6758
1976	9.2170	6.6961	6.6961	6.6961	6.6961	6.6961	7.0856	7.9431	7.9431	7.9431	7.9431	7.9089	7.4610
1977	7.8874	7.8874	7.8874	7.9916	9.8231	13.8419	17.6553	16.8965	16.8965	17.6619	16.8956	9.7254	12.6117
1978	8.6256	8.6256	8.6256	8.6256	18.5013	23.2041	24.9340	29.5608	23.7404	23.8437	24.7093	14.4977	18.1812
1979	8.2289	8.2289	8.2289	8.2828	9.6413	15.5252	18.9545	18.9545	21.1671	25.5331	25.5331	17.9273	15.5539
1980	7.7989	7.3123	7.3123	7.3123	7.3123	7.5247	9.6644	10.4810	10.4810	10.4810	10.4810	8.6233	8.7374
Ave./T	9.7379	8.9366	8.8418	9.0249	10.7046	16.2046	16.7321	16.0646	16.1151	16.4383	15.5141	12.5242	13.0883

TABLE III.3-3

Water Release with Max. 35.000m3/s for 1951-1980 Unit : m³/s

** DQWL2324 : 1951-80 Daily Release etc. calculated on OPTQ0324. Caled.Dam(175.2km2) with Nanu1/Nanu2 for Caledonia/Talawakelle Scheme **

Input Data:B:OPTQ0324.DAT , Calc.Results:B:DQWL2324.DAT , Firm Q: 6.6961m3/s , Max.Turbine Q: 35.00m3/s ,
Eff.Strg.Capacity: 30.00MCM , Dead Strg.Capacity: 15.70MCM , N.H.W.L.:EL.1360.0m , L.W.L.:EL.1340.6m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1951	11.8427	10.5049	9.4443	9.4443	9.7263	34.0296	24.7137	17.5588	17.3344	17.3344	16.6371	11.0354	15.8050
1952	10.5529	10.1784	10.1784	11.5603	21.2225	28.2652	21.7242	18.5705	18.5705	14.5206	9.1106	8.9210	15.2917
1953	8.9210	8.9210	8.9210	9.7015	9.7882	13.6373	15.8898	16.0946	16.0946	16.0946	16.0946	14.7230	12.9288
1954	14.2157	12.0841	10.3936	10.3936	10.3936	10.3936	12.4053	17.0910	17.1658	17.1658	17.1658	17.1658	13.8512
1955	16.0393	15.5028	15.5028	15.5195	25.2694	34.7257	29.7263	17.1495	15.1586	15.1586	14.5195	9.7923	18.6837
1956	8.9576	8.9576	8.9576	8.9576	8.9576	20.4621	20.4567	17.9623	17.9623	17.9623	17.9623	12.1338	14.1452
1957	7.5684	7.2396	7.2396	7.2396	7.6356	14.1028	13.5717	12.6663	12.6663	12.6663	18.7249	26.0056	12.3087
1958	19.4540	10.5875	10.4080	10.4080	10.4080	11.0137	14.0424	14.0424	14.0424	14.0424	13.7977	9.8528	12.6960
1959	8.2417	8.2417	8.2417	8.2417	8.2417	19.4517	28.6209	14.4731	14.3577	14.3577	13.4573	11.2723	13.1314
1960	11.2111	11.2111	11.2111	11.2111	11.2585	13.5999	16.9422	18.7758	21.7573	23.9292	22.5592	11.0882	15.3985
1961	8.7838	8.7838	8.7838	8.8880	10.5964	12.9447	12.9447	12.9447	11.4270	10.8095	10.8095	9.1576	10.5826
1962	7.9066	7.9066	7.9066	7.9066	10.9362	13.7765	14.2655	14.4656	14.4656	14.4656	11.7586	9.2962	11.2743
1963	9.1991	9.1452	9.1452	9.1452	9.1452	9.5332	9.9224	9.9224	11.7740	14.5174	15.0341	13.8690	10.8712
1964	9.9275	7.7642	7.7642	7.7642	7.7642	7.7642	12.3292	13.2827	13.2827	13.2827	12.1038	8.6186	10.1493
1965	8.3578	8.3578	8.3578	11.0585	14.8150	14.5326	12.9883	12.9883	12.9883	12.9883	12.9883	11.8168	11.8705
1966	8.4146	7.7832	7.7832	7.7832	7.7832	7.7832	7.7832	7.7832	10.7948	17.7826	14.4961	8.3276	9.5316
1967	7.4830	7.4744	7.4744	7.4744	7.4744	7.9598	9.2947	9.2947	9.2947	14.2380	19.4640	15.0592	10.1779
1968	7.9040	7.6396	7.6396	7.6396	7.6396	10.3700	22.7275	22.4300	21.2973	20.1678	14.6972	9.1694	13.3051
1969	8.4234	8.4234	8.4234	8.4234	9.7474	13.1236	13.1236	13.1236	13.1236	13.1236	12.8954	12.8701	11.2513
1970	11.8043	10.9789	10.9213	10.9213	10.9213	10.9213	12.6998	13.9258	13.9258	13.9258	13.9258	13.8584	12.4055
1971	11.5285	9.7236	9.7236	10.0427	10.4073	12.2779	18.2217	18.8268	24.7077	20.3728	13.9243	12.0840	14.3478
1972	7.7395	7.7395	7.7395	7.7717	11.1718	11.2014	17.5868	19.3970	19.2624	23.2143	21.3660	16.1093	14.2191
1973	7.4310	6.5621	6.5621	6.5621	6.5621	6.5926	6.6757	11.7025	9.8386	9.5799	9.5799	9.5799	8.1146
1974	8.8424	8.5887	8.5887	8.5887	10.7586	13.8179	18.8489	29.6200	25.4255	17.4951	9.1914	9.1914	14.1230
1975	9.1914	9.1914	9.1914	9.1914	9.1914	23.4178	21.5624	21.5223	24.1742	27.8714	27.5986	14.9900	17.2820
1976	9.2170	6.6961	6.6961	6.6961	6.6961	6.6961	7.0856	7.9431	7.9431	7.9431	7.9431	7.9089	7.4610
1977	7.8874	7.8874	7.8874	7.9916	9.8231	13.8419	17.6553	16.8965	16.8965	17.6619	16.8956	9.7254	12.6117
1978	8.6256	8.6256	8.6256	8.6256	18.5014	23.2041	24.9341	29.5608	23.7403	23.8436	24.7093	14.4977	18.1812
1979	8.2289	8.2289	8.2289	8.2828	9.6413	15.5252	18.9545	18.9545	21.1671	25.5331	25.5331	17.9273	15.5539
1980	7.7989	7.3123	7.3123	7.3123	7.3123	7.5247	9.6644	10.4810	10.4810	10.4810	10.4810	8.6233	8.7374
Ave./T	9.7233	8.9366	8.8418	9.0249	10.6597	14.7497	16.2454	15.9817	16.0373	16.4176	15.5141	12.1557	12.8760

TABLE III.3-4

Reservoir Water Level for 1951-1980

Unit : EL.m

** DQWL2324 : 1951-80 Daily Release etc. calculated on OPTQ0324. Caled.Dam(175.2km2) with Nanul/Nanu2 for Caledonia/Talawakelle Scheme **

Input Data:B:OPTQ0324.DAT , Calc.Results:B:DQWL2324.DAT , Firm Q: 6.6961m3/s , Max.Turbine Q: 35.00m3/s ,
Eff.Strg.Capacity: 30.00MCM , Dead Strg.Capacity: 15.70MCM , N.H.W.L.:EL.1360.0m , L.W.L.:EL.1340.6m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1951	1358.97	1359.58	1355.87	1349.75	1343.78	1355.68	1359.02	1358.69	1346.97	1354.98	1356.92	1358.66	1354.89
1952	1359.18	1357.77	1350.93	1342.91	1347.78	1357.25	1358.61	1349.26	1348.74	1358.35	1359.44	1359.08	1354.11
1953	1356.07	1349.36	1343.40	1343.81	1347.34	1343.68	1342.47	1351.43	1350.96	1351.77	1357.19	1359.33	1349.75
1954	1359.70	1359.78	1355.98	1351.85	1346.43	1345.24	1341.43	1347.57	1350.88	1349.44	1358.04	1356.63	1351.85
1955	1359.17	1358.58	1353.39	1345.07	1349.92	1353.20	1358.63	1359.73	1356.89	1357.74	1359.72	1359.97	1356.00
1956	1359.64	1357.25	1353.45	1347.75	1342.98	1347.40	1359.63	1357.44	1357.08	1358.34	1355.88	1359.95	1354.75
1957	1359.86	1358.70	1356.49	1350.54	1343.75	1350.45	1357.79	1356.76	1354.49	1343.53	1341.91	1347.80	1351.81
1958	1359.91	1359.05	1355.78	1352.62	1348.98	1344.83	1358.06	1356.76	1353.71	1350.71	1358.54	1359.91	1354.90
1959	1359.27	1355.94	1349.05	1343.33	1342.62	1347.47	1358.46	1359.39	1356.53	1356.15	1359.40	1359.43	1353.93
1960	1356.39	1352.30	1351.52	1343.79	1341.87	1342.47	1341.52	1348.33	1344.49	1358.62	1359.22	1359.95	1350.06
1961	1358.82	1355.69	1350.39	1342.58	1343.13	1353.07	1348.35	1353.28	1359.90	1358.19	1359.06	1359.89	1353.51
1962	1359.08	1357.18	1352.53	1345.89	1345.48	1349.18	1346.30	1346.55	1353.36	1354.61	1359.91	1359.61	1352.44
1963	1359.40	1358.10	1352.67	1346.61	1344.15	1341.80	1342.89	1344.04	1342.21	1346.38	1355.31	1359.54	1349.39
1964	1359.93	1359.25	1358.26	1354.92	1350.27	1343.28	1341.54	1347.56	1352.17	1354.19	1358.55	1359.87	1353.30
1965	1358.03	1354.03	1346.75	1341.72	1345.45	1359.42	1357.55	1354.59	1352.70	1352.39	1358.06	1359.87	1353.38
1966	1359.84	1358.61	1356.05	1353.64	1353.43	1347.86	1345.63	1344.53	1343.60	1359.59	1359.80	1359.95	1353.53
1967	1359.55	1358.41	1355.84	1352.29	1347.97	1342.47	1346.93	1347.35	1344.17	1347.45	1358.69	1359.58	1351.70
1968	1359.90	1358.03	1353.96	1347.78	1346.92	1342.05	1346.91	1357.43	1358.55	1359.68	1359.91	1359.86	1354.25
1969	1359.14	1356.12	1348.98	1343.33	1342.58	1356.49	1357.83	1352.79	1356.12	1356.57	1359.33	1355.74	1353.73
1970	1359.82	1359.37	1357.30	1351.85	1348.95	1344.65	1341.82	1353.19	1355.73	1352.40	1356.06	1359.17	1353.32
1971	1359.77	1356.99	1351.25	1343.27	1346.84	1343.00	1348.36	1346.73	1349.59	1359.55	1359.11	1358.96	1351.95
1972	1359.33	1356.78	1350.32	1342.99	1349.37	1348.05	1351.18	1358.10	1345.52	1348.29	1358.94	1358.80	1352.32
1973	1359.93	1358.99	1356.44	1352.82	1347.07	1341.56	1341.01	1351.42	1359.25	1355.82	1357.17	1357.68	1353.22
1974	1359.52	1356.06	1350.58	1343.76	1340.92	1347.03	1346.79	1359.05	1356.76	1359.93	1359.46	1356.37	1353.01
1975	1358.45	1355.26	1351.28	1344.59	1342.23	1350.46	1356.02	1350.03	1345.82	1351.52	1358.37	1359.85	1351.99
1976	1359.82	1358.71	1355.29	1353.99	1352.46	1346.54	1343.10	1345.74	1348.16	1346.45	1355.84	1359.83	1352.14
1977	1358.48	1354.44	1347.34	1342.03	1342.08	1343.92	1350.08	1358.10	1361.08	1349.72	1359.72	1359.93	1351.41
1978	1358.73	1354.65	1349.60	1345.69	1350.71	1352.74	1345.91	1355.10	1354.02	1346.93	1352.05	1359.89	1352.16
1979	1358.91	1355.32	1348.53	1341.79	1344.27	1342.92	1352.32	1356.85	1344.53	1352.86	1355.31	1359.75	1351.13
1980	1359.81	1357.54	1351.84	1345.60	1345.02	1341.72	1342.14	1348.30	1350.77	1353.21	1358.37	1359.97	1351.18
Ave./T	1359.15	1356.93	1352.37	1346.95	1346.16	1347.53	1349.61	1352.54	1351.49	1353.51	1357.51	1358.83	1352.70

TABLE III.3-5

Spilled Water for 1951-1980

Unit : MCM

** DQWL2324 : 1951-80 Daily Release etc. calculated on OPTQ0324. Caled.Dam(175.2km2) with Nanu1/Nanu2 for Caledonia/Talawakelle Scheme **

Input Data:B:OPTQ0324.DAT , Calc.Results:B:DQWL2324.DAT , Firm Q: 6.6961m3/s , Max.Turbine Q: 35.00m3/s ,
Eff.Strg.Capacity: 30.00MCM , Dead Strg.Capacity: 15.70MCM , N.H.W.L.:EL.1360.0m , L.W.L.:EL.1340.6m

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1951	0.0000	0.0000	0.0000	0.0000	0.0000	49.1294	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	49.1294
1952	0.0000	0.0000	0.0000	0.0000	3.6078	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.6078
1953	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1954	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1955	0.0000	0.0000	0.0000	0.0000	0.0000	32.6075	0.1514	0.0000	0.0000	0.0000	0.0000	0.0000	32.7588
1956	0.0000	0.0000	0.0000	0.0000	0.0000	10.3294	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	10.3294
1957	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	29.6077	29.6077
1958	1.1694	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.1694
1959	0.0000	0.0000	0.0000	0.0000	0.0000	8.6533	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	8.6533
1960	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1961	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1962	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1963	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1964	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1965	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1966	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1967	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1968	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1969	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1970	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1971	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	5.3664	2.3382	0.0000	0.0000	7.7046
1972	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	9.2927	0.0000	0.0000	0.0000	0.0000	0.0000	9.2927
1973	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1974	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	29.6636	6.6664	0.0000	0.0000	0.0000	0.0000	36.3300
1975	0.0000	0.0000	0.0000	0.0000	0.0000	12.4180	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	12.4180
1976	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1977	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1978	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1979	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1980	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ave./T	0.0390	0.0000	0.0000	0.0000	0.1203	3.7713	1.3036	0.2222	0.1789	0.0779	0.0000	0.9869	6.7000

III.3.3 Determination of Optimum Combination of Reservoir Scale and Installed Capacity

The three cases of water level at Caledonia reservoir of EL.1,365m, 1,360m and 1,355m (with subsequent maximum turbine discharges at Caledonia power station of 30, 35 and 40m3/s, respectively, and at Talawakelle power station of 45, 50, and 55m3/s, respectively) are comparatively studied in terms of output, generated energy, B-C, B/C, and construction unit cost (Rs./kWh) for Caledonia/Talawakelle Scheme in TABLE III.3-6. The same comparison for the Caledonia One Step Scheme is presented in TABLE III.3-7.

In this case, water level at Talawakelle pond is determined at EL 1,200, and effective storage capacity at 2.0MCM.

TABLE III.3-6 OPTIMUM COMBINATION FOR TWO - STEP DEVELOPMENT

Item		Caledonia								
		HWL 1,355			HWL 1,360			HWL 1,365		
		30	35	40	30	35	40	30	35	40
Maximum Turbine Discharge of Talawakelle P/S: $45m^3/s$										
Maximum Output	MW	217	223	228	221	228	234	223	230	236
Generated Energy	GWh	778	780	781	803	806	806	818	819	820
Construction Cost	$Rs.10^6$	9,210	9,320	9,470	9,450	9,560	9,730	9,940	10,050	10,210
Economic Viability										
B	$Rs.10^6$	1,099	1,113	1,125	1,130	1,145	1,158	1,147	1,162	1,176
C	"	802	811	825	823	832	847	865	874	888
B-C	"	297	302	300	307	313	311	282	288	288
B/C	"	1.37	1.37	1.36	1.37	1.38	1.37	1.33	1.33	1.32
Construction Unit Cost	Rs./KWh	1.02	1.02	1.04	1.01	1.02	1.04	1.04	1.05	1.07
Maximum Turbine Discharge of Talawakelle P/S: $50m^3/s$										
Maximum Output	MW	237	243	248	242	248	254	244	251	257
Generated Energy	GWh	782	785	786	804	809	812	819	821	821
Construction Cost	$Rs.10^6$	9,450	9,560	9,710	9,700	9,800	9,980	10,180	10,290	10,450
Economic Viability										
B	$Rs.10^6$	1,145	1,160	1,171	1,176	1,191	1,205	1,190	1,207	1,220
C	"	823	833	846	845	854	870	886	896	910
B-C	"	322	327	325	331	337	335	304	311	310
B/C	"	1.39	1.39	1.38	1.39	1.39	1.39	1.34	1.35	1.34
Construction Unit Cost	Rs./KWh	1.04	1.04	1.06	1.03	1.04	1.06	1.07	1.08	1.09
Maximum Turbine Discharge of Talawakelle P/S: $55m^3/s$										
Maximum Output	MW	258	264	269	262	269	275	264	271	277
Generated Energy	GWh	786	789	790	809	811	811	821	822	823
Construction Cost	$Rs.10^6$	10,280	10,390	10,540	10,520	10,630	10,800	11,010	11,120	11,280
Economic Viability										
B	$Rs.10^6$	1,190	1,205	1,216	1,220	1,235	1,248	1,235	1,250	1,264
C	"	895	905	918	917	926	941	959	968	982
B-C	"	295	300	298	303	309	307	276	282	282
B/C	"	1.33	1.33	1.32	1.33	1.33	1.33	1.29	1.29	1.29
Construction Unit Cost	Rs./KWh	1.12	1.12	1.14	1.12	1.13	1.14	1.15	1.16	1.18

TABLE III.3-7 OPTIMIZATION OF RESERVOIR SCALE AND INSTALLED CAPACITY FOR CALEDONIA ONE STEP DEVELOPMENT SCHEME

Item		Normal High Water Level (EL.m)		
		1,355	1,360	1,365
Maximum Turbine Discharge: $35m^3/s$				
Maximum Output	MW	186	187	188
Generated Energy	GWh	618	660	684
Construction Cost	$Rs.10^6$	7,320	7,590	8,020
Economic Viability				
B	$Rs.10^6$	903	941	963
C	"	638	661	697
B-C	"	265	280	266
B/C	"	1.42	1.42	1.38
Construction Unit Cost	Rs./KWh	1.02	0.99	1.00
Maximum Turbine Discharge: $40m^3/s$				
Maximum Output	MW	213	214	215
Generated Energy	GWh	625	664	688
Construction Cost	$Rs.10^6$	7,660	7,920	8,350
Economic Viability				
B	$Rs.10^6$	963	999	1,023
C	"	668	690	728
B-C	"	295	369	295
B/C	"	1.44	1.45	1.40
Construction Unit Cost	Rs./KWh	1.05	1.02	1.04
Maximum Turbine Discharge: $45m^3/s$				
Maximum Output	MW	240	241	242
Generated Energy	GWh	629	667	690
Construction Cost	$Rs.10^6$	8,160	8,620	8,890
Economic Viability				
B	$Rs.10^6$	1,022	1,057	1,080
C	"	712	752	775
B-C	"	310	305	305
B/C	"	1.43	1.44	1.39
Construction Unit Cost	Rs./KWh	1.11	1.08	1.10

III.4 Determination of Power Station Site and Type, and Main Headrace Route

Following selection of the Caledonia reservoir, Talawakelle pond, and given the existing location of Kotmale reservoir, it was subsequently necessary to select the economically and technically optimum headrace - power staiton - tailrace routes to connect these points.

Features of intake at Caledonia and Talawakelle are as follows:

Item	Caledonia Scheme	Talawakelle Scheme
Normal H.W.L. of reservoir and pond	EL.1,360m	EL.1,200m
Usable Water Depth	19m	7m
Tailwater Level	EL.1,198m	EL.703m
Maximum Turbine Discharge	$35m^3/s$	$50m^3/s$
Maximum Intake from Tributaries	Nanu $6.4m^3/s$	Puna $4.5m^3/s$ Pundal $3.6m^3/s$ Devon $3.3m^3/s$

III.4.1 Determination of Caledonia Tunnel Route

The following three tunnel routes were proposed for the Caledonia power station and an outline of each alternative is presented hereunder.

Route C-1: Kotmale left bank intake,
left bank route, surface power station

Route C-2: Kotmale right bank intake,
straight route, underground power station

Route C-3: Kotmale right bank intake,
right bank route, surface power station

Proposed routes are discussed below. Route locations are indicated in FIG.4.3-3 and comparative profiles are given in FIG.4.3-4 of the Main Report.

Route C-1 (Left bank intake, left bank route)

The intake will be located on the left bank of the Agra Oya 350m upstream from the confluence of the Agra and Dambagastalawa rivers and the power station will be a surface type on the left bank of the Kotmale Oya, with tailwater discharge into the Talawakelle reservoir near the confluence of the Kotmale and Nanu rivers.

The tunnel route will make a wide detour to the left to bypass the lowland area where numerous affluents run into the left bank of the Kotmale Oya. A river which flows into the left bank of the Kotmale Oya about 2.2km upstream from Lindula has carved a steep valley. Where the canal route crosses this river, culvert instead of tunnel is planned.

The Kotmale Oya meanders widely to the right between the Caledonia and Talawakelle dams and tunnel length is rather large at 7,570m. Gradient at the power station site is gentle and penstock extension is long, resulting in a larger construction cost.

Route C-2 (Right bank intake, Straight route)

The proposed route almost directly joins the Caledonia reservoir and Talawakelle regulating pond, and with a total length of 5,150m for the headrace and tailrace tunnels, it is the shortest of the three proposed routes.

The intake is located directly upstream from the Caledonia Dam on the Kotmale right bank, and, as discharge will be at the upstream end of the Talawakelle regulating pond, the power station will be an underground type and the tailrace route will cross the Kotmale Oya. Rock outcrops occur in the riverbed where the proposed tailrace route crosses and overburden of about 40m is available. On the basis of field survey results, no difficulties are envisioned to arise with respect to either construction or operation and maintenance.

Route C-3 (right bank intake, right bank route)

Intake will be from the right bank directly upstream from the Caledonia dam. The proposed tunnel route runs along a ridge between the Kotmale and Nanu rivers and the power station site is located on the right bank at the upstream end of the Talawakelle regulating pond.

As the tunnel route is fairly circuitous, following the mountain ridge, tunnel is rather long at 5,870m. The penstock route is also rather long due to the gentle gradient at the site. A further disadvantage is that the tunnel route crosses a fractured zone. As the outlet is situated at the upstream end of the Talawakelle regulating pond, there is some possibility that it may be affected by sedimentation, although the residual catchment area below Caledonia dam is small.

The above routes were compared as shown in the following table and on this basis, route C-2, the direct route with right bank intake and underground power station, is considered the optimum route.

TABLE III.4-1 COMPARISON FOR CALEDONIA SCHEME ALTERNATIVE ROUTES

Name of Route of P/S	Unit	C-1	C-2	C-3
Catchment Area				
Total	km^2		235.0	
Main River	km^2		175.2	
Tributaries	km^2		59.8	
Dam				
Type			C.Grvty	
Height	m		70	
Reservoir/Pond				
N.H.W.L.	EL.m		1,360	
L.W.L.	EL.m		1,341	
Storage Capacity				
Gross	MCM		45.7	
Effective	MCM		30.0	
Tunnel				
Headrace	m	7,570	2,980	5,870
Branch	m	4,130	4,130	4,130
Tailrace	m	0	2,170	0
Power Generation				
Rated Head	m	139	144	140
Max. Turbine Discharge	m^3/s	35	35	35
Installed Capacity	MW	42	44	43
Annual Generated Energy 1/	GWh	130	135	132
-Firm Energy	GWh	73	76	74
-Secondary Energy	GWh	57	59	58
Construction Cost 2/	$Rs.10^6$	4,489	4,160	4,278
Evaluation				
B (Annual Benefit) 3/ 4/	$Rs.10^6$	196	204	200
C (Annual Cost) 3/	$Rs.10^6$	387	359	369
B/C		0.51	0.57	0.54
B-C	$Rs.10^6$	-191	-155	-169
Construction Unit Cost	Rs./kWh	34.53	30.81	32.41
Energy Cost	Rs./kWh	3.50	3.13	3.29

Note: 1/ Effective value considering 5% of loss in generation
2/ Construction cost is based on price levels as of December '86
3/ Discount rate at 10%
4/ Benefit from Output and Firm Energy is based on diesel, the same from Secondary Energy is based on oil-thermal

III.4.2 Determination of Talawakelle Tunnel Route

The following items were considered in determining the Talawakelle tunnel route which utilizes a total head of 499m from the normal H.W.L. of the Talawakelle regulating pond (1,200m) to the normal H.W.L. of the existing Kotmale reservoir (703m).

(1) Tailwater level is to be between average water level in the reservoir (695.0m) and normal H.W.L. (703.0m) in consideration of present operation of the Kotmale reservoir.

(2) Normal H.W.L. of the Kotmale reservoir will increase to 731.5m with raising of the dam. However, the present normal HWL of 703m will serve as the base for design output and generated energy.

(3) Rising of the riverbed due to sediment flow from the existing Kotmale reservoir will begin from the upstream end of the reservoir. The tailrace outlet will be easily affected by sedimentation if it is located at the upstream end of the reservoir. Long term sedimentation conditions should particularly be taken into consideration for the case of normal H.W.L. increase to 731.5m. If the outlet is located in the steeper portion downstream of the confluence of the Kotmale and Puna rivers sedimentation is envisioned to be negligible.

(4) Maximum intake from Devon Oya will be $3.3m^3/s$

(5) Maximum intake diversion from tributaries will be $4.5m^3/s$ in the case of a straight tunnel route, and $8.1m^3/s$ for a detour route with the addition of maximum intake of $4.5m^3/s$ from Puna.

(6) Intake from Pundal Oya will be stored at Talawakelle pond where the power station is not operating.

Based on the above considerations, three alternative routes were selected for the Talawakelle tunnel as follows:

Route T-1: straight route, underground power station

Route T-2: detour route via the Pundul river intake point, underground power station

Route T-3: detour route via the Pundul river intake point, semi-surface power station

Route T-1 (direct route)

Intake will be from the right bank about 100m upstream from the Talawakelle Dam with construction of the tailrace outlet within the existing Kotmale reservoir area where no sedimentation will occur (about 3km downstream from the Puna River confluence). The power station is an underground type located 1.0km upstream from the confluence with the Pundal Oya on the right bank of the Kotmale.

As the tailwater level is set at the average water level in the Kotmale reservoir, head up to the normal highwater level can be effectively utilized untill the existing Kotmale dam is to be raised. Although the route is direct, tunnel length is almost the same as that for the detour route because the outlet elevation is set at EL.695m. Moreover, due to topographical restrictions the power station will be constructed 350m underground and consequently larger scale facilities such as access tunnels, cables and ventilating shafts will be required. Branch canal from the Pundal Oya is also quite long at 5,600m thereby further increasing construction costs. However, as the tunnel route is closer to the Kotmale Oya than that of other alternatives, facilitating construction of numerous working shafts, the construction period can be shortened.

Route T-2 (Detour route, underground power station)

Intake is located about 100m upstream of the Talawakelle dam on the right bank. The tunnel route runs via the Pundal intake site to the tailrace outlet at the upstream end of the existing Kotmale reservoir, and an underground power station is planned. Tunnel is rather long at 13.1km and it is impossible to avoid crossing supposed fracture zone. Moreover, construction of work shafts along the 8km stretch upstream of the Pundal Oya is envisioned to be difficult in view of topographical limitations.

Intake from the Puna Oya will be discharged into the Pundal Oya for intake of the combined flow of the two rivers. Intake discharge will pass through a desilting basin into a vertical shaft connected directly to the headrace. Tailrace outlet elevation is EL.703m as the outlet is located at the uppermost end of the existing Kotmale reservoir. Power station and tailrace design will take into consideration increased hydraulic pressure to result from future raising of Kotmale dam height.

Route T-3 (Detour route, semi-underground power station)

The tunnel route and facilities up to the surge tank are the same as those for route T-2. The major portion of the penstock will be surface type and the power station will be a semi-surface type as it is located close to the existing Kotmale reservoir. Construction cost increase for longer penstock is greater in this case than construction cost reductions from shorter tunnel route and semi-surface type power station. If raising of the Kotmale Dam is considered, the required distance of the site from the Kotmale reservoir will increase and consequently the construction cost will be almost the same as that for the route T-2 alternative.

The above routes were compared as shown in the following table and on this basis, Route T-2, the bypass route with underground power station, is considered as the optimum route.

TABLE III.4-2 COMPARISON FOR TALAWAKELLE SCHEME ALTERNATIVE ROUTES

Item	Unit	T-1	T-2	T-3
Catchment Area				
Total	km^2		363.4	
Main River	km^2		297.2	
Tributaries	km^2		66.2	
Dam				
Type			C.Gravity	
Height	m		20	
Reservoir/Pond				
N.H.W.L.	EL.m		1,200	
L.W.L.	EL.m		1,193	
Storage Capacity				
-Gross	MCM		2.6	
-Effective	MCM		2.0	
Tunnel				
Headrace	m	8,620	13,066	13,066
Branch	m	15,020	9,420	9,420
Tailrace	m	4,540	406	50
Power Generation				
Rated Head	m	477	468	468
Max. Turbine Discharge	m^3/s	50	50	50
Installed Capacity	MW	208	204	204
Annual Generated Energy 1/	GWh	675	674	673
-Firm Energy	GWh	331	331	331
-Secondary Energy	GWh	344	343	342
Construction Cost 2/	$Rs.10^6$	5,826	5,640	5,704
Evaluation				
B (Annual Benefit) 3/ 4/	$Rs.10^6$	995	986	985
C (Annual Cost) 3/	$Rs.10^6$	511	495	500
B/C		1.95	1.99	1.97
B-C	$Rs.10^6$	484	491	485
Construction Unit Cost	Rs./kWh	8.63	8.37	8.48
Energy Cost	Rs./kWh	0.89	0.86	0.87

Note: 1/ Effective value considering 5% of loss in generation
2/ Construction cost is based on price levels as of December '86
3/ Discount rate at 10%
4/ Benefit from Output and Firm Energy is based on diesel, the same from Secondary Energy is based on oil-thermal

III.5 Optimization of Diversion From Tributaries

As intake from the Nanu, Pundal and Puna rivers is envisioned to have little adverse environmental effect on downstream water use, downstream maintenance flow is considered unnecessary and intake volume will be as much as economically feasible. Rivers from which intake is possible are outlined in the following table. However, for the subject project, $10km^2$ catchment area was designated as the object of diversion.

TABLE III.5-1 TRIBUTARIES TARGETTED FOR DEVELOPMENT

Destination	River	No. of Intakes	Catchment Area (km^2)	Intake Tunnel Length (km)	Intake Time(hr)
Caledonia Reservoir	Nanu Oya	2	59.8	4.1	24
	Devon Oya	1	24.5	4.2	16*
Talawakelle Regulating Pond	Pundal Oya Puna Oya	1 2	21.2 28.6	- 5.2	24 24

* One third of daily discharge is planned not to be diverted from the Devon Oya in order to preserve Devon Falls. Diversion from the Devon oya is accordingly considered at 2/3 of daily inflow

An intake dam, inlet, and desilting basin are planned at each intake site to divert discharge to the headrace canal.

Nanu Oya

There are two intake sites on the Nanu Oya with catchment areas of $43.3km^2$ and $16.5km^2$. An access road of about 0.7km must be constructed from the new Lindula-Nuwara Eliya road to intake No.1 through area occupied by tea estate. For intake No.2, however, construction of an access road is unnecessary as the intake river follows the bus road. Maximum intake is projected at $6.0m^3/s$. Major dimensions of the diversion dam are outlined as follows.

Feature	Intake No.1	Intake No.2	Total
Dam Height (m)	20	17	-
Dam Crest Length (m)	85	52.5	-
Maximum Intake (m^3/s)	4.3	1.7	6.0

Gradient between intakes No.1 and 2 is gentle, however topography is complex. One portion of the area is tea field.

Both a tunnel alternative and an open excavation alternative were comparatively studied for the canal between the two intakes. On the basis of this study, the tunnel alternative was adopted as the optimum.

	Tunnel Proposal	Open Canal Proposal
Length (m) Tunnel Open Canal Total	 1,650 0 1,650	 0 5,500 5,500
Const. Cost (Rs.10^6)	25.6	71.0

As the canal route cuts across the catchment divide between the Kotmale and Nanu river between intake No. 2 and the Caledonia reservoir, the entire length of this segment (2,370m) is to be tunnel.

Devon Oya

Intake is at a point upstream of Devon Falls with a catchment area of 36.8km^2. Diverted discharge is conveyed by tunnel to the Talawakelle regulating pond.

There are numerous waterfalls in the Upper Kotmale river basin, of which St. Clair Falls and Devon Falls have abundant head and discharge, as well as scenic beauty. Moreover, both falls are situated close to major roads. With completion of the present Project however, flow to St. Clair Falls will be greatly reduced. To reduce the flow of both falls would adversely affect plans for development of tourism and accordingly, intake from Devon Falls is to be limited to 2/3 of daily discharge. Diversion will not be performed for 1/3 in order to preserve the falls for tourism development.

Intake point is 1.2km above the falls, and adjacent to highway A-7. An existing concrete weir at the site, constructed for irrigation but no longer in use, could have its crest raised and be utilized as the intake dam. The existing weir has a crest length of 70.0m and crest height of 10.0m.

Both a tunnel route and open canal route are possible for the intake canal. However, the tunnel route was selected as the open canal route has a segment which runs parallel to highway A-7, and would require partial reconstruction of both the highway as well as the railway. A detour route was selected for the tunnel as the directest route would make difficult a work access shaft for the upstream 3,400m tunnel segment. The maximum tunnel segment is 2,000m.

Feature	
Dam height (m)	10.0
Dam crest length (m)	70.0
Max intake (m^3/s)	3.3

Puna Oya

There are two intake sites for Puna Oya with catchment areas of 10.1km^2 and 18.5km^2 to divert discharge to directly upstream of the Pundal Oya intake dam. Intake site No.1 is accessible by a farm road which runs through a tea estate. This road is located entirely within the estate area and is passable; however, maintenance is poor. It must be repaired and widened in order to be used for construction purposes. Extension of the road which runs from Route A5 to the intake site is approximately 2.2km.

Intake site No.2 will require construction of an access road about 0.5km in length. As riverbed gradient at the site area is a steep 1:4, the intake structure is to be positioned at the upstream-most edge of this steep portion to minimize difficulties in design and construction. Discharge is to be diverted to the tunnel canal from intake No.1 by means of 120m long box culvert and 25m high vertical shaft. Outlet for the diversion tunnel is to be directly upstream of the Pundal Oya intake dam. Between intakes No.1 and 2, the 1,970m diversion canal route is to be tunnel where cliff is encountered and where the route intersects highway A-5.

Feature	Intake No.1	Intake No.2	Total
Dam Height (m)	10	10	-
Dam Crest Length (m)	70	70	-
Maximum Intake (m^3/s)	2.0	2.6	4.5

Pundal Oya

The maximum intake of 4.5m^3/s for the Puna Oya (catchment area: 28.6km^2) will be combined with the Pundal catchment area of 21.2km^2 (max. 3.6m^3/s)for Pundal Oya intake, and the intake discharge will pass directly to a water tank via the settling tank. Widening of an existing road which extends 0.3km to the intake site is considered.

The intake site is located in the steep portion of the river where large boulders occur in the riverbed. Overburden is estimated to be shallow and rock outcrops are visible.

Intake at this point is to be directly into the headrace canal. In order to minimize air and silt inflow, a settling basin is to be constructed to prevent silting, and vertical and horizontal shafts to prevent air influx.

The vertical shaft is to also function as an auxiliary surge tank as it is positioned near the main surge tank and would be subject to the effects of surging. Vertical shaft would have an inner diameter of 10.0m to limit inflow velocity (10cm/s). The large portion of aeration created by roiling would be eliminated by the relatively slow flow velocity in the shaft. However, an 11m long horizontal shaft would be constructed inside the tunnel to surface and remove any remaining air. A distended wall would be included at the ceiling of the horizontal shaft connecting with the diversion shaft to capture released air and purge it from the tunnel by air pipe.

Dam Height (m)	16.0	
Dam Crest Length (m)	70.0	
Maximum Intake (m^3/s)	8.1	(of which 4.5m^3/s is diverted discharge from the Puna Oya)

Optimum Intake Discharge from Tributaries

The optimum maximum discharge for each tributary was determined on the basis of the difference (B-C) of annual costs (C) required by intake facility scale, and the benefit derived from the corresponding intake discharge (B).

Facility cost includes direct facility cost required for intake, and overall facility cost resulting from the scale of intake.

Capital recovery factor for calculation of annual costs, and for determining benefit are based on values presented in section 4.3 of the Main Report.

On this basis, optimum intake is as follows:

	Nanu Oya	Devon Oya	Puna Oya	Pundal Oya
Maximum intake discharge (m3/s)	6.0	3.3	4.5	3.6*

* With addition of the 4.5m^3/s of riverbed discharge from the Puna Oya, facilities at Pundal Oya will be of a scale to intake 8.1m^3/s.

III.6 Required Capacity for Talawakelle Regulation Pond

Due to fluctuations in operating time at Caledonia power station and variations in discharge from the residual catchment between the Caledonia and Talawakelle dams, discharge entering the Talawakelle regulating pond is not constant. For the reason set out below, inflow to the pond will be regulated, and spill will not occur.

a. In order to permit adjustment of operating time at Caledonia power station to conform to power supply and demand.

b. In order to secure at all times necessary discharge for peak generation at Talawakelle power station.

c. In order to minimize ineffective spill, thereby maximizing effective utilization of water resoources.

In order to achieve the above, an effective regulating capacity of 1.08MCM is necessary. Effective water use depth was determined at 7.0m as overall ponding capacity is small at 2.55MCM and the effect of silting is great. A water utilization depth of 7.0m yields a storage capacity at the site of 1.95MCM.

Amount of lost effective storage capacity due to silting cannot be precisely forecasted at the present stage. However, if silting contour is assumed to change linearly from the upstream extreme of the pond to the dam crest, effective storage capacity would be 1.3MCM, which is a 20% surplus over required storage capacity.

On the basis of riverbed gradient and catchment area at the confluence of the Kotmale and Nanu rivers, silting at the vicinity of the confluence would be assumed to begin with sediment load from the Nanu Oya. In such case, upstream of the confluence point, storage capacity of the Kotmale Oya below the sediment plane would be dead water.

As pond length is great in comparison to usable water depth, removal of silt by actual flow would not be likely and silt removal operations would be necessary at some point in the future.

III.7 Study for Staged Development

From the standpoint of power supply and demand planning, complete development of the Project for start-up of operation by 1997 is at the present stage considered necessary. However, should power demand growth rate change, or unexpected difficulties in procuring funding, materials or equipment occur, it would be possible for partial project implementation as required.

The following three cases for partial development are considered:

Case 1: Development at Caledonia only

Case 2: Development at Talawakelle only

Case 3: Development at Talawakelle, incorporating Caledonia dam

The above three cases are premised on the assumption that the entire development plan would eventually be implemented. Partial implementation is thus considered as one step towards final Project completion.

The cost-effectiveness for each case is computed as follows:

TABLE III.7-1 CONSTRUCTION COST FOR VARIOUS STAGED DEVELOPMENT PLANS

	Caledonia	Talawakelle	Total
Caledonia only	4,160	0	4,160
Talawakell only	0	5,640	5,640
Talawakell with Caledonia dam & Intake	2,370	5,640	8,010

TABLE III.7-2 OUTPUT AND ENERGY FOR VARIOUS STAGED DEVELOPMENT PLANS

	Caledonia			Talawakell		
	P	Farm E	E	P	Farm E	E
Proposed Project	44	73	135	204	327	673
Caledonia only	44	73	135	0	0	0
Talawakell only	0	0	0	204	207	637
Talawakell with Caledonia dam & Intake	0	0	0	204	327	673

TABLE III.7-3 BENEFIT-COST COMPARARISON FOR VARIOUS STAGED DEVELOPMENT PLANS

	P	Farm E	E	Cost	B	C	B-C	B/C	Rs./kWh
Proposed Project	248	407	809	9,800	1,191	854	337	1.39	1.24
Caledonia only	44	73	135	4,160	204	359	-155	0.57	2.64
Talawakelle only	204	207	637	5,640	953	495	458	1.93	0.76
Talawakelle with Caledonia dam & Intake	204	327	673	8,010	985	698	287	1.41	1.02

Each case is discussed below.

Development at Caledonia alone

Under this case, development of Caledonia dam and Caledonia power station alone are performed.

Comparing development of the proposed overall scheme, construction cost at Caledonia is Rs.1 billion less expensive than construction at Talawakelle; however, the former scheme is markedly less cost effective.

The advantage of development at Caledonia alone is that firm output and firm energy can be maintained at design levels even in drought years through regulation of river discharge.

However, as there is no re-regulating pond (Talawakelle dam), peak generation is a problem.

Development at Talawakelle alone

Under this case, development of Talawakelle dam and Talawakelle power station alone are performed. Of all the cases for partial Project implementation, this one is the most cost-effective.

Under the Project, 3 turbine/generator units are envisaged for Talawakelle, and these units could be installed phase-wise in response to power demand growth.

As discharge regulation is not performed at Caledonia under this case, firm discharge drops 46% from $9.29 m^3/s$ to $4.99 m^3/s$. As a result both firm output and firm energy decrease.

Development at Talawakelle, incorporating Caledonia dam

Under this scheme, development at Talawakelle would also include construction of Caledonia dam for regulation of river discharge. Spill from Caledonia dam would exit by means of spillway pipe constructed in the dam body, and power generation would be performed at Talawakelle only. The advantage of this case is that power generating potential at Talawakelle is fully realized.

Caledonia power station would be constructed at the second stage of implementation. However, in order to avoid having to forceably lower the reservoir level at Caledonia dam and thereby limiting its storage capacity during subsequent Caledonia power station construction, the power station intake structure (including regulating gate) and one portion of the headrace tunnel would have to be constructed during first stage implementation. In similar fashion, as usable water depth at Talawakelle pond is 7.0m, the segment of Caledonia power station tailrace from the tailrace gate to outlet should also be constructed during the first phase to avoid impairment of regulating function at the pond during second stage implementation. In such event, excavation of tailrace tunnel for Caledonia would be limited to proceeding from the power station side.

III.8 Effect of Raising Kotmale Dam

At present there exists a plan to raise Kotmale dam in order to increase full water level from EL.703.0m to a maximum EL.731.5m. As an operation plan for the reservoir following dam raising has not yet been formulated, average water level for the reservoir was estimated on the basis of the following:

(1) If operation remains the same as at present, average water level would be EL.724.2m.

(2) If the entire storage capacity is utilized yearly, water level would fluctuate from normal high water level of EL.731.5m to minimum water level of EL.655m, with average level of EL.712.5m.

(3) Average water level was consequently assumed on the safe side at the average of the above two average levels in (1) and (2) at 718.0m, following dam raising.

With raising of Kotmale reservoir level, firm output at Talawakelle power station would drop due to 28.5m loss of effective head (equivalent to the rise of tail water level from EL.703m to 731.5m) and efficiency loss of generating equipment.

Generated energy likewise decreases as a result of 15m loss of effective head (equivalent to the rise of average tail water level from EL.703 to 718m) and drop in generating equipment efficiency.

However, Talawakelle is designed as a peak power station, and if design is such that maximum turbine discharge approximates that at which maximum turbine efficiency is achieved, it would still be possible to obtain the original design maximum turbine discharge of $50m^3/s$ (total for three units) even with a loss of 28.5m of effective head.

At present, turbines with rated effective head of 468m are planned. In the event that maximum turbine efficiency is desired after dam raising, it would be possible to replace runners with new ones rated for 15m less head; however, the merit of doing this is limited. It is therefore preferable to postpone new runner consideration until such time as the originally planned runners wear out from long term use and need to be replaced anyway.

Efficiencies of original and new turbines are compared as follows:

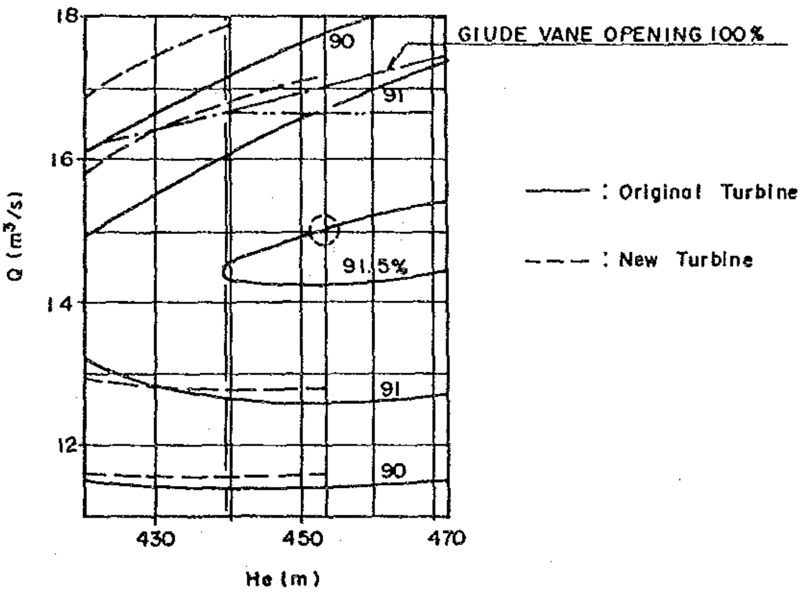
TABLE III.8-1 FIRM OUTPUT AND GENERATED ENERGY BEFORE AND AFTER KOTMALE DAM RASING

Item	Unit	Before Raising	After Raising with Original turbine	After Raising with New turbine
Tailrace Water Level	m	703	731.5	
Effective Head	m	468	439.5	
Maximum Turbine Q	m^3/s	16.7	16.7	
Turbine Efficiency	%	91.2	90.5	95.0
Generator Efficiency	%	97.8	97.7	97.7
Firm Output	kW	68,200	63,400	63,800
Output Ratio	%	100	93.0	93.5

Item	Unit	Before Raising	After Raising with Original turbine	After Raising with New turbine
Average Tailwater Level	m	703	718	
Effective head	m	468	453	
Maximum Turbine Q	m^3/s	16.7	16.7	
Turbine Efficiency	%	91.2	91.0	91.1
Generator Efficiency	%	97.8	97.7	97.7
Average Output	kW	68,200	65,760	65,830
Generated Energy Ratio	%	100	96.4	96.5

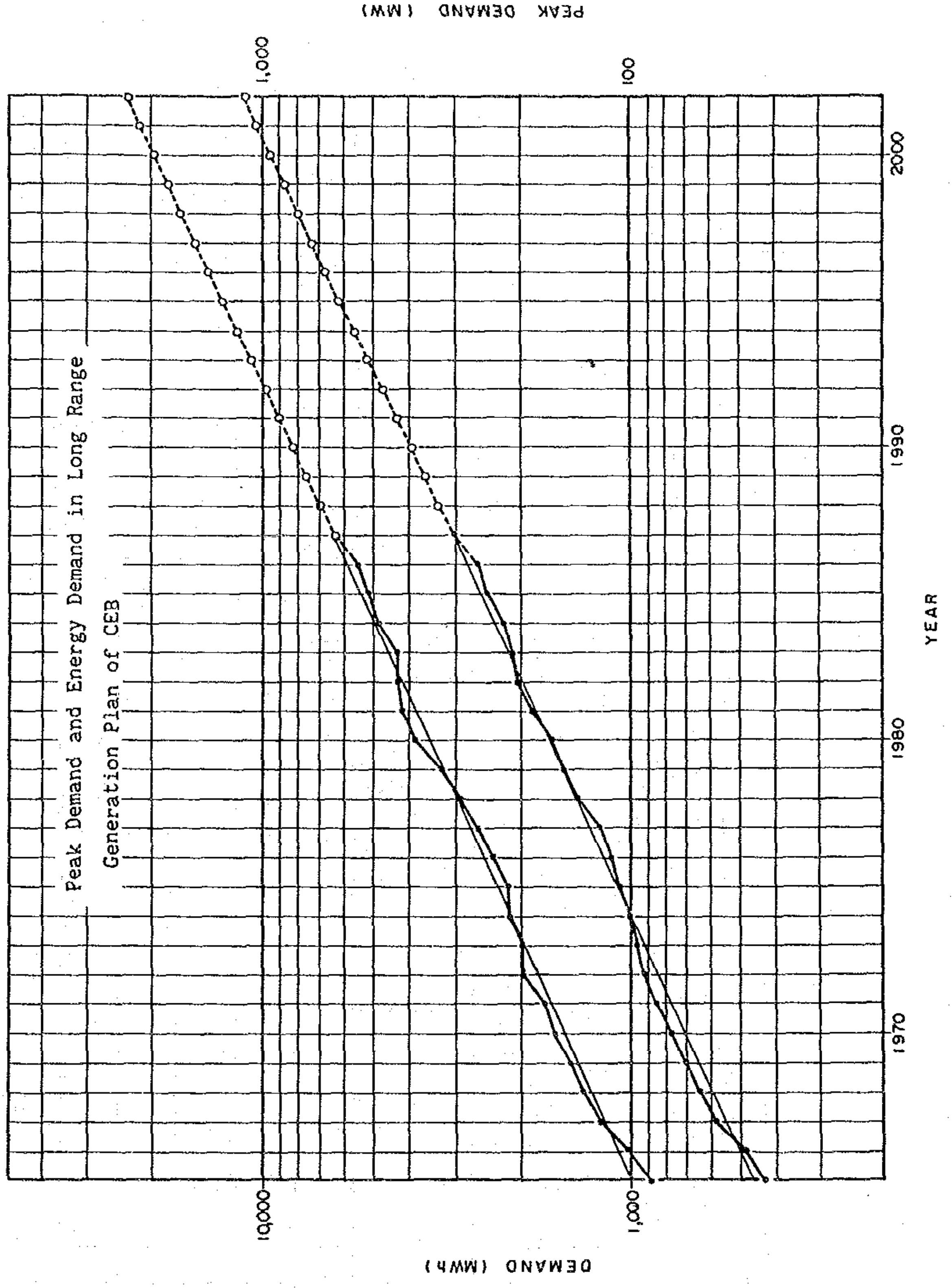
As shown in Table TABLE III.8-1, firm output following reservoir raising is 93% utilizing the original turbines. Replacement with new runners would increase firm output by only 0.5%.

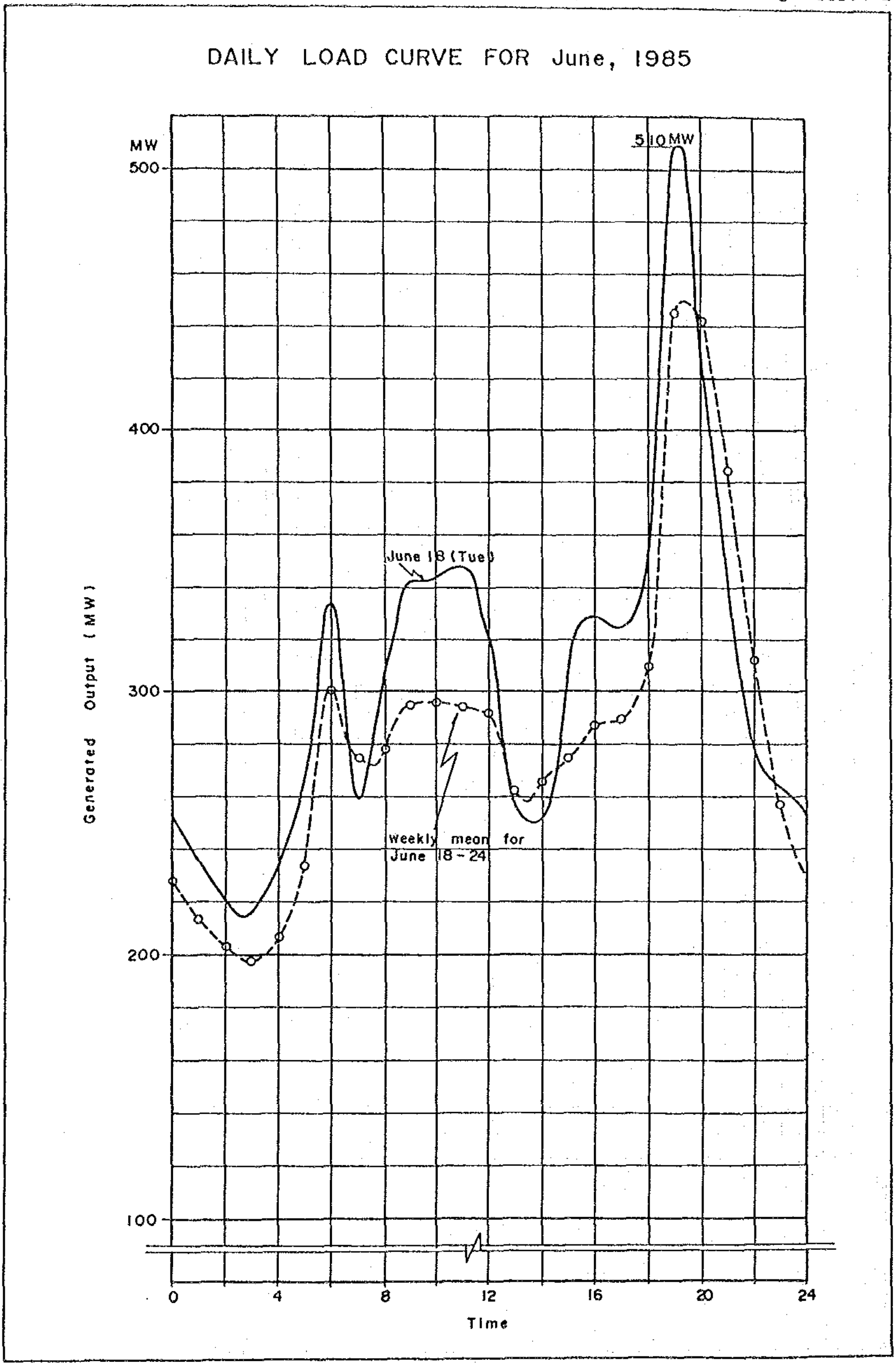
Generated energy after dam raising would be 96.4% with the original turbines. With new turbines, the value is essentially the same at 96.5%.



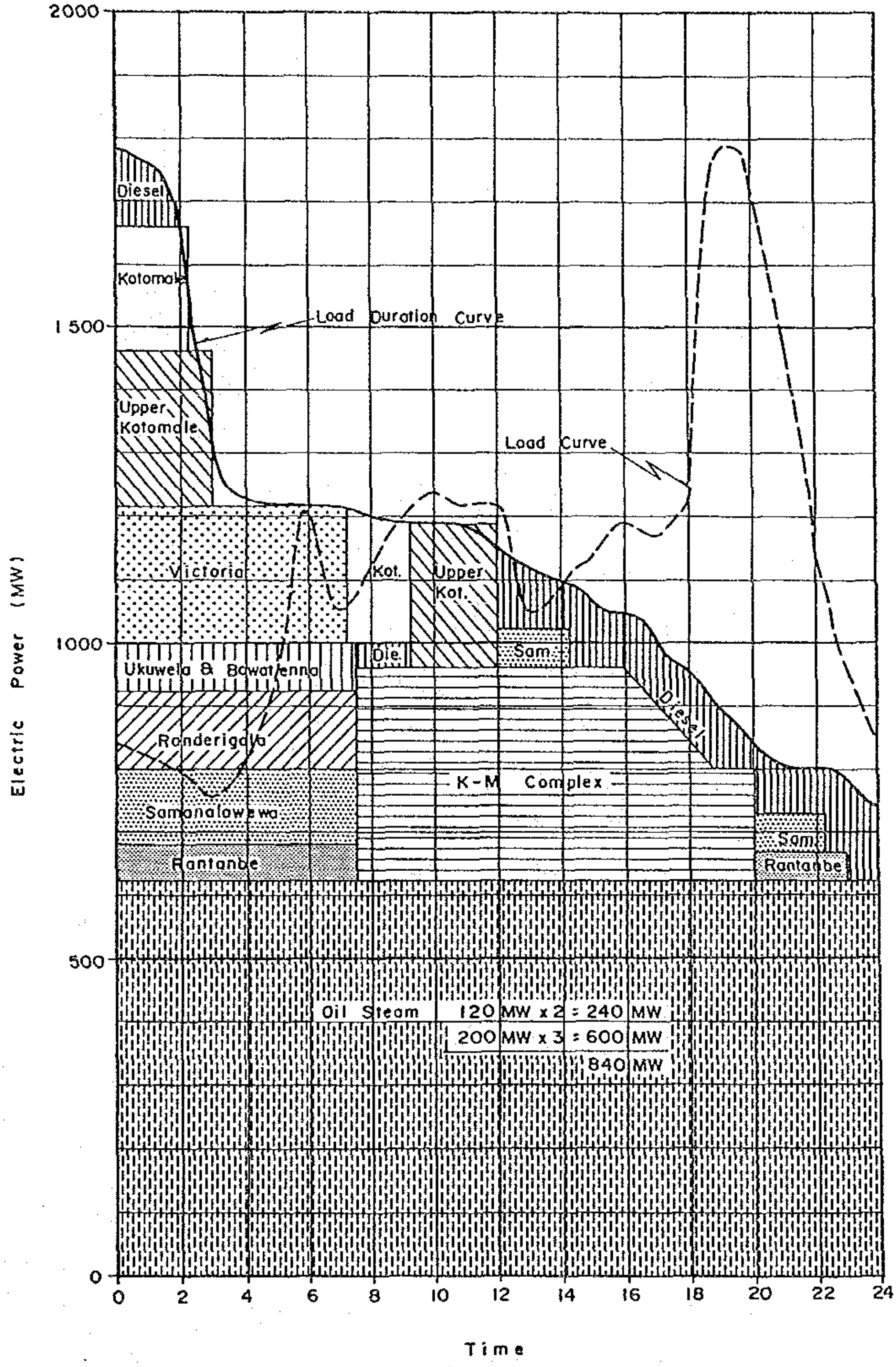
FIGURES

ILLUSTRATIONS


Peak Demand and Energy Demand in Long Range
Generation Plan of CEB
PEAK DEMAND (MW)
1,000
100
DEMAND (MWh)
10,000
1,000
YEAR
1970
1980
1990
2000

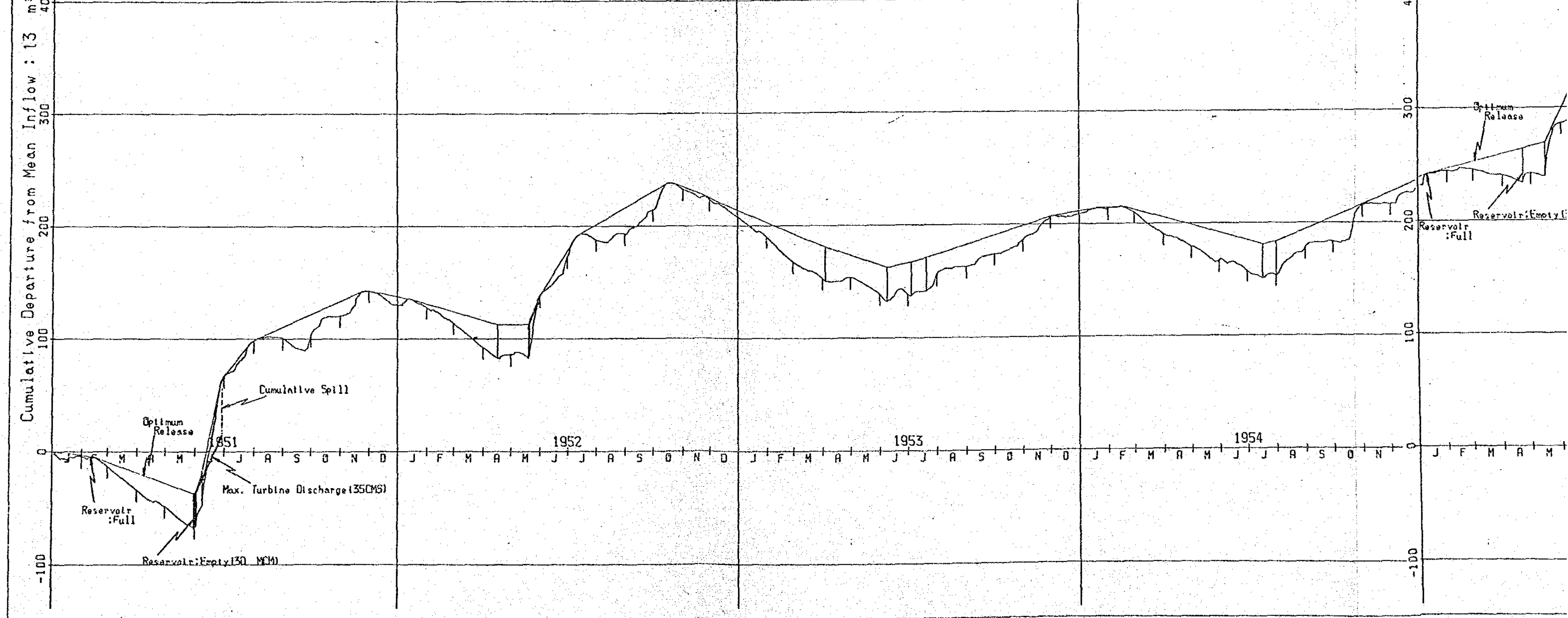

DAILY LOAD CURVE FOR June, 1985
MW
500
400
300
200
100
510MW
June 18 (Tue)
Weekly mean for
June 18 - 24
Generated Output (MW)
0
4
8
12
16
20
24
Time

ENERGY ALLOCATION (AN EXAMPLE) BY STATIONS AS OF YEAR 2000



RESERVOIR OPERATION SIMULATION
RSTQ2324:Calod.P/S NHWL1360.0 Max.Q:35CMS
Actual Average Q :13.0881

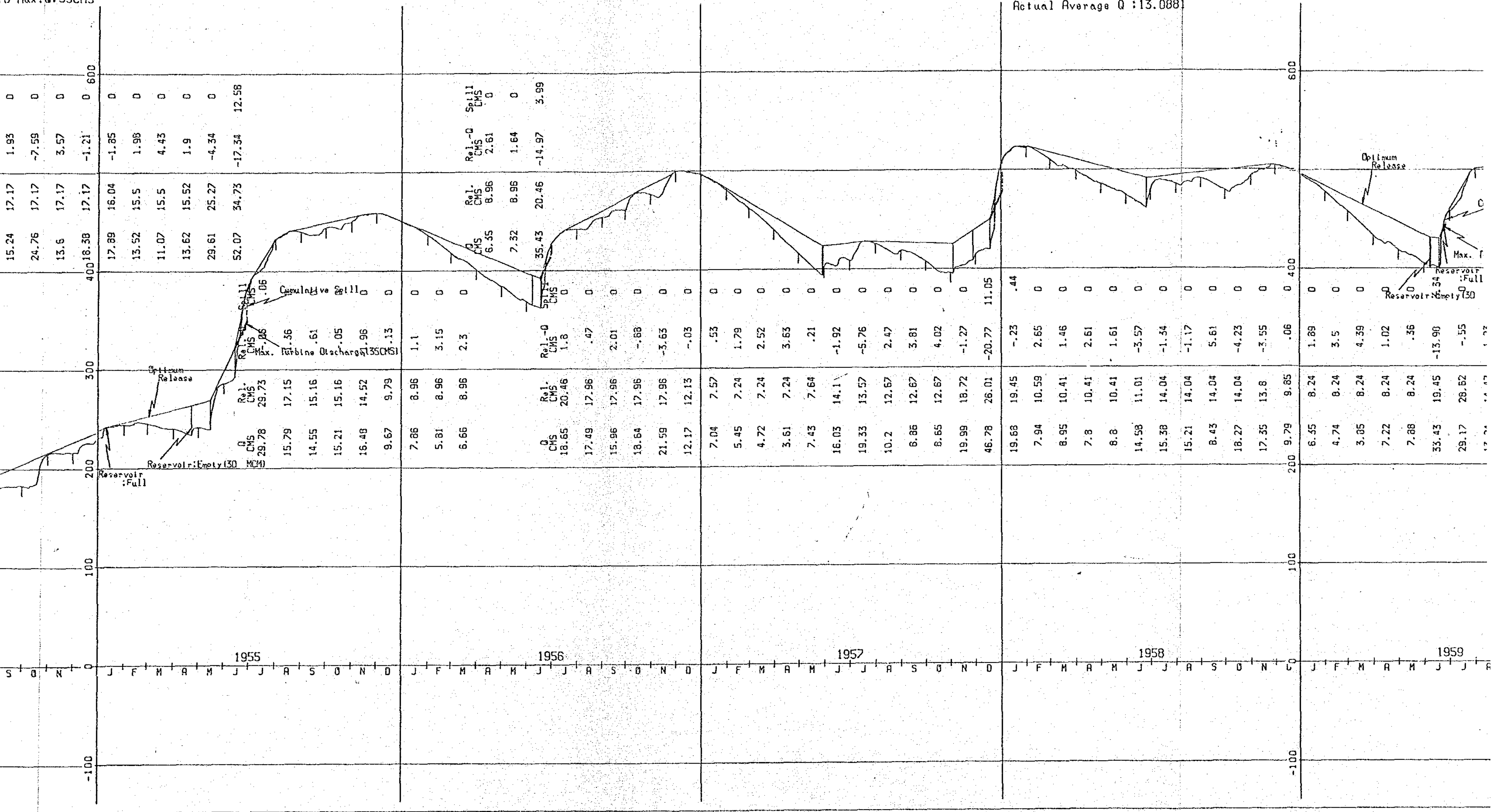
1951	J	11.42	11.84	.42	0
	F	9.5	10.5	1	0
	M	5.13	9.44	4.32	0
	A	7.43	9.44	2.01	0
	M	6.12	9.73	3.6	0
	J	64.56	34.03	-30.53	18.95
	J	24.57	24.71	.14	0
	A	14.11	17.56	3.45	0
	S	13.99	17.33	3.34	0
	O	19.44	17.33	-2.1	0
	N	21.52	16.64	-4.89	0
	D	8.19	11.04	2.85	0
1952	J	12.31	10.55	-1.76	0
	F	7.47	10.18	2.71	0
	M	4.92	10.18	5.26	0
	A	10.55	11.56	1.01	0
	M	32.37	21.22	-11.15	1.35
	J	26.35	28.27	1.91	0
	J	18.75	21.72	2.98	0
	A	14.92	18.57	3.65	0
	S	21.14	18.57	-2.57	0
	O	19.92	14.52	-5.4	0
	N	9.38	9.11	-.27	0
	D	7.09	8.92	1.83	0
1953	J	6.53	8.92	2.39	0
	F	3.76	8.92	5.17	0
	M	7.4	8.92	1.52	0
	A	13.18	9.7	-3.48	0
	M	7.63	9.79	2.16	0
	J	12.93	13.64	.71	0
	J	19.42	15.89	-3.53	0
	A	15.57	16.09	.52	0
	S	17.25	16.09	-1.16	0
	O	17.46	16.09	-1.37	0
	N	20.96	16.09	-4.86	0
	D	13.9	14.72	.82	0
1954	J	14.64	14.22	-.45	0
	F	11.69	12.08	.39	0
	M	5.59	10.39	4.81	0
	A	8.72	10.39	1.67	0
	M	8.26	10.39	2.14	0
	J	9.75	10.39	.64	0
	J	11.39	12.41	1.01	0
	A	21.9	17.09	-4.81	0
	S	15.24	17.17	1.93	0
	O	24.76	17.17	-7.59	0
	N	13.6	17.17	3.57	0
	D	18.38	17.17	-1.21	0
1955	J	17.89	16.04	-1.85	0
	F	13.52	15.5	1.98	0
	M	11.07	15.5	4.43	0
	A	13.62	15.52	1.9	0
	M	29.61	25.27	-4.34	0

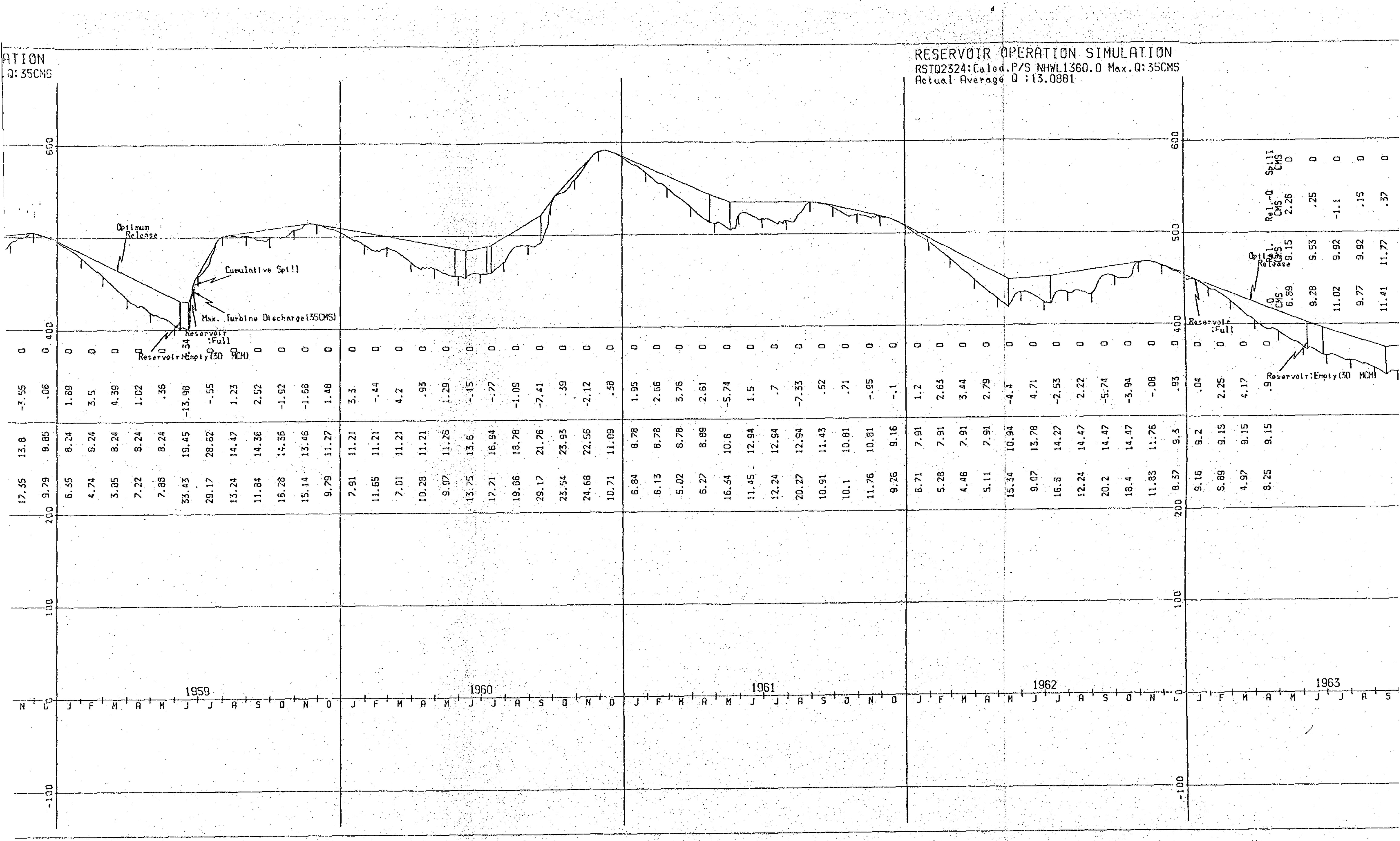


SIMULATION
.0 Max.Q:35CMS

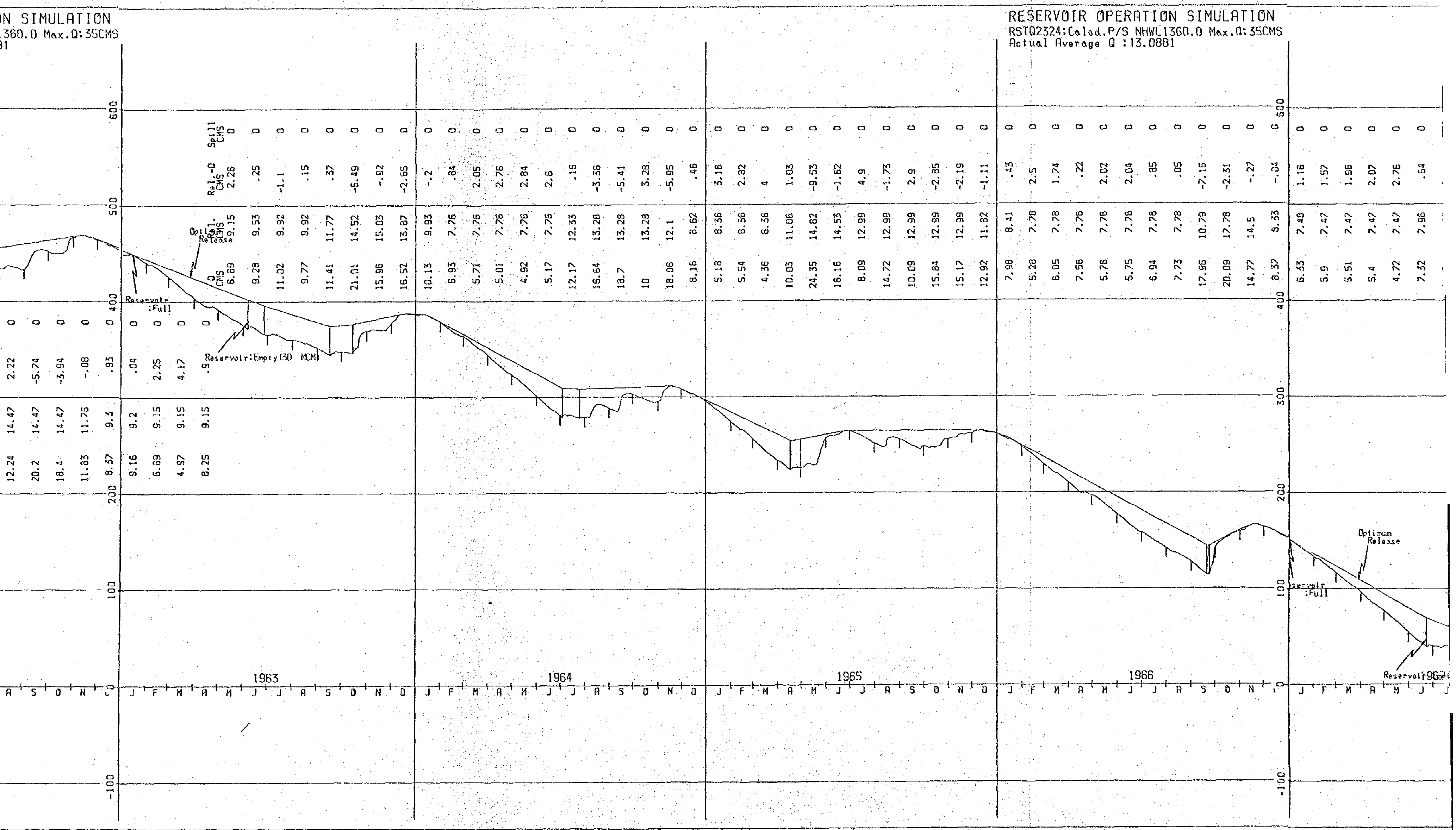
RESERVOIR OPERATION SIMULATION

RSTQ2324:Calcd.P/S NHWL1360.0 Max.Q:35CMS
Actual Average Q :13.088





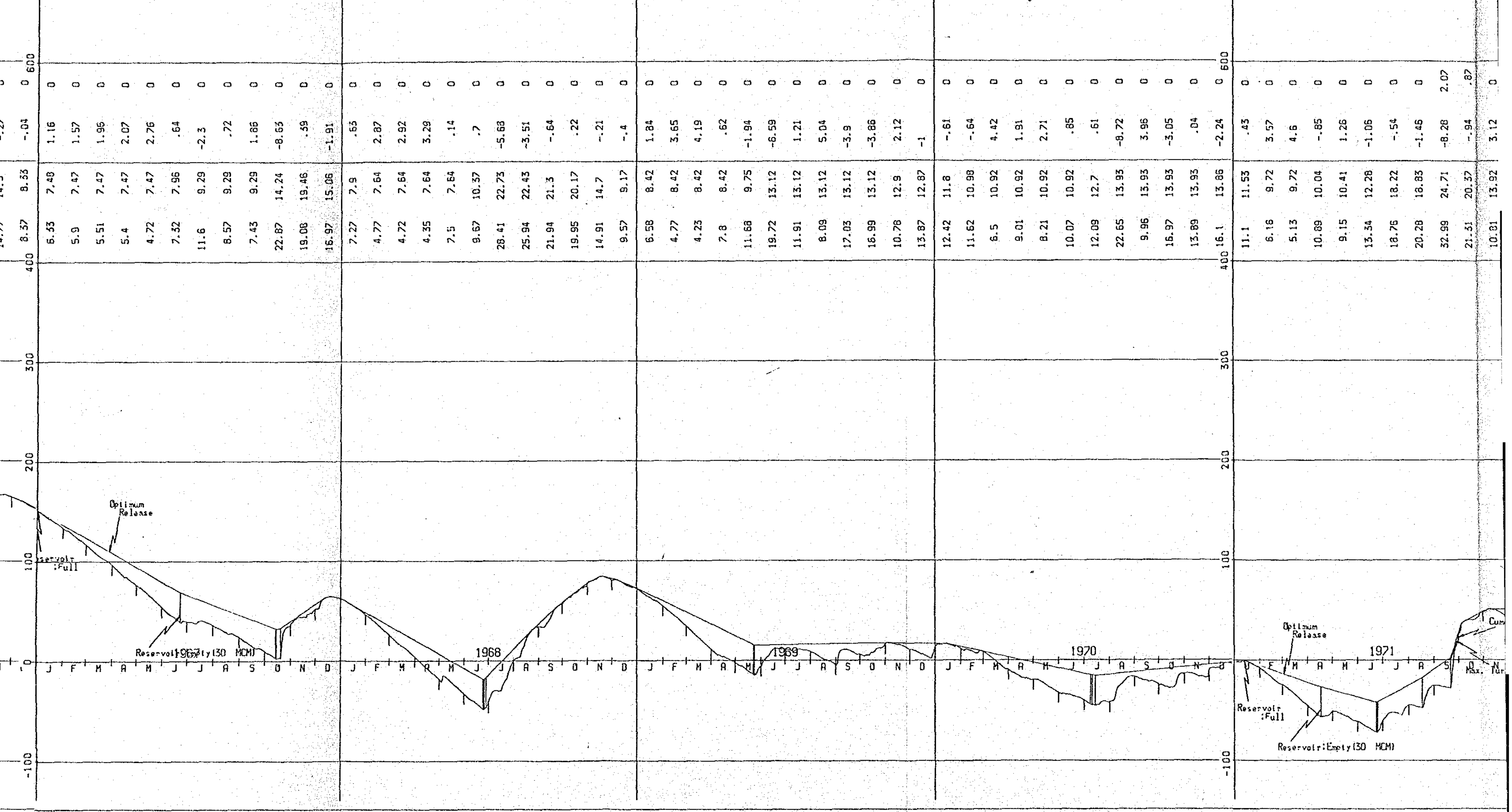
ATION
Q:35CMS
RESERVOIR OPERATION SIMULATION
RSTQ2324:Caled.P/S NHWL1360.0 Max.Q:35CMS
Actual Average Q :13.0881
Optimum Release
Cumulative Spill
Max. Turbine Discharge(35CMS)
Reservoir :Full
Reservoir:Empty(30 MCM)
Spill CMS
Rel.-Q CMS
Rel. CMS
Q CMS
600
500
400
200
100
0
-100
1959
1960
1961
1962
1963

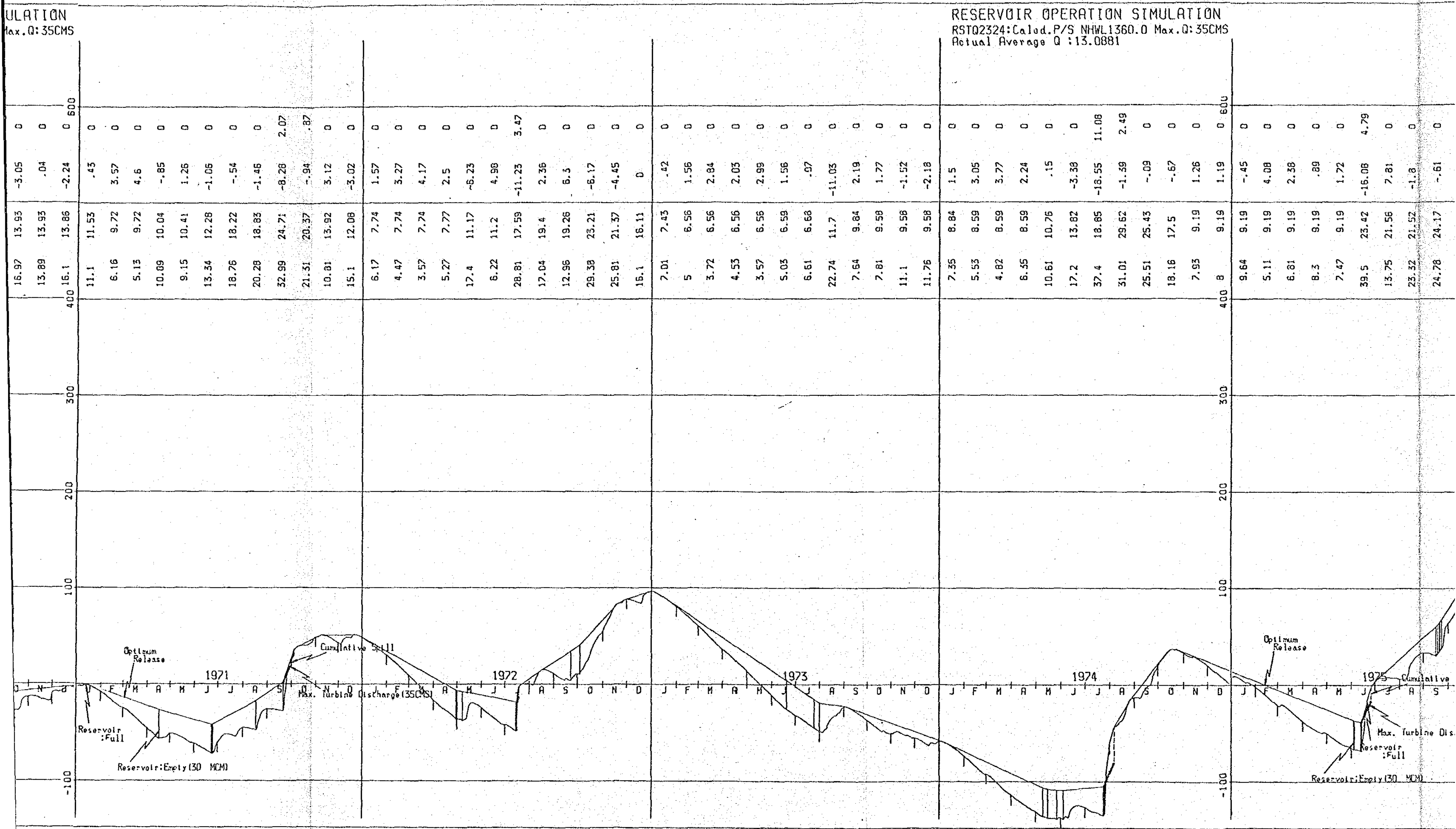


N SIMULATION
.360.0 Max.Q:35CMS
RESERVOIR OPERATION SIMULATION
RSTQ2324:Caled.P/S NHWL1360.0 Max.Q:35CMS
Actual Average Q :13.0881
Spill CMS
Rel.-Q CMS
Rel. CMS
Q CMS
Optimum Release
Reservoir :Full
Reservoir:Empty(30 MCM)
600
500
400
300
200
100
0
-100
1963
1964
1965
1966
J F M A M J J A S O N D

ION
35CMS

RESERVOIR OPERATION SIMULATION
RSTQ2324:Calod.P/S NHWL1360.0 Max.Q:35CMS
Actual Average Q :13.0881




ULATION
Max.Q:35CMS
RESERVOIR OPERATION SIMULATION
RSTQ2324:Calcd.P/S NHWL1360.0 Max.Q:35CMS
Actual Average Q :13.0881
600
400
300
200
100
-100
1971
1972
1973
1974
1975
Optimum Release
Reservoir :Full
Reservoir:Empty(30 MCM)
Cumulative Spill
Max. Turbine Discharge(35CMS)
Max. Turbine Dis.
Cumulative

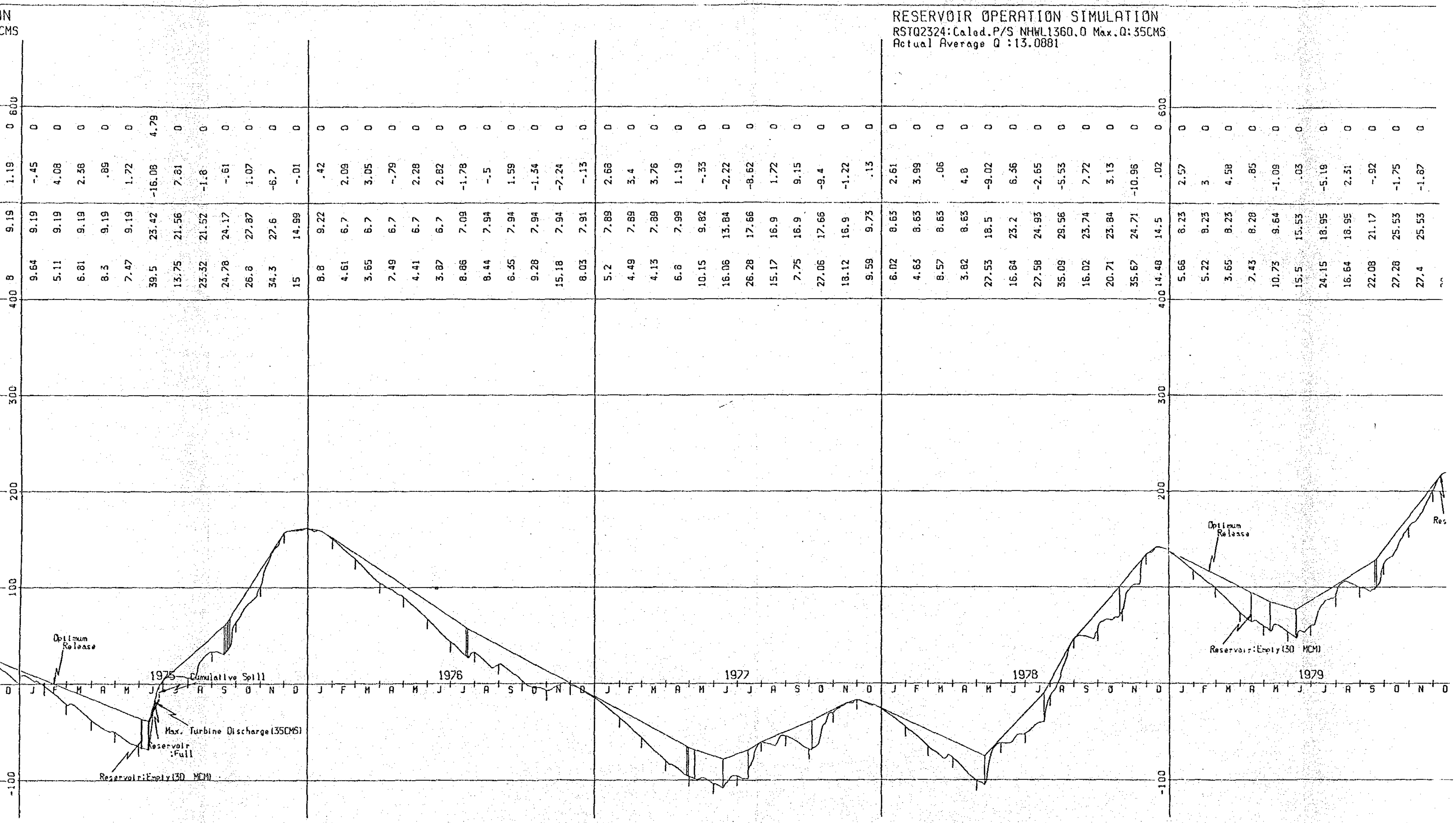
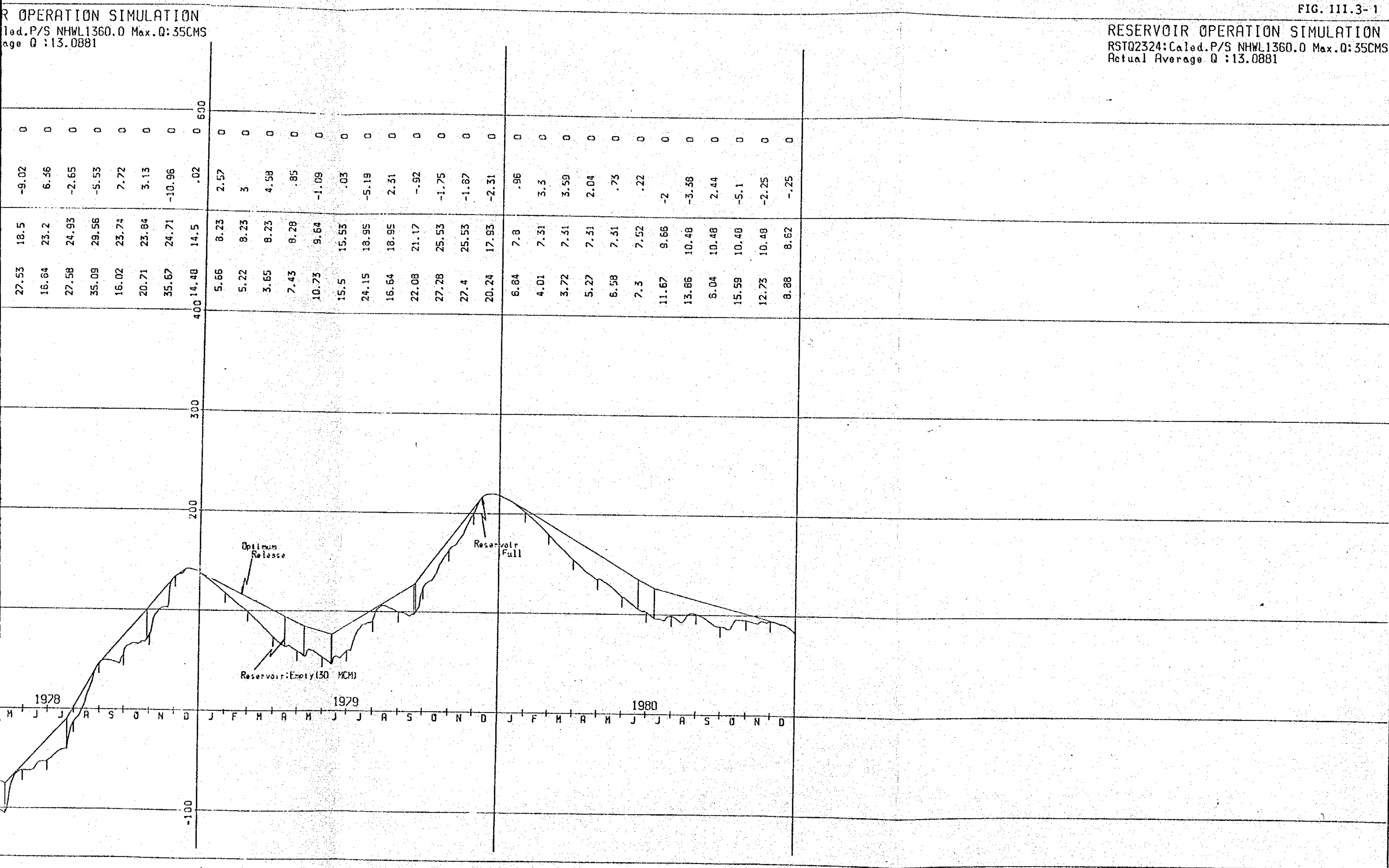
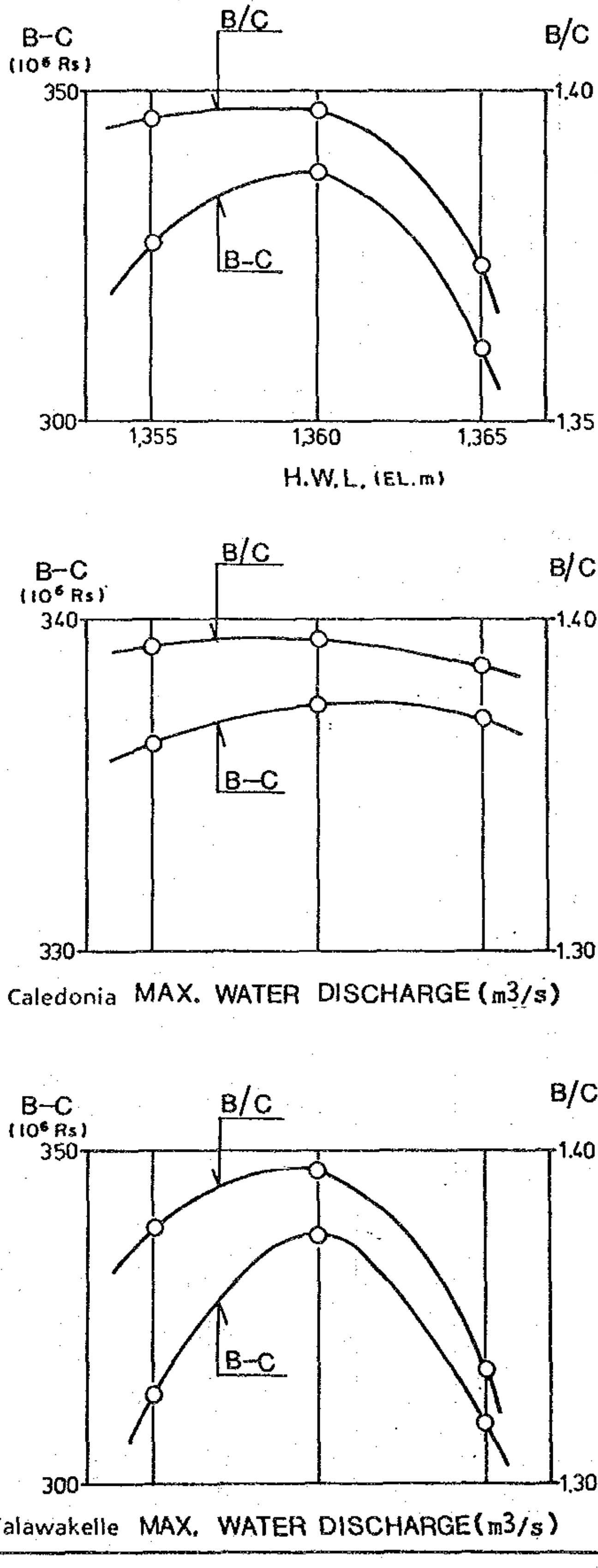

RESERVOIR OPERATION SIMULATION
RSTQ2324:Calod.P/S NHWL1360.0 Max.Q:35CMS
Actual Average Q :13.0881
Optimum Release
Cumulative Spill
Max. Turbine Discharge(35CMS)
Reservoir :Full
Reservoir:Empty(30 MCM)
1975
1976
1977
1978
1979

FIG. III.3-1

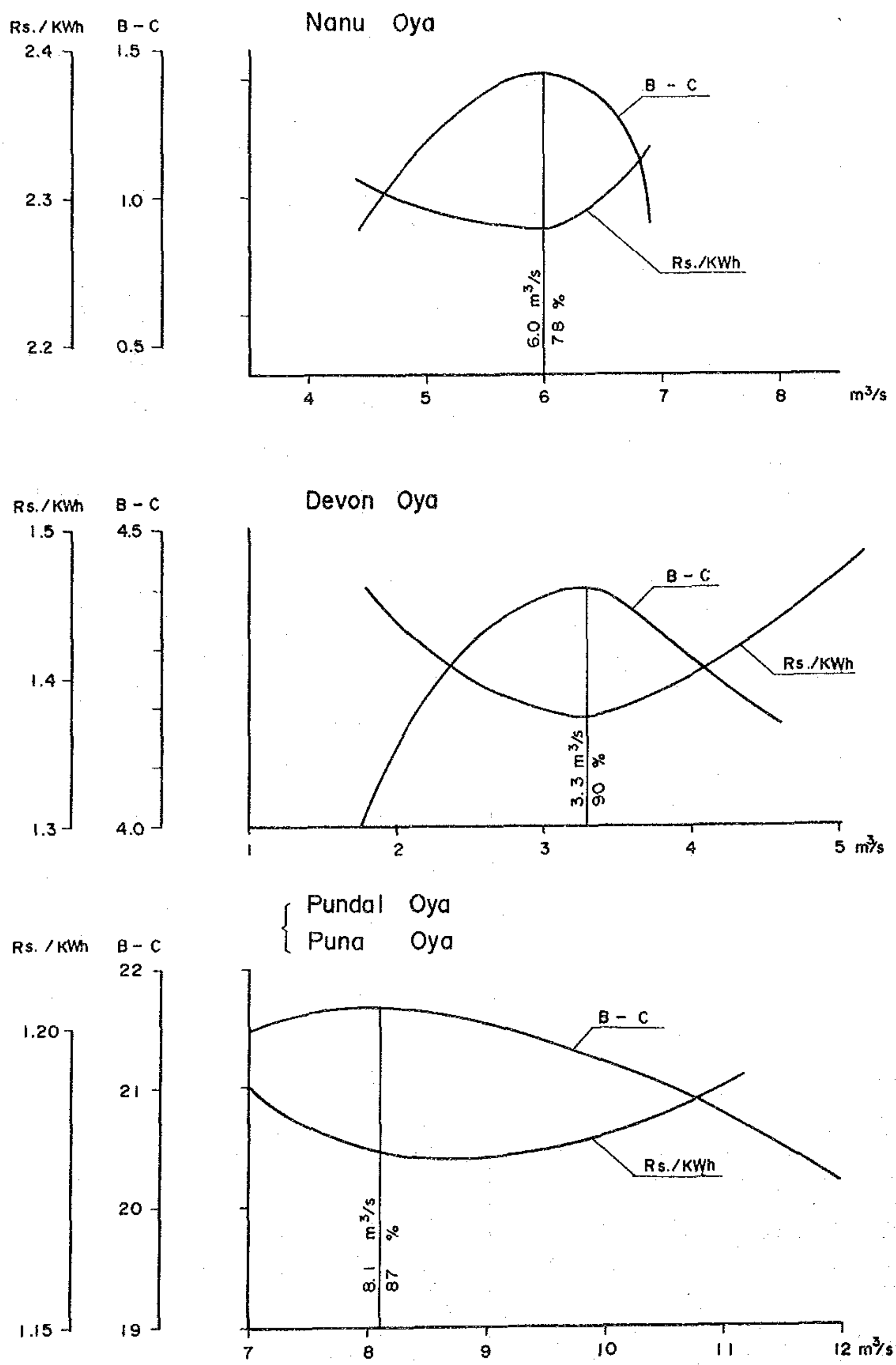
RESERVOIR OPERATION SIMULATION
RSTQ2324:Caled.P/S NHWL1360.0 Max.Q:35CMS
Actual Average Q :13.0881

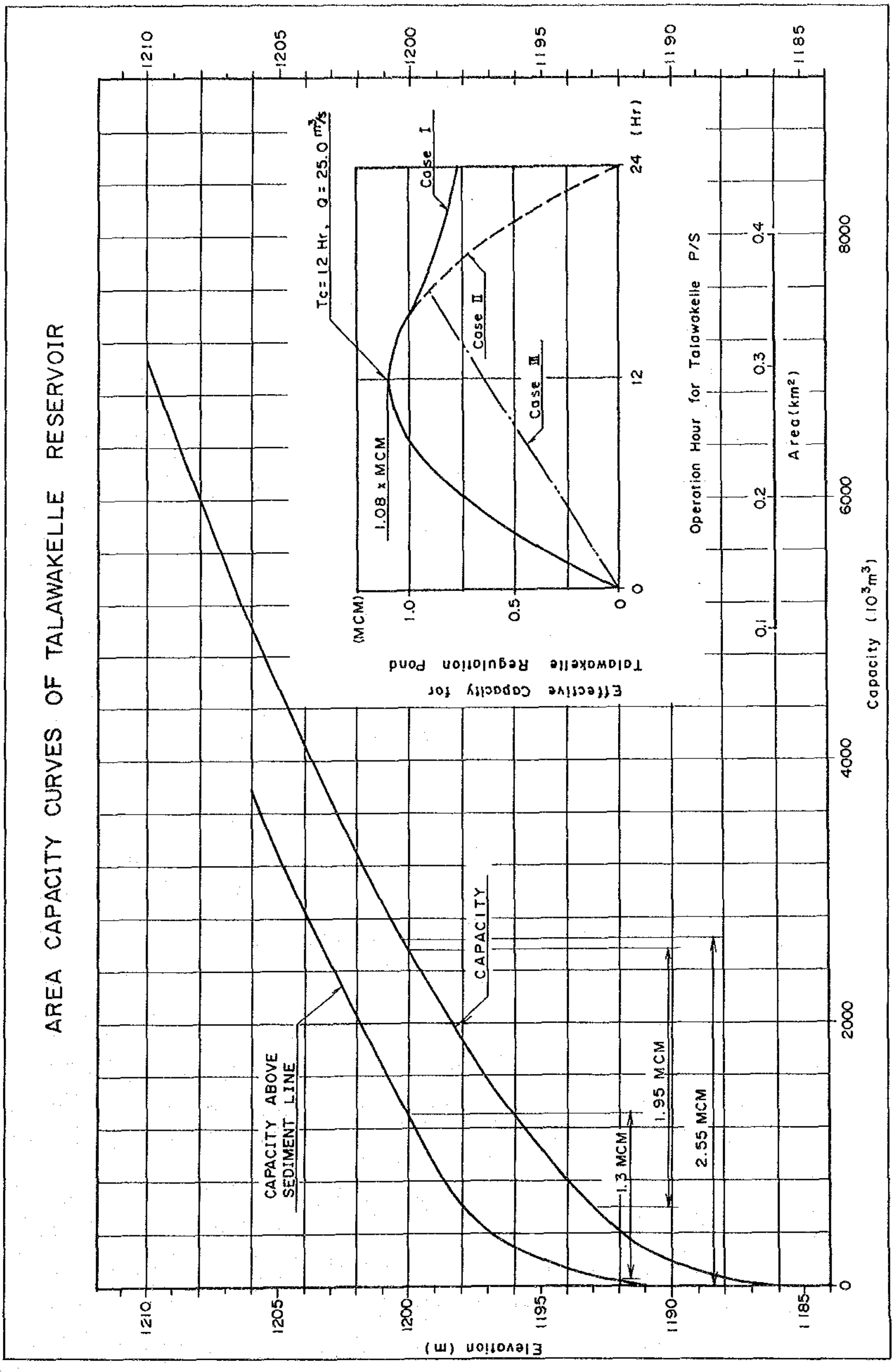


Optimization of Reservoir Scale
and Installed Capacity



OPTIMIZATION OF MAXIMUM DIVERSION DISCHARGE FROM TRIBUTARIES




AREA CAPACITY CURVES OF TALAWAKELLE RESERVOIR
Elevation (m)
1210
1205
1200
1195
1190
1185
Capacity (10³m³)
0
2000
4000
6000
8000
Area (km²)
0.1
0.2
0.3
0.4
CAPACITY
CAPACITY ABOVE SEDIMENT LINE
1.3 MCM
1.95 MCM
2.55 MCM
Effective Capacity for Talawakelle Regulation Pond
(MCM)
1.0
0.5
0
Operation Hour for Talawakelle P/S
12
24
(Hr)
Tc=12 Hr, Q=25.0 m³/s
1.08 x MCM
Case I
Case II
Case III

APPENDIX IV

DAM ENGINEERING

APPENDIX IV DAM ENGINEERING

List of Illustrations

APPENDIX IV

DAM ENGINEERING

IV.1 Reservoir Routing for Determination of Crest Level Elevation

Results of reservoir routing for PMF and 1,000-year return period flood are presented in the following table. The conditions for calculation are as follows:

Spillway width: 180.0m

Discharge formula: $Q = CBH^{2/3}$

C: 1.7 to 2.15 (depending upon H)

B: overflow width (m)

H: overflow water depth (m)

TABLE IV.1-1 RESERVOIR ROUTING FOR PMF HYDROGRAPH

Time		Inflow (m3/s)	Reservoir Water Level (EL.m)	Outflow (m3/s)	Stored Volume (m3)
D A T E		(QI)	(H)	(QO)	(V)
		19.60	1360.01	2.87	45730100.
1	1	62.40	1360.04	14.93	45845650.
1	2	182.60	1360.14	48.74	46172040.
1	3	298.60	1360.32	108.95	46754370.
1	4	375.10	1360.53	180.75	47445580.
1	5	431.50	1360.73	250.73	48120800.
1	6	493.70	1360.93	317.36	48763610.
1	7	566.30	1361.12	419.38	49345480.
1	8	653.30	1361.28	529.35	49833040.
1	9	747.80	1361.42	628.18	50271460.
1	10	895.30	1361.59	739.75	50766770.
1	11	1183.20	1361.84	912.45	51534110.
1	12	1665.90	1362.26	1240.86	52786520.
1	13	2171.60	1362.80	1699.48	54401400.
1	14	2527.40	1363.35	2275.68	55704310.
1	15	2396.90	1363.52	2464.95	56034910.
1	16	2035.30	1363.30	2211.96	55594430.
1	17	1713.30	1363.00	1869.20	54995820.
1	18	1486.10	1362.78	1686.77	54353980.
1	19	1313.10	1362.56	1492.50	53669860.
1	20	1159.20	1362.35	1319.05	53059220.
1	21	1030.10	1362.17	1167.62	52523960.
1	22	927.40	1362.02	1039.76	52074170.
1	23	851.90	1361.90	949.73	51695840.
2	0	776.80	1361.78	871.59	51349120.
2	1	657.90	1361.65	782.60	50954040.
2	2	491.10	1361.47	662.57	50420920.
2	3	369.30	1361.28	528.50	49825720.
2	4	289.30	1361.11	413.49	49315610.
2	5	231.90	1360.97	332.89	48910290.
2	6	186.80	1360.86	294.06	48535440.
2	7	151.70	1360.74	254.82	48156750.
2	8	123.80	1360.64	218.00	47801580.
2	9	101.00	1360.54	184.78	47481220.
2	10	81.40	1360.45	155.34	47197330.
2	11	64.70	1360.38	129.45	46947700.

TABLE IV.1-2 RESERVOIR ROUTING FOR 1000-YEAR RETURN PERIOD FLOOD HYDROGRAPH

Time		Inflow (m3/s)	Reservoir Water Level (EL.m)	Outflow (m3/s)	Stored Volume (m3)
D A T E		(QI)	(H)	(QO)	(V)
		16.80	1360.01	2.46	45725810.
1	1	42.50	1360.03	10.95	45808400.
1	2	111.30	1360.09	31.69	46008480.
1	3	166.40	1360.19	65.47	46333460.
1	4	209.60	1360.30	103.97	46705260.
1	5	240.70	1360.42	142.08	47072910.
1	6	269.80	1360.52	177.67	47416260.
1	7	310.00	1360.62	212.96	47756750.
1	8	366.60	1360.74	252.36	48137060.
1	9	433.40	1360.87	298.75	48585070.
1	10	536.20	1361.04	370.01	49126590.
1	11	709.10	1361.26	515.84	49773600.
1	12	1003.50	1361.55	712.21	50645790.
1	13	1286.50	1361.92	962.27	51753730.
1	14	1428.90	1362.24	1220.14	52713110.
1	15	1376.70	1362.38	1343.53	53148580.
1	16	1185.30	1362.33	1301.82	52998560.
1	17	1013.20	1362.17	1165.11	52515390.
1	18	874.90	1362.00	1015.66	51988580.
1	19	764.20	1361.83	902.58	51486120.
1	20	664.30	1361.67	793.88	51003800.
1	21	584.10	1361.52	695.93	50569270.
1	22	526.50	1361.40	614.73	50209160.
1	23	482.00	1361.31	550.93	49926280.
2	0	434.30	1361.23	497.66	49688160.
2	1	375.70	1361.15	444.18	49450860.
2	2	283.40	1361.05	377.76	49157740.
2	3	214.30	1360.94	321.02	48795780.
2	4	168.80	1360.82	280.34	48402910.
2	5	136.40	1360.70	240.17	48015350.
2	6	111.00	1360.59	203.53	47662000.
2	7	91.00	1360.50	171.27	47350950.
2	8	75.10	1360.42	143.51	47083320.
2	9	62.20	1360.35	120.11	46855940.
2	10	51.00	1360.29	100.10	46663320.
2	11	41.40	1360.24	83.12	46499840.