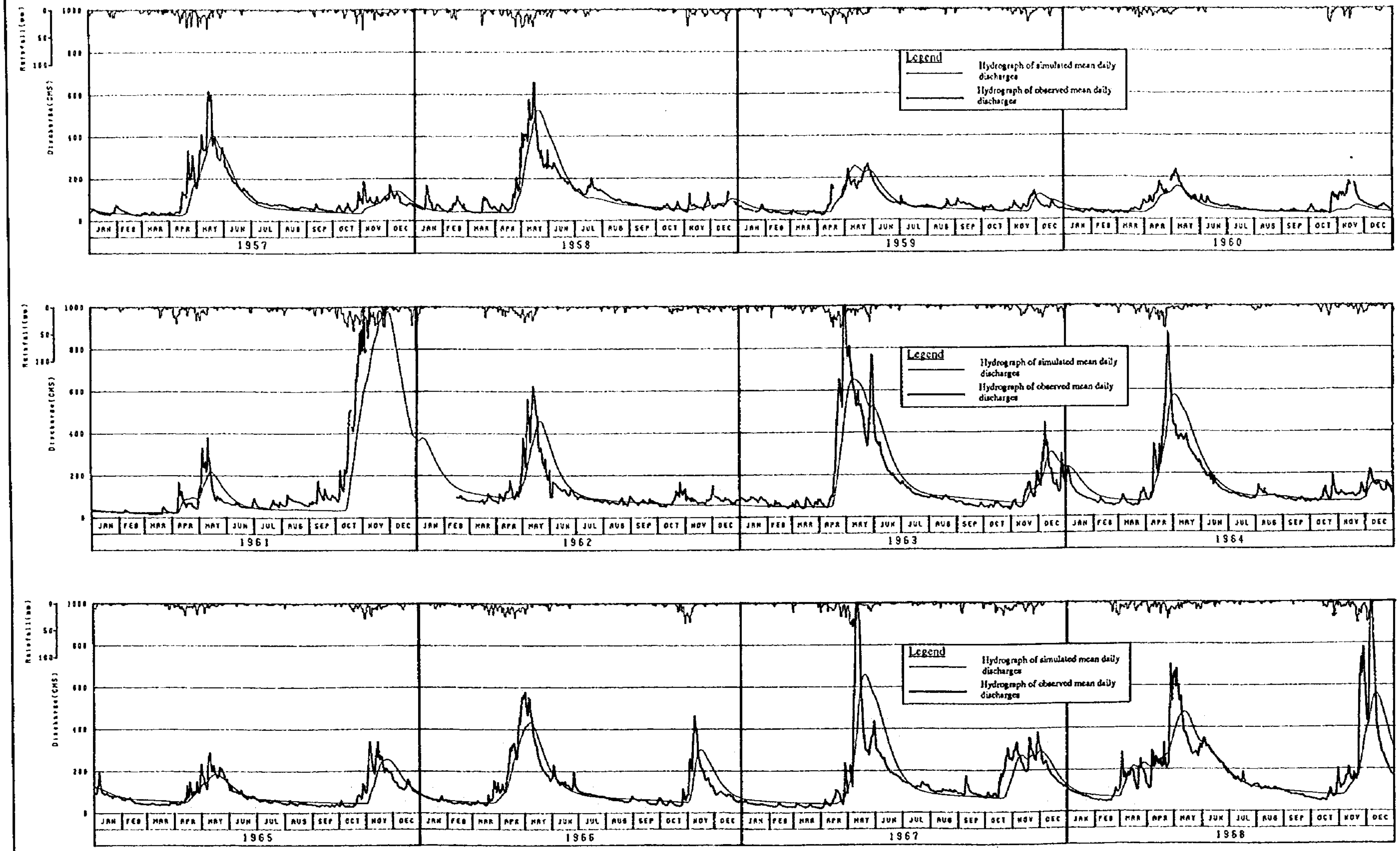
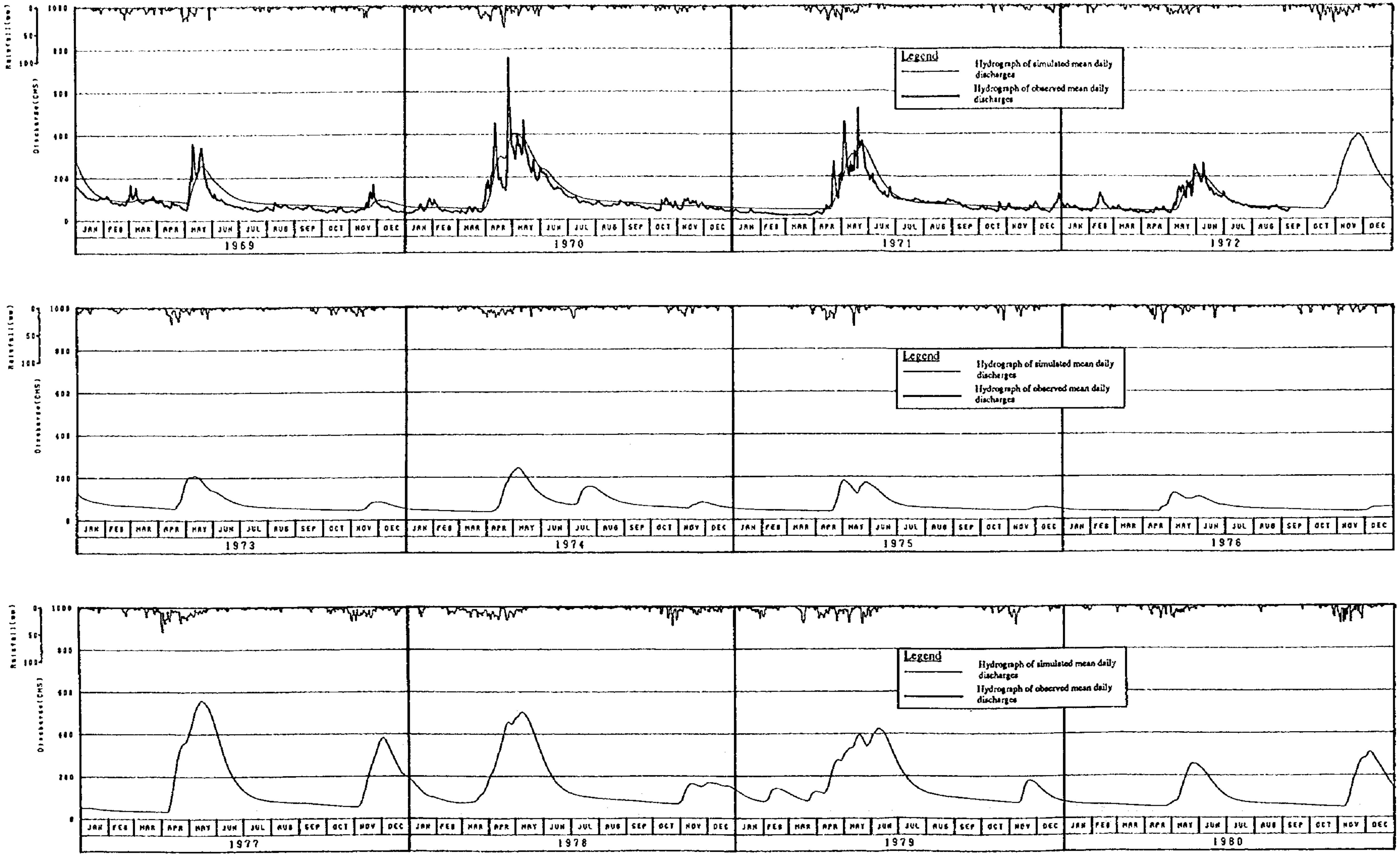


JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Hydrographs of Mean Daily Discharges Observed and Simulated at SGS 4EA7	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.20 (1)



JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Hydrographs of Mean Daily Discharges Observed and Simulated at SGS 4EA7	Fig. No.
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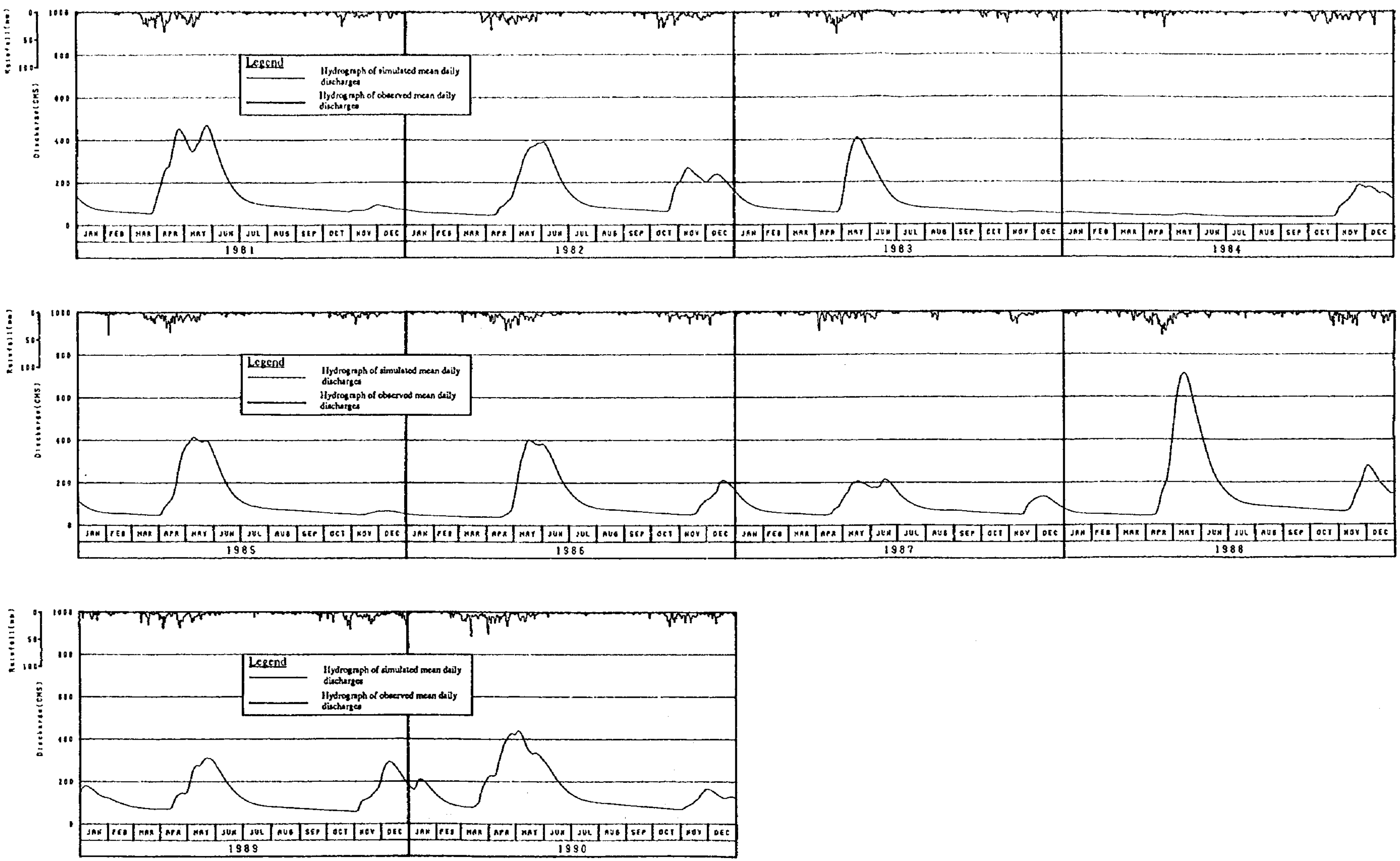

JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Hydrographs of Mean Daily Discharges Observed and Simulated at SGS 4EA7	Fig. No.
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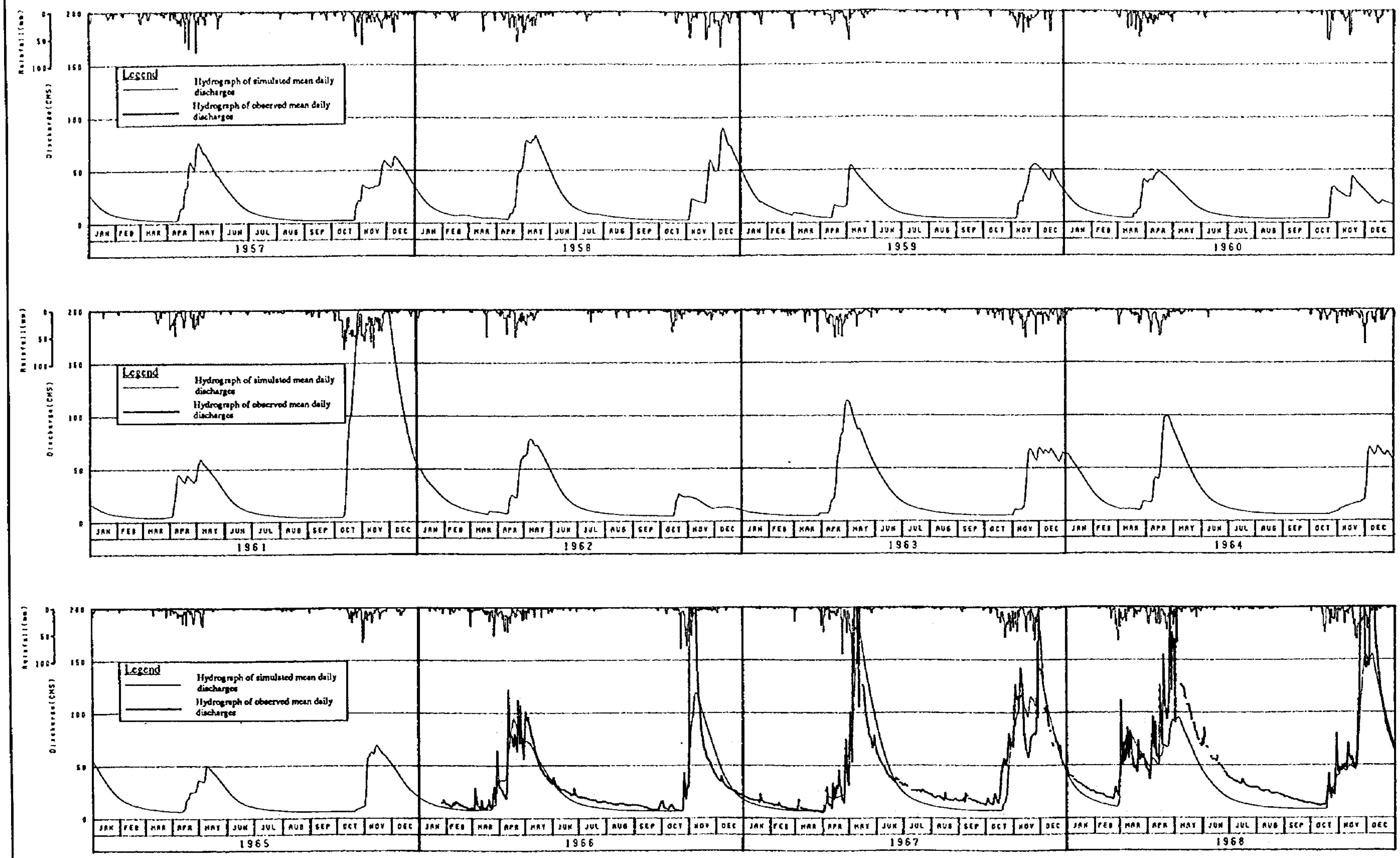
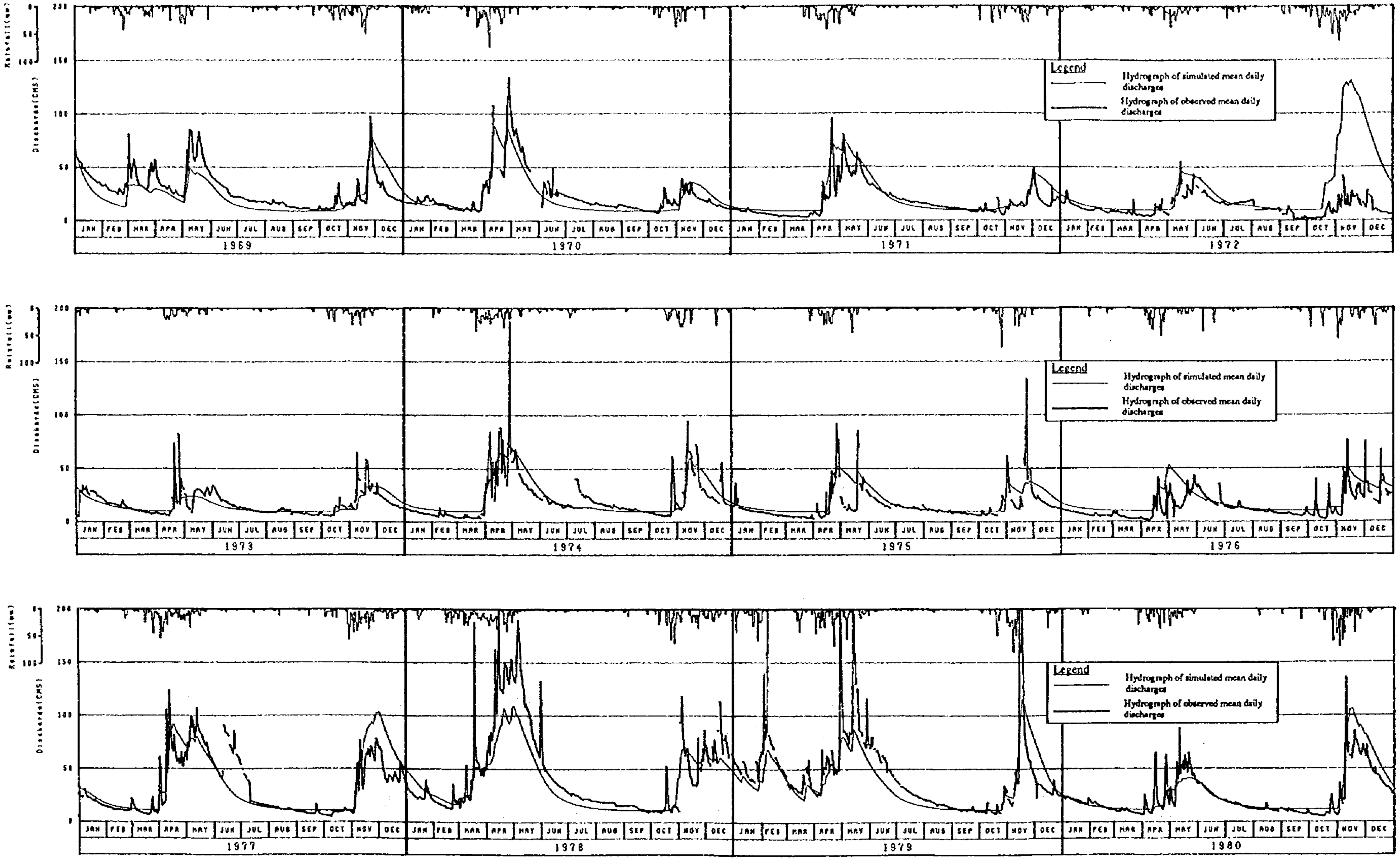


JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Hydrographs of Mean Daily Discharges Observed and Simulated at SGS 4F19	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.21 (1)



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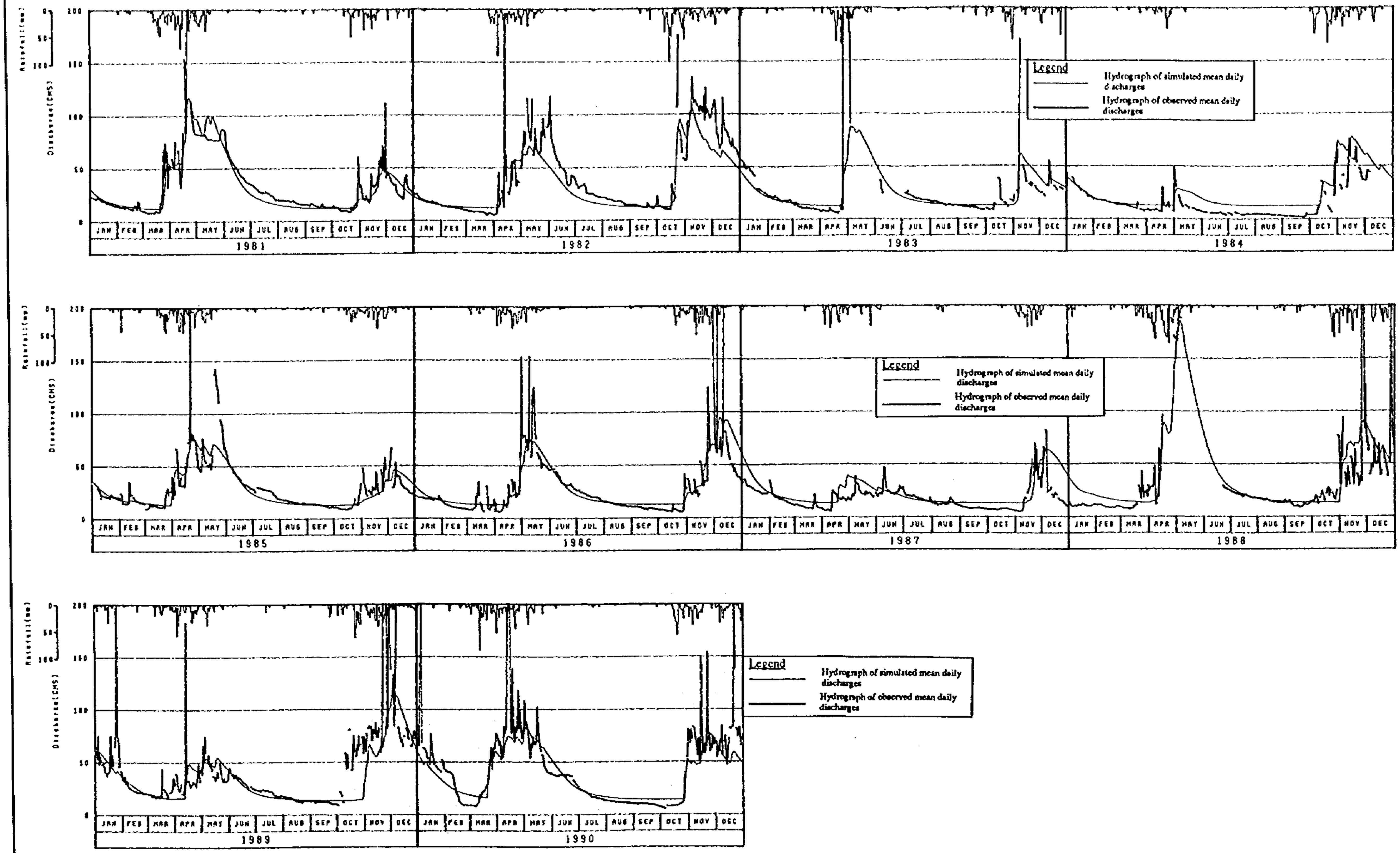

JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Hydrographs of Mean Daily Discharges Observed and Simulated at SGS 4F19	Fig. No.
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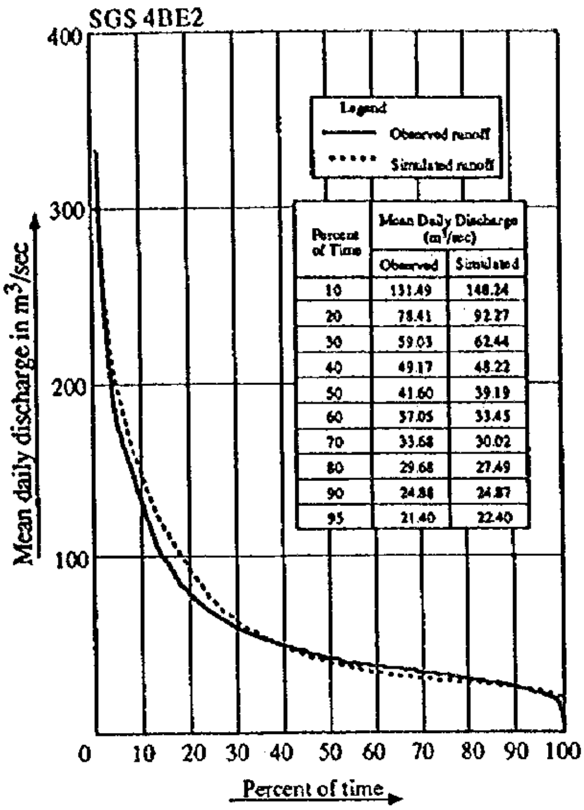
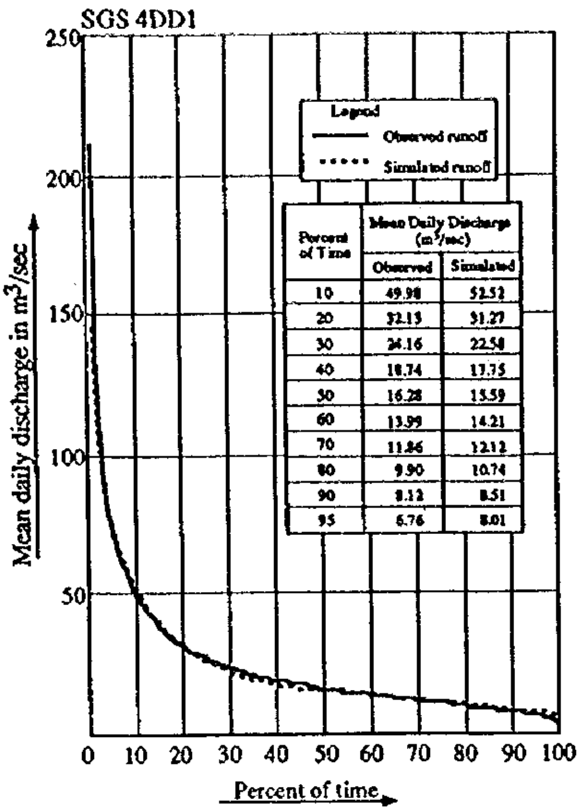
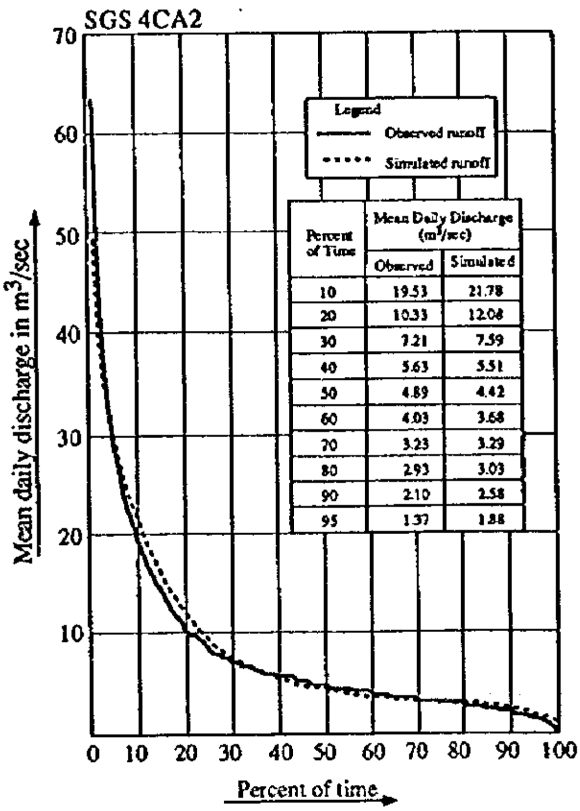


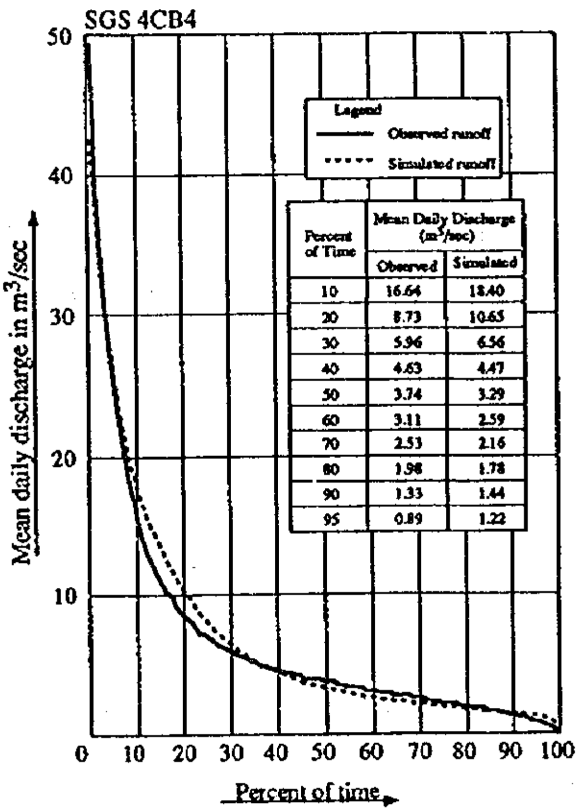
Percent of Time	Mean Daily Discharge (m^3/sec)	
	Observed	Simulated
10	131.49	148.24
20	78.41	92.27
30	59.03	62.44
40	49.17	48.22
50	41.60	39.19
60	37.05	33.45
70	33.68	30.02
80	29.68	27.49
90	24.88	24.87
95	21.40	22.40



Percent of Time	Mean Daily Discharge (m^3/sec)	
	Observed	Simulated
10	49.98	52.52
20	32.13	31.27
30	24.16	22.58
40	18.74	17.75
50	16.28	15.59
60	13.99	14.21
70	11.86	12.12
80	9.90	10.74
90	8.12	8.51
95	6.76	8.01

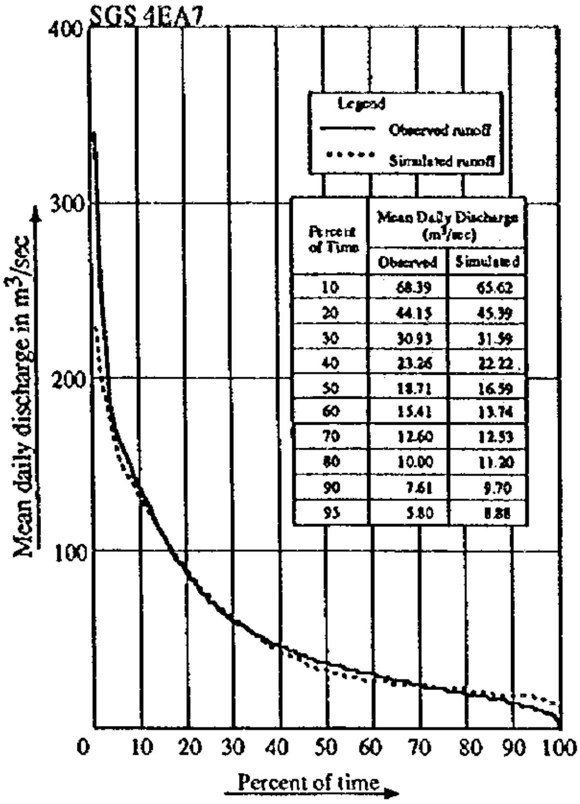


Percent of Time	Mean Daily Discharge (m^3/sec)	
	Observed	Simulated
10	19.53	21.78
20	10.33	12.08
30	7.21	7.59
40	5.63	5.51
50	4.89	4.42
60	4.03	3.68
70	3.23	3.29
80	2.93	3.03
90	2.10	2.58
95	1.37	1.88

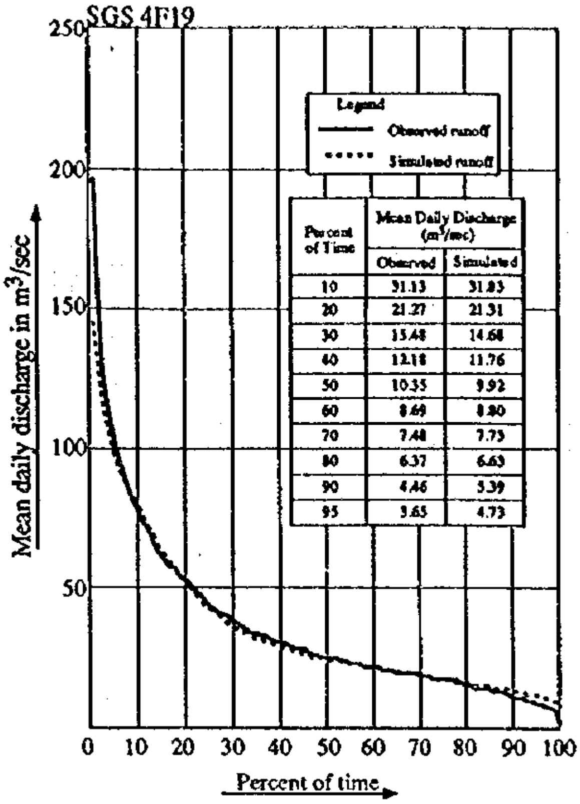


Percent of Time	Mean Daily Discharge (m^3/sec)	
	Observed	Simulated
10	16.64	18.40
20	8.73	10.65
30	5.96	6.56
40	4.63	4.47
50	3.74	3.29
60	3.11	2.59
70	2.53	2.16
80	1.98	1.78
90	1.33	1.44
95	0.89	1.22

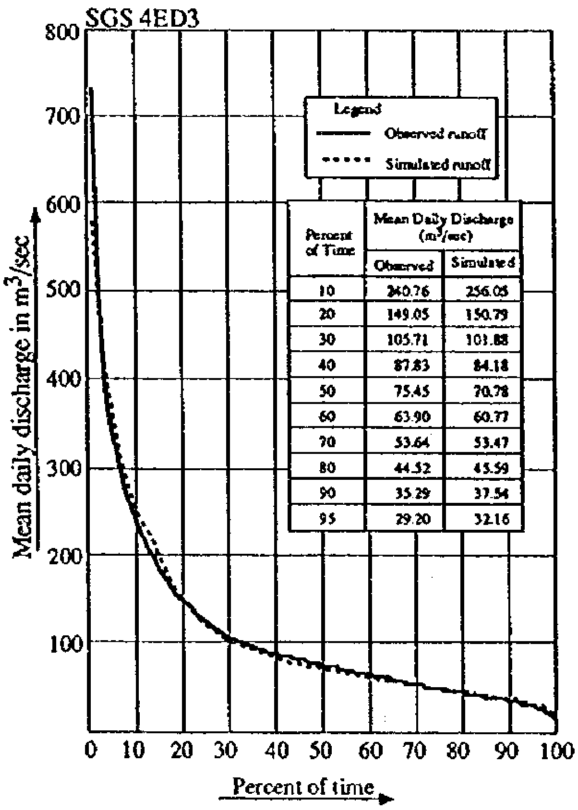
JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Flow Duration Curves Worked out Based on Mean Daily Discharges Observed and Simulated	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.22 (1)



Percent of Time	Mean Daily Discharge (m^3/sec)	
	Observed	Simulated
10	68.39	65.62
20	44.15	45.39
30	30.93	31.59
40	23.26	22.22
50	18.71	16.59
60	15.41	13.74
70	12.60	12.53
80	10.00	11.20
90	7.61	9.70
95	5.80	8.88

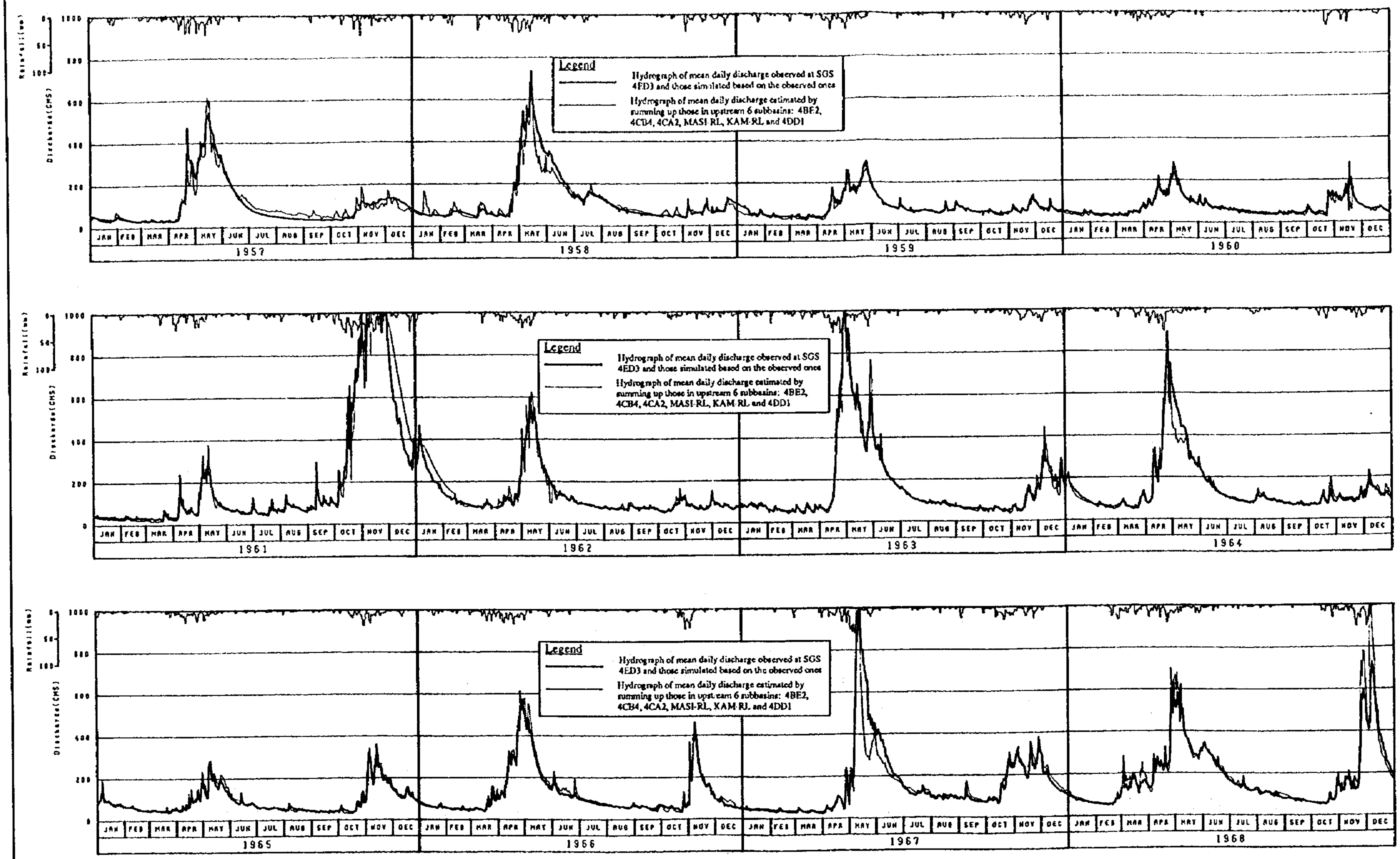


Percent of Time	Mean Daily Discharge (m^3/sec)	
	Observed	Simulated
10	31.13	31.83
20	21.27	21.31
30	15.48	14.68
40	12.18	11.76
50	10.35	9.92
60	8.69	8.80
70	7.48	7.73
80	6.37	6.63
90	4.46	5.39
95	3.65	4.73

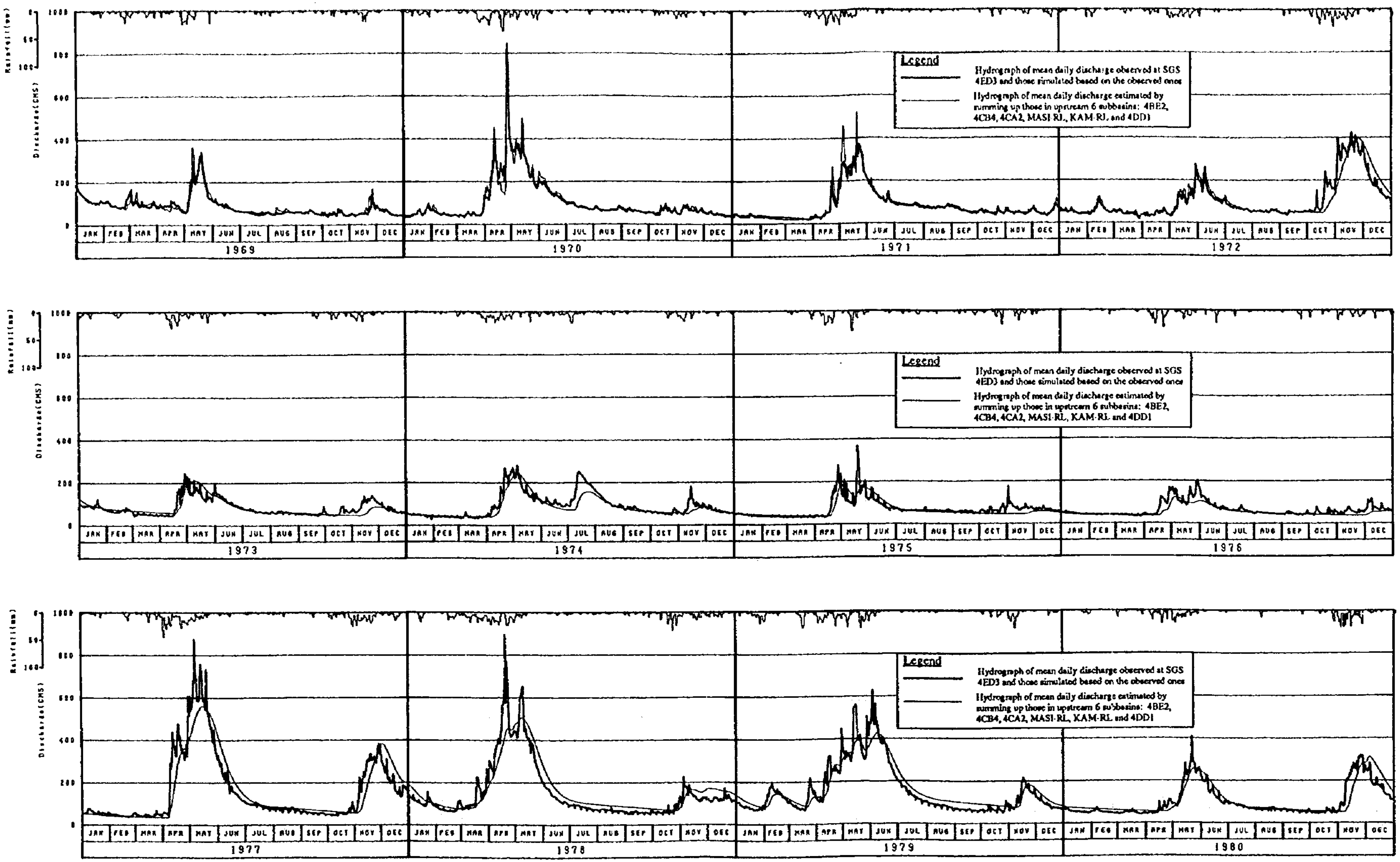


Percent of Time	Mean Daily Discharge (m^3/sec)	
	Observed	Simulated
10	240.76	256.05
20	149.05	150.79
30	105.71	103.88
40	87.83	84.18
50	75.45	70.78
60	63.90	60.77
70	53.64	53.47
80	44.52	45.59
90	35.29	37.54
95	29.20	32.16

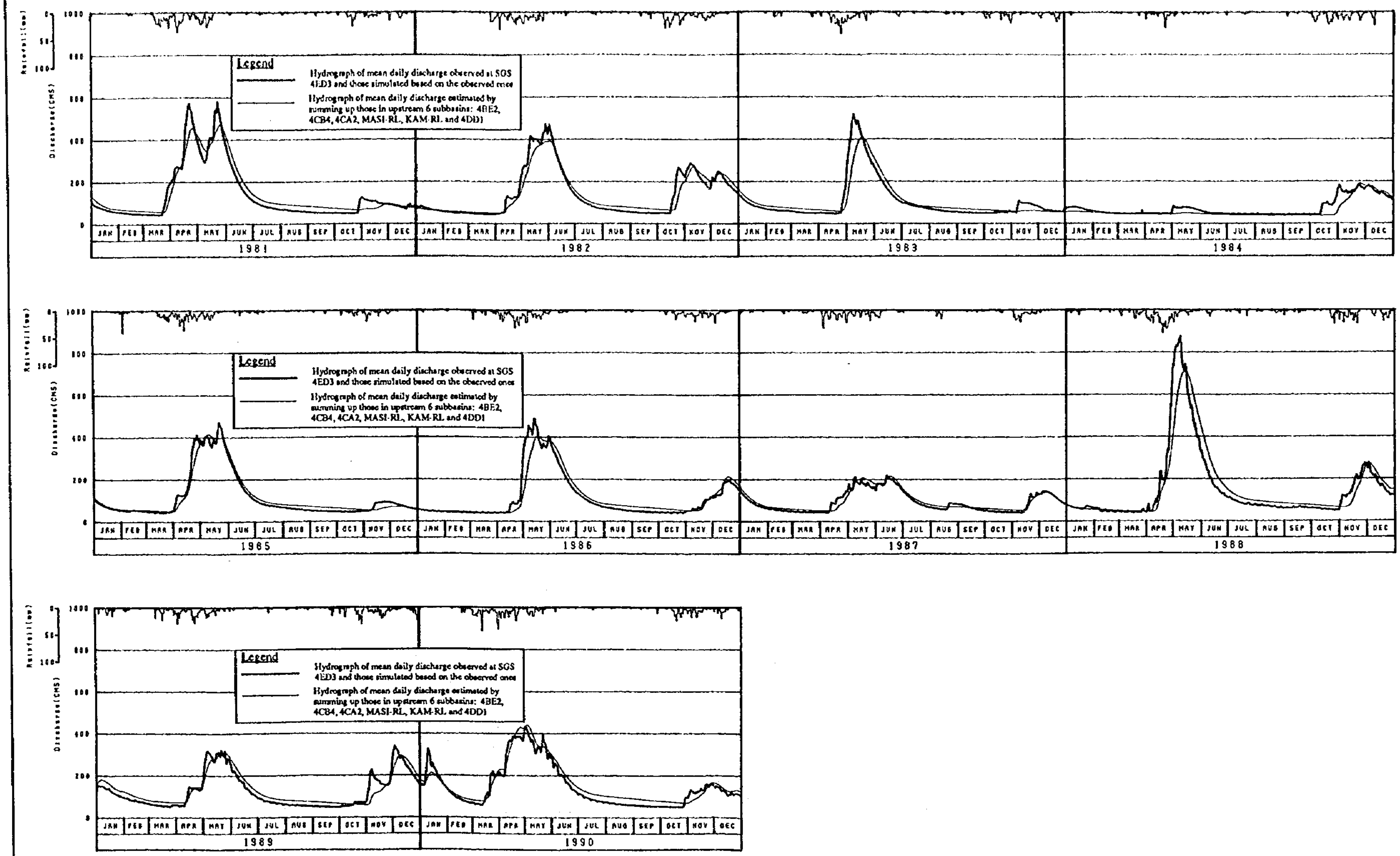
JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Flow Duration Curves Worked out Based on Mean Daily Discharges Observed and Simulated	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.22 (2)



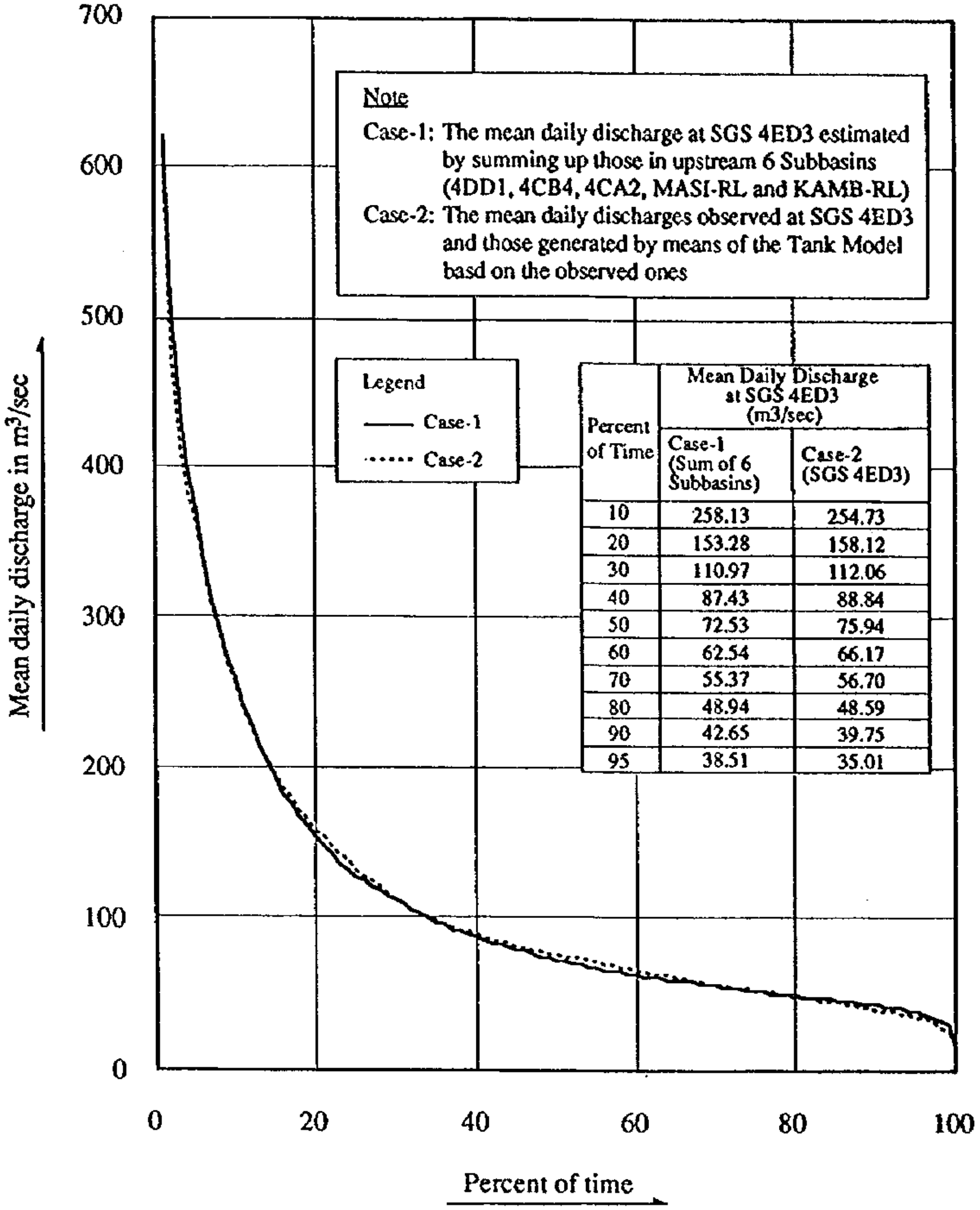
JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Hydrographs of Mean Daily Discharges at SGS 4ED3, Worked out by Means of Different Methods	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.23 (1)



JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Hydrographs of Mean Daily Discharges at SGS 4ED3, Worked out by Means of Different Methods	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.23 (2)

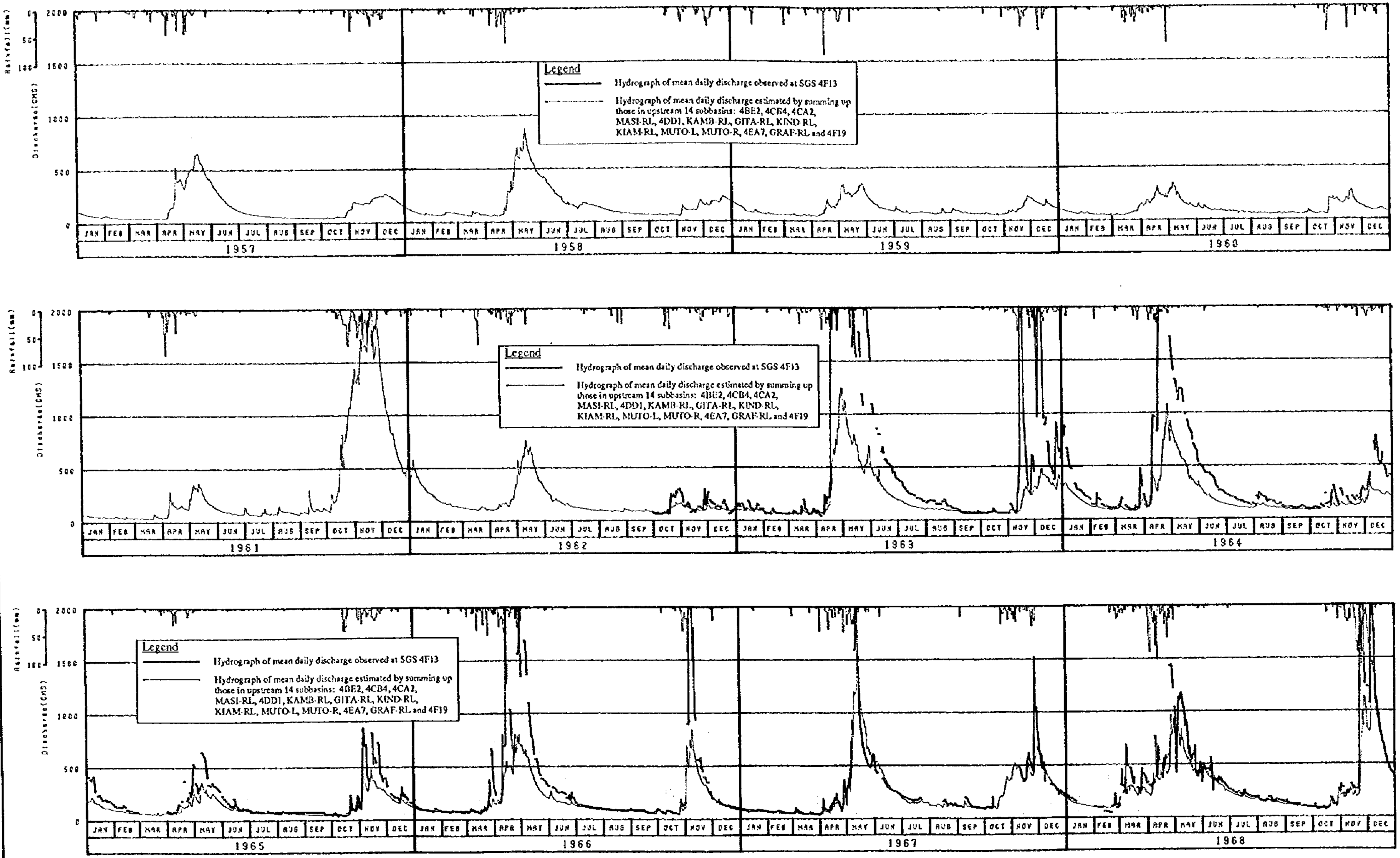


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Comparison of Hydrographs of Mean Daily Discharges at SGS 4ED3, Worked out by Means of Different Methods	Fig. No. B3.23 (3)

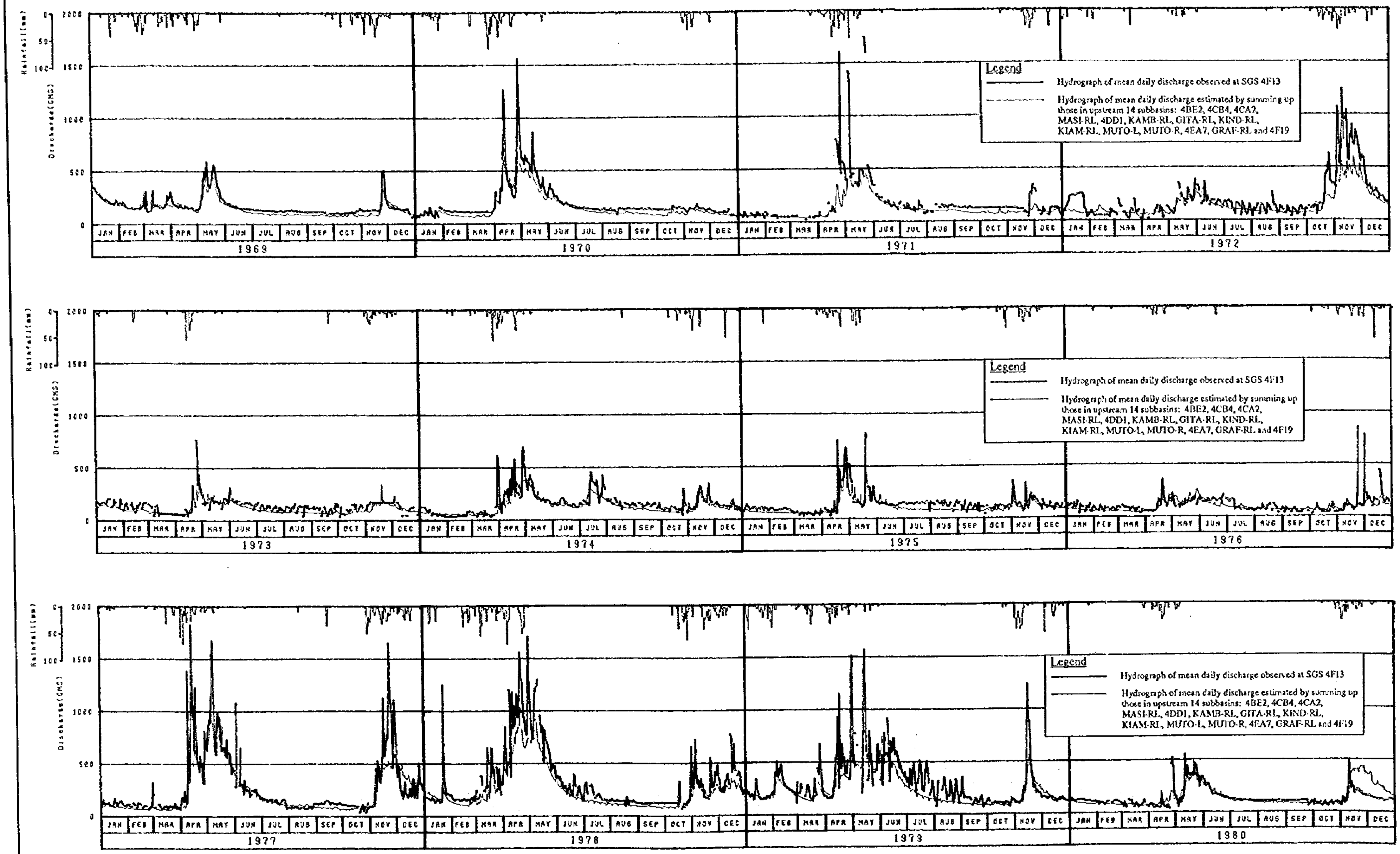


Percent of Time	Mean Daily Discharge at SGS 4ED3 (m3/sec)	
	Case-1 (Sum of 6 Subbasins)	Case-2 (SGS 4ED3)
10	258.13	254.73
20	153.28	158.12
30	110.97	112.06
40	87.43	88.84
50	72.53	75.94
60	62.54	66.17
70	55.37	56.70
80	48.94	48.59
90	42.65	39.75
95	38.51	35.01

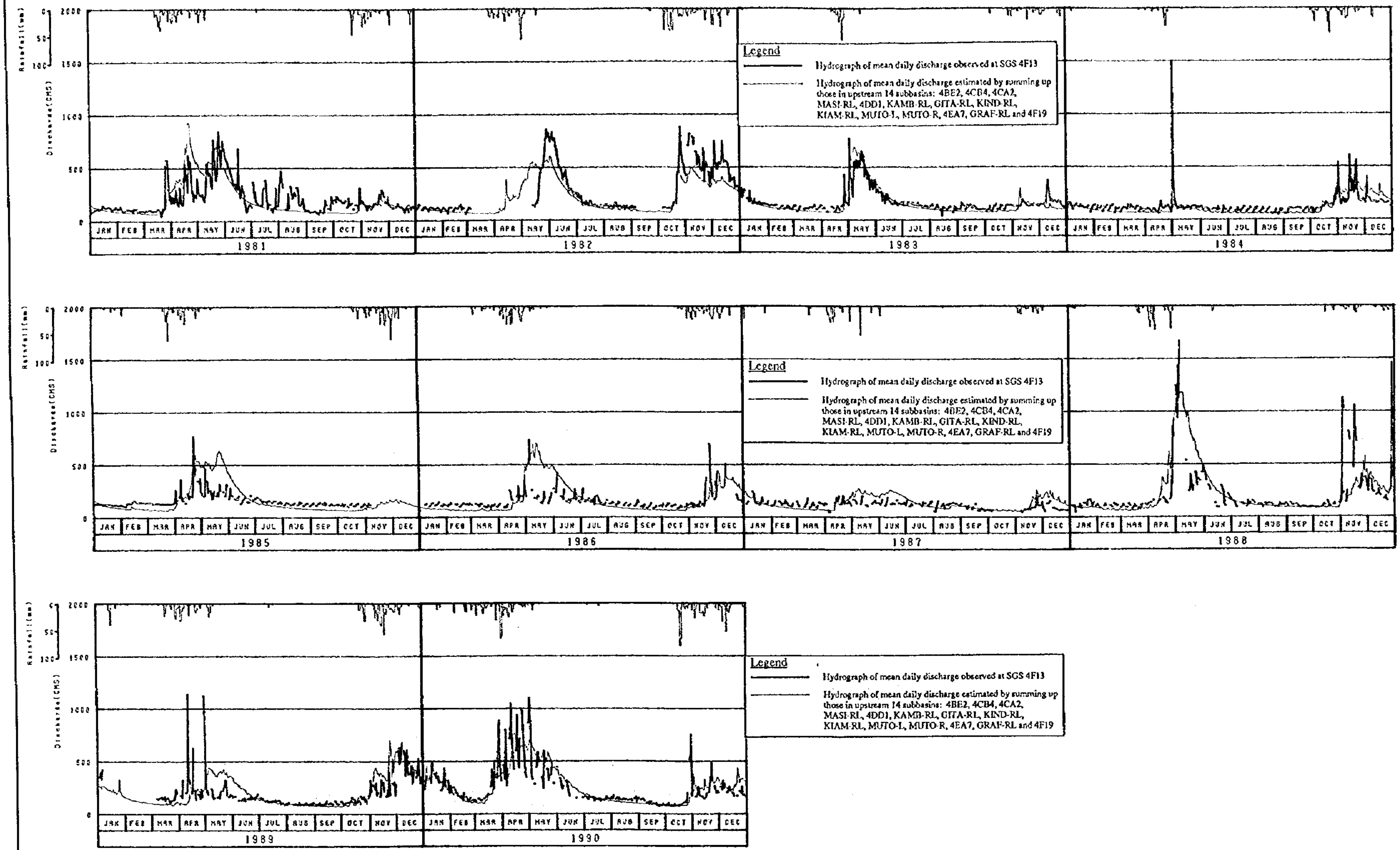
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Comparison of Flow Duration Curves of Mean Daily Discharges at SGS 4ED3, Worked out by Means of Different Two Methods	Fig. No. B3.24



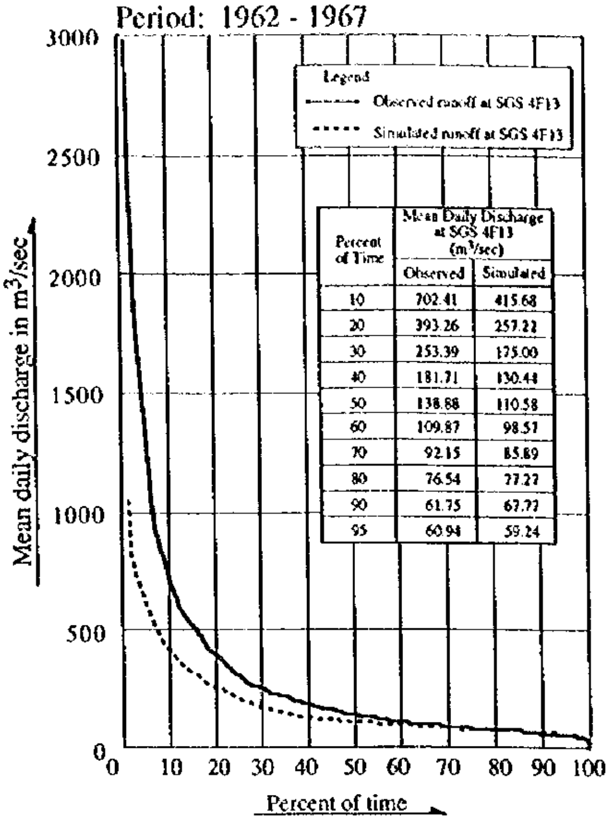
JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Flow Duration Curves at SGS 4F13, Worked out Based on Mean Daily Discharges Observed and Estimated by Summing up Those in Upstream 14 Subbasins	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.25 (1)



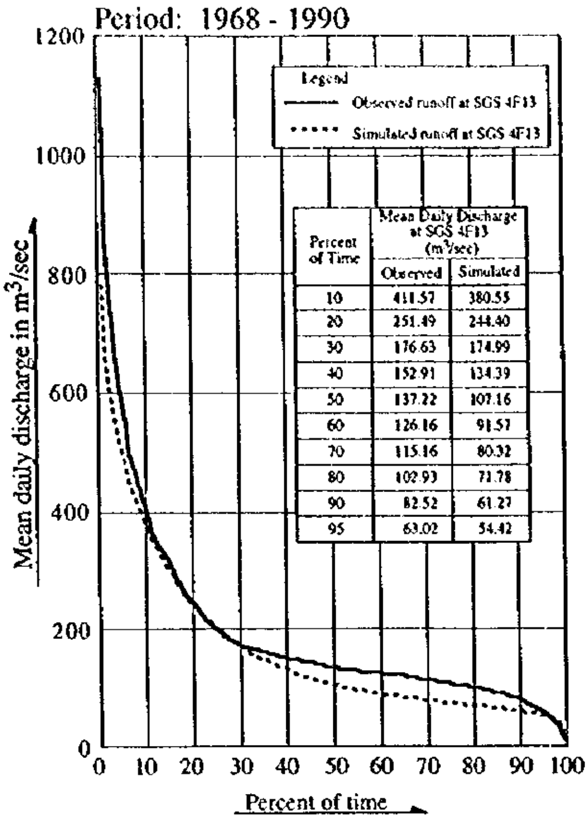
JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Flow Duration Curves at SGS 4F13, Worked out Based on Mean Daily Discharges Observed and Estimated by Summing up Those in Upstream 14 Subbasins	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.25 (2)



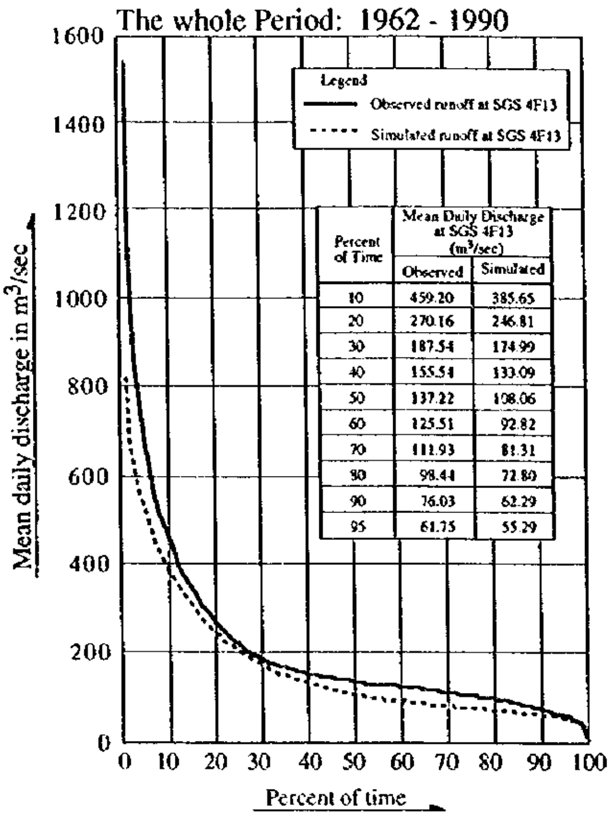
JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Flow Duration Curves at SGS 4F13, Worked out Based on Mean Daily Discharges Observed and Estimated by Summing up Those in Upstream 14 Subbasins	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B3.25 (3)



Percent of Time	Mean Daily Discharge at SGS 4F13 (m^3/sec)	
	Observed	Simulated
10	702.41	415.68
20	393.26	257.22
30	253.39	175.00
40	181.71	130.44
50	138.88	110.58
60	109.87	98.57
70	92.15	85.89
80	76.54	77.27
90	61.75	67.77
95	60.94	59.24



Percent of Time	Mean Daily Discharge at SGS 4F13 (m^3/sec)	
	Observed	Simulated
10	411.57	380.55
20	251.49	244.40
30	176.63	174.99
40	152.91	134.39
50	137.22	107.16
60	126.16	91.57
70	115.16	80.32
80	102.93	71.78
90	82.52	61.27
95	63.02	54.42



Percent of Time	Mean Daily Discharge at SGS 4F13 (m^3/sec)	
	Observed	Simulated
10	459.20	385.65
20	270.16	246.81
30	187.54	174.99
40	155.54	133.09
50	137.22	108.06
60	125.51	92.82
70	111.93	81.31
80	98.44	72.80
90	76.03	62.29
95	61.75	55.29

Note
The "Simulated" and "Simulated runoff" are the mean daily discharges derived by summing up those in the upstream 14 subbasins, which were estimated by means of the Tank Model Method.

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Comparison of Flow Duration Curves at SGS 4F13, Worked out Based on Mean Daily Discharges Observed and Estimated by Summing up those in Upstream 14 Subbasins	Fig. No. B3.26

B4 FLOOD ANALYSIS

B4.1 Major Flood Records in the Project Catchment

In the upper and middle Tana basins, the large-scale floods during the separate two wet seasons, namely between March and May and between November and December, when it is strongly affected by the Indian monsoon. The major flood records in the project catchment are explained in the following Subsections.

B4.1.1 Flood Records at SGS 4F13 on the Tana Mainstream

As discussed in the foregoing Chapter B3, the existing stage-discharge rating curves at SGS 4F13 overestimate daily runoff in the high stage heights. Concerning the stage height records before the year 1968, which were read on sloped staff gauges, it is too hard to relate them to the datum of the present ground elevation, since no data on the sloped staff gauges installed for reading high stages are available. Accordingly, it would not be possible to incorporate in the present flood analysis the flood records at SGS 4F13, which took place before 1968. While, the streamflow thereat after 1968 has been affected by reservoir operation of upstream dams since 1968 in which the Gitaru and Kindaruma dams were completed as the initial large-scale hydropower development on the Tana mainstream. Thus, the floods observed at SGS 4F13 after 1968 are not natural one, being peak-cut through regulation effect of the upstream reservoirs.

The rainfall records reveal that the severe rainfall continued over the project catchment between early October and end of November 1961. According to the data and information obtained from MOWD, on the other hand, the highest stage height was observed in November 1961, when the flood water level roses to about EL. 460.3. Although the stream gauging station 4F13 was not in operation at the time of occurrence of the flood, the flood mark was recorded as shown in Figure B4.1.

The extent of the 1961 flood was examined based on the topographic data made available through the present topographic survey. Figure B4.2 shows a river bed profile in the reach adjacent to SGS 4F13, which was worked out through the present topographic survey. On the basis of the river bed profile, the mean gradient of river bed is derived to be about 1/1,000. The SGS 4F13 is located about 1,800 m downstream of the large fall called the Grand Falls. Judging from the river profile, the hydraulic jumps take place at the place just downstream of the fall, causing the subcritical flow in the downstream reach thereof.

The river cross section at SGS 4F13 was surveyed in the present topographic survey, which was conducted in 1995. Figure B4.1 shows the river cross section at in 1995 as well as that surveyed by MOWD in 1963. There seems to no significant change in the both river cross sections at SGS 4F13.

Assuming the roughness of coefficient at 0.045, the peak discharge of the 1961 flood is estimated approximately at 3,400 m^3/sec.

B4.1.2 Flood Records at SGS 4ED3 on the Tana Mainstream

Table B4.1 shows the annual maximum peak discharges at SGS 4ED3 located on the main stem of the Tana river, occupying a catchment area of 9,520 km^2. The annual maximum peak discharges are in a range of 177 to 1,633 m^3/sec. The historical maximum peak discharge of 1,633 m^3/sec was recorded on 20 November, 1961. This flood took place in the same period as that of the aforesaid maximum stage height at SGS 4F13. Thus, the 1961 flood is considered to be the largest flood in the project catchment among the recorded floods.

The hydrographs of major floods recorded at SGS 4ED3 are illustrated in Figure B4.3 together with their basin average daily rainfalls. As seen in the Figure, the 1961 flood is regarded as the outstandingly large-scale one not only in peak discharge, but also in volume.

B4.1.3 Flood Records at SGS 4EA7 on the Mutonga River and SGS 4F19 on the Kazita River

The annual maximum discharges at SGS 4EA7 on the Mutonga river and SGS 4F19 on the Kazita river are listed in Table B4.1. The historical maximum discharge at SGS 4F19 was observed to be 156 m^3/sec on 17 November, 1973, while that at SGS 4EA7 to be 414 m^3/sec on 17 November, 1989. However, the flood records at these stream gauging stations data which correspond to the aforesaid 1961 flood are not available since these stream gauging station were installed after then.

B4.2 Frequency Analysis for Recorded Maximum Discharge

The flood records at SGS 4F13, the Grand Falls dam site, are not usable for determining the design floods for the main dam and it's diversion facilities as aforesaid. As a first step of the flood analysis, the probability of flood at the dam site was examined based on the results of the frequency analysis at other stream gauging stations located within the project catchment. In consideration of the catchment area of 17,234 km^2 at the Grand Falls dam site as well as the runoff characteristics, the stream gauging station 4ED3 was considered to be the most suitable one whose annual maximum discharges were applied to size the probable floods at the Grand Falls dam site.

To examine the extent of the probable floods of various return periods at the proposed Grand Falls dam site, the frequency analysis was carried out applying the following three methods to the annual maximum discharges at each of SGS 4F13, 4EA7 and 4F19:

i) Gumbel
ii) Log Pearson's Type III
iii) Iwai

The results of the frequency analysis for the annual maximum discharges are shown in Table B4.2. As a result of the frequency analysis, the 50-year and 10,000-year probable floods at SGS 4ED3 with a catchment area of 9,520 km2 are estimated to be 2,150 and 6,650 m^3/sec, respectively.

The estimated probable floods at 4ED3 are transferred to the proposed Mutonga and Grand Falls dam sites with the following Creager's equation:

$$Qp = 46 \times C \times A^{\alpha}$$
$$\alpha = 0.894 \times A^{-0.048} - 1$$

where,
C : Creager's coefficient
A : Catchment area in $mile^2$
Qp : Specific discharge in $feet^3/sec/mile^2$

The probable floods of various return periods were calculated with the Creager's C values derived for the catchment of 4ED3 as summarized below:

Probable Floods at SGS 4F13 Estimated Based on Creager's C Values for SGS 4ED3

Return Period (in years)	SGS 4ED3 (C.A.=9,520 km2)		SGS 4F13 ($C.A.=17,234 km^2$)
	Probable Flood (m^3/sec)	Creager's C Value	Probable Flood (m^3/sec)
1.01	150	0.46	180
2	607	1.85	740
5	1,038	3.16	1,220
20	1,629	4.96	1,980
50	2,144	6.53	2,610
100	2,578	7.85	3,130
200	3,052	9.29	3,710
500	3,748	11.41	4,560
1,000	4,331	13.18	5,260
10,000	6,654	20.26	8,080

B4.3 Construction of Storage Function Model

B4.3.1 Basic Concept of Storage Function Model

(1) Basin runoff model

Flood runoff from subbasin is estimated by means of storage function method. The storage function is expressed by the following equations:

$$S = KQ^{P}$$
$$ds/dt = (1/3.6) \cdot f \cdot r \cdot A - Q$$

where,
- S : basin storage (m^3)
- Q : runoff from subbasin (m^3/sec)
- K, P : constant
- t : time (sec)
- f : runoff coefficient
- r : basin mean rainfall (mm/hr)
- A : catchment area (km^2)

Constants of K and P in storage function are initially estimated by means of the following empirical formula:

$$K = 118.84 \cdot i^{0.3}$$
$$P = 0.175 \cdot i^{-0.235}$$

where, i : average river bed slope

Finally, flood runoff from subbasin is adjusted taking lag time into consideration. The lag time is roughly estimated by empirical formula developed by Kraven. The Kraven's formula is expressed as follows:

$$Tl = L/V$$

where,
- Tl : lag time in subbasin (hr)
- L : river length (km)
- V : flow velocity (m/sec)
  - V = 3.5 m/sec $i > 1/100$
  - V = 3.0 m/sec $1/200 < i < 1/100$
  - V = 2.1 m/sec $i < 1/200$
- i : average river bed slope

(2) River channel model

In case that the river bed slope is rather gentle or the water level is affected by the backwater due to the relatively higher water level in the mainstream, the flood runoff generally retards through river channel.

The storage function of river channel is estimated by the river cross section, river bed gradient and river length through the non-uniform/uniform flow calculation.

The flood runoff through a river channel is estimated by the following equations:

$$S = KO^{P}$$
$$ds/dt = I - O$$

where,
S : storage volume in river channel (m^3)
K, P : constants
O : outflow from river channel (m^3/sec)
I : inflow to river channel (m^3/sec)

The lag time in river channel is estimated by the preceding empirical formula.

B4.3.2 Determination of Parameters of Storage Function Model

The trial calculations were made to find out the parameters of the storage function model for the project catchment based on the recorded flood hydrographs as well as the daily rainfall data. The simulation model for the project catchment was made as shown in Figure B4.4, for which the parameters were attempted to be worked out through the trial calculations in order that the simulated floods hydrograph come to similar to the observed one with respect to its shape and peak discharge.

For the trial calculation to determine the parameters, the 1967 flood was selected since the flood records were available not only at SGS 4ED3, but also at SGS 4EA7 and 4F19. Taking into account that the flood records were obtained by means of the staff gauge reading once or twice a day, on the other hand, the actual peak discharge would be larger than the observed one. Hence, the parameters were so determined that the simulated peak discharge came to slightly larger than the observed one. Besides, the parameters derived based on the 1967 flood were applied to the rainfall records corresponding to the 1961 flood, which was considered to be the historically largest flood among the recorded ones, in order to check whether or not the peak discharges of simulated flood hydrographs at SGS 4F13 and 4ED3 are agreeable to those of the observed ones.

As a result of a number of trial calculations, the parameters for the major basins were determined as shown in Table B4.3, in case which the simulated flood hydrographs slightly exceed the observed ones at each of the stream gauging stations SGS 4ED3, 4EA7 and 4F19 concerning the 1967 flood. The flood hydrographs at the proposed

Mutonga and Grand Falls dam site were simulated by means of the storage function model using these parameters.

B4.4 Estimate of Design Rainfalls to be Applied to Storage Function Model

B4.4.1 Probable Basin Average Rainfalls for Different Durations

The rainfall analysis was made on a daily data basis to determine the design rainfalls to be applied to the Storage Function Model in order to estimate the probable floods at the proposed Mutonga and Grand Falls dam sites.

Based on the long-term basin average daily rainfalls for the project catchment which were derived by means of the Thiessen's Polygons, the annual maximum rainfalls were estimated for various consecutive days. The durations of rainfall were examined for the range from 1-day to 70-days. The daily rainfall data for a total of 34 years from 1957 to 1990 were used to estimate the basin average rainfalls.

The annual maximum basin average rainfalls for those different durations were derived as shown in Table B4.4 and Figure B4.5. The Table exhibits that the amount of rainfall in 1961, which caused a large-scale flood over the project catchment, is elimenently large as compared with those in other years.

The frequency analysis was carried out to estimate the probable rainfalls for each of the different durations applying the aforesaid three methods. Of the three methods, as a result, the Log Pearson's Type III gave the largest probable value with respect to every duration. Taking into consideration the safer side design of the planned dams, the probable rainfalls calculated by the Log Pearson's Type III were adopted to determine the design rainfalls. The probable basin rainfalls for the different durations are summarized in Table B4.5.

B4.4.2 Daily Rainfall Pattern of Major Rainstorms

Since no hourly rainfall data related to the project catchment were obtained during the field investigation period, the pattern of the design rainfall was made on a daily basis.

For the purpose of determining the rainfall pattern, the major rain storms which significantly contributed to the past large-scale floods in the project catchment were examined carefully. The recorded flood hydrographs and the corresponding daily rainfalls at SGS 4ED3 are illustrated in Figure B4.3, while the stage heights of major floods at SGS 4F13 as well as the corresponding daily rainfalls are in Figure B4.6. From the meteo-hydrological records, the following tendency on the rainfall pattern concerned with the past large-scale floods were detected:

i) There is a possibility that the large-scale flood is to take place in either of the separate two wet seasons,

ii) The heavy rainfall of more than 100 mm/day seldom takes place in the project catchment. Usually, the base flow of floods is gradually increased by the long-lasting rainfalls.

iii) The duration of rainfall contributing to occurrence of large-scale of flood is 30 to 50 days, but the peak of floods is dominated by the rainfall amount for the last 10 day with the highest rainfall intensity.

From the above, a duration of the design rainfall is determined to be 60 days taking into account some allowance. The daily rainfall pattern for each of the probable basin average rainfalls were set up in accordance with the following procedures concerning each of the return periods:

i) To set up the pattern for the 60-days rainfall at an interval of 10 days, the differences between the probable rainfalls at an interval of 10-days were calculated for each of the return periods as shown in Table B4.5. In succession, the 10-day probable rainfall as well as the five differences were arranged so that the 10-day rainfall with the highest intensity was set in the fifth 10 days with reference to the usual rainfall patterns in the project catchment. while, the difference between the 50-day and 60-day, which has the lowest intensity, was allocated to take the last or sixth 10-day. The other four differences, namely the difference between 10-day and 20-day probable rainfalls to that between 40-day and 50-day probable rainfalls, were arranged to take the portion of the fourth 10-day to first 10-day. Consequently, the pattern of the design rainfalls for the various return periods were set up as shown in Figure B4.8.

ii) The daily rainfall pattern for the designing rainfalls at an interval of 10 days were worked out based on the daily rainfall pattern on the rain storm observed between 2 October and 30 November 1961.

B4.4.3 Areal Distribution of Rainfall Amount

The areal distribution of the design rainfalls over the project catchment were examined dividing the project catchment into the four areas, namely catchments covered by SGS 4ED3, 4EA7, 4F19 and the remaining area. The ratios of rainfall amount in each of these areas to the basin average rainfall in the project catchment for the major rain storms were obtained as shown in Table B4.6. Through the examination, the ratios were determined as summarized in the average following table:

Average Ratios of areal rainfall to basin average rainfall in the project catchment

No.	Subbasin or SGS	Catchment Area (km^2)	Ratios of Areal Rainfall	
			10-day Rainfall	60-day Rainfall
1	SGS 4ED3	9,520	1.0	1.0
2	Subbasin 4EA7	1,880	1.3	1.3
3	Subbasin 4F19	1,673	1.1	1.3
4	Remaining area	4,161	0.8	0.7

From the above, the ratios of areal rainfall to the basin average rainfall in the project catchment were determined to be 1.3 for the catchments of 4EA7 and 4F19, 1.0 for the catchment located upstream of SGS 4ED3. Concerning the remaining area which mostly comprises the drier area with lesser rainfall intensity, the ratio was adopted to be 0.7.

B4.5 Estimate of Probable Floods at the Mutonga and Grand Falls Dam Sites

The flood hydrographs at the proposed Mutonga and Grand Falls dam sites were simulated applying the storage function models with the parameters to the aforesaid design rainfalls. The simulation was carried out in the following two cases:

Case-1 : Simulation on the condition with Masinga and Kiambere reservoirs, in which the regulation effect of the both reservoirs are considered.

Case-2 : Simulation on the condition without Masinga and Kiambere reservoirs, in which the regulation effect of the both reservoirs are neglected.

In the Case-1 above, the initial water level of the Masinga and Kiambere reservoirs were assumed to be at the full supply level.

The flood hydrographs at SGS 4ED3 and the proposed Mutonga and Grand Falls dam sites, which were constructed by means of the storage function models applying the aforesaid procedures, are shown in Figures B4.9 and B4.10. The peak discharges of floods at the proposed Mutonga and Grand Falls dam sites were estimated for various return periods in each of the two cases above as shown in Table B4.7 and summarized below:

Estimated Probable Floods for Mutonga and Grand Falls Dams by Means of the Storage Function Model

(Unit: m^3/sec)

Return Period (in years)	Case-1: Without Masinga and Kiambere Reservoir		Case-2: With Masinga and Kiambere Reservoirs	
	Mutonga Dam	Grand Falls Dam	Mutonga Dam	Grand Falls Dam
50	2,400	2,800	1,600	2,000
200	4,000	4,500	2,600	3,100
10,000	10,900	12,800	8,900	10,800

On the other hand, the 50-year, 200-year and 10,000-year probable floods at the Grand Falls dam site were estimated to be 2,600, 3,700 and 8,100 m3/sec by means of transposing the probable floods at SGS 4ED3 to the Grand Falls dam site with the Creager's C value as discussed in the foregoing Section B4.2.

The annual maximum discharges at SGS, which were applied to the frequency analysis, were measured before completion of the Masinga reservoir. Hence, it is meaningful that the probable floods transposed from those at SGS 4ED3 be compared with those estimated by means of the storage function model on the condition without the upstream dams. As a result of the comparison, it is judged that the 50-year and 200-year probable floods estimated by the both methods are comparable. Besides, the 10,000-year probable flood estimated by the storage function model has a sufficient allowance in comparison with that transposed from SGS 4ED3.

Table B4.1 Annual Maximum Discharge in the Grand Falls Catchment

Year	4ED3 (CA=9,520 km2)		4EA7 (CA=1,880 km2)		4F19 (CA=1,673 km2)		4F13 (CA=17,234 km2)	
	Date	Maximum Discharge (m3/sec)	Date	Maximum Discharge (m3/sec)	Date	Maximum Discharge (m3/sec)	Date	Maximum Discharge[/1] (m3/sec)
1951	May 24	756	-	-	-	-	-	-
1952	May 14	376	-	-	-	-	-	-
1953	May 6	287	-	-	-	-	-	-
1954	May 21	437	-	-	-	-	-	-
1955	May 7	177	-	-	-	-	-	-
1956	Apr. 29	837	-	-	-	-	-	-
1957	May 15	615	-	-	-	-	-	-
1958	May 16	657	-	-	-	-	-	-
1959	May 27	263	-	-	-	-	-	-
1960	Nov. 18	286	-	-	-	-	-	-
1961	Nov. 20	1,633	-	-	-	-	-	-
1962	May 12	622	-	-	-	-	-	-
1963	Apr. 29	1,262	-	-	-	-	Nov. 15	4,677
1964	Apr. 25	872	-	-	-	-	Apr. 17	5,627
1965	Nov. 5	340	-	-	-	-	Nov. 5	870
1966	Apr. 30	578	Oct. 31	335	-	-	Nov. 7	3,981
1967	May 10	1,307	May 8	366	-	-	May 11	2,497
1968	Dec. 03	1,485	Dec. 04	470	Dec. 4	89	Dec. 03	3,969
1969	May 8	359	Nov. 24	97	Apr. 8	68	May 10	591
1970	Apr. 24	757	Apr. 27	134	Apr. 9	76	Apr. 25	1,558
1971	May 18	518	Apr. 20	95	Apr. 27	71	May 21	1,744
1972	Jun. 5	262	May 12	55	Nov. 6	109	Nov. 6	1,239
1973	-	-	Apr. 23	82	Nov. 17	156	Apr. 23	767
1974	-	-	Apr. 25	186	Mar. 28	89	Apr. 25	695
1975	-	-	Nov. 19	134	Apr. 18	135	May 16	815
1976	-	-	Nov. 8	76	Dec. 15	51	Nov. 20	849
1977	-	-	Apr. 9	123	Dec. 22	73	Apr. 11	1,826
1978	-	-	Apr. 10	208	Mar. 11	154	Apr. 26	1,706
1979	-	-	Apr. 25	359	May 9	142	May 10	1,574
1980	-	-	Nov. 5	135	Nov. 5	51	May 6	553
1981	-	-	Apr. 18	263	Mar. 23	96	May 21	843
1982	-	-	Apr. 8	196	Nov. 2	65	Oct. 21	884
1983	-	-	Apr. 27	261	Apr. 21	55	Apr. 27	771
1984	-	-	(Nov. 8)	76	Nov. 27	156	Apr. 25	1,490
1985	-	-	Apr. 16	206	Nov. 2	87	Apr. 17	771
1986	-	-	Dec. 5	250	Dec. 5	108	Apr. 29	736
1987	-	-	Nov. 30	82	Nov. 17	92	Jan. 5	735
1988	-	-	Apr. 27	261	Apr. 27	143	Apr. 29	1,668
1989	-	-	Nov. 17	414	Nov. 27	71	Apr. 5	1,141
1990	-	-	Apr. 6	257	Nov. 20	77	Apr. 24	1,104

Note:

/1 : The maximum discharges at SGS 4F13 before 1968 are overestimated, while those after 1968 are affected by the regulation effect of the upstream reservoirs.

Table B4.2 Results of Flood Frequency Analysis for Annual Maximum Discharges

Return Period (in years)	4ED3 (CA=9,520 km2)			4EA7 (CA=1,880 km2)			4F19 (CA=1,673 km2)		
	Iwai's Method	Peason Type III Method	Gumbel's Method	Iwai's Method	Peason Type III Method	Gumbel's Method	Iwai's Method	Peason Type III Method	Gumbel's Method
1.01	150	130	-	39	42	-	38	40	31
1.5	430	420	430	133	133	139	77	77	77
2	560	550	610	173	173	188	90	90	91
5	960	940	1,040	288	290	306	122	122	127
10	1,280	1,250	1,320	374	379	385	142	145	151
20	1,630	1,580	1,600	464	473	460	161	166	174
30	1,850	1,790	1,750	520	531	504	172	179	187
40	2,010	1,940	1,870	560	573	534	180	188	196
50	2,150	2,060	1,950	592	607	558	186	195	203
80	2,430	2,330	2,130	662	681	608	198	210	218
100	2,580	2,470	2,220	696	717	631	204	217	225
200	3,050	2,910	2,480	807	836	704	222	240	247
500	3,750	3,550	2,830	964	1,005	800	246	271	276
1000	4,330	4,100	3,100	1,093	1,144	873	264	295	298
10000	6,650	6,230	3,970	1,583	1,681	1,114	326	382	371

Table B4.3 Parameters of Storage Function for Each Subbasin

Subbasin Name	Catchment Area (km2)	River Length (km)	River Gradient	Coeff. of Storage Function		F1	Rsa (mm)	Base Flow (m3/sec)	Lag Time (hr)
				K	P				
4CA2	518	70	1/70	34.795	0.458	0.35	800	4.2	5.6
4CB4	316	58	1/64	34.604	0.460	0.35	800	2.6	4.6
4BE2	3,672	118	1/139	31.507	0.495	0.35	900	32.0	10.9
MASI-RL	2,829	120	1/300	25.687	0.581	0.30	800	21.2	15.9
4DD1	1,961	96	1/38	42.838	0.389	0.35	900	16.1	7.6
KAMB-RL	224	30	1/100	40.335	0.408	0.30	900	1.8	2.8
GITA-RL	147	14	1/23	51.098	0.339	0.20	900	1.2	1.1
KIND-RL	140	23	1/46	43.276	0.386	0.20	2,000	1.1	1.8
KIAM-RL	2,168	74	1/57	37.458	0.432	0.20	2,000	17.4	5.9
MUTO-R	1,045	83	1/55	42.418	0.392	0.20	1,500	13.7	6.6
MUTO-L	465	45	1/29	43.276	0.386	0.20	1,500	6.1	3.2
4EA7	1,880	80	1/80	33.513	0.472	0.35	1,200	23.0	6.4
GRAF-RL	196	22	1/44	40.558	0.406	0.20	1,500	1.5	1.8
4F19	1,673	63	1/25	44.717	0.376	0.35	1,200	16.0	5.0

Table B4.4 Annual Maximum Rainfalls for Different Durations of Rainy Days

(Unit : mm)

Year	Duration								
	1-day	3-day	10-day	20-day	30-day	40-day	50-day	60-day	70-day
1957	38.8	63.4	141.2	255.9	360.6	447.8	492.8	527.4	562.7
1958	33.7	71.4	161.5	284.2	407.8	465.4	495.4	537.6	575.5
1959	27.8	71.1	136.6	216.6	285.7	324.9	384.7	404.2	425.5
1960	34.8	89.8	131.0	179.6	253.0	300.5	363.3	388.3	413.0
1961	42.7	106.9	289.6	523.8	749.5	960.3	1,132.8	1,181.4	1,207.7
1962	21.3	54.5	146.8	265.1	342.4	429.6	468.4	519.6	534.8
1963	34.8	86.6	216.2	379.0	460.5	538.2	610.0	651.7	685.3
1964	28.7	73.5	202.3	340.0	410.2	488.5	531.2	577.8	599.2
1965	31.2	77.3	155.1	235.2	321.6	389.3	413.5	443.7	462.0
1966	44.3	102.4	261.1	345.8	369.6	472.3	550.5	576.2	613.1
1967	38.4	105.0	295.1	431.9	511.8	584.8	634.6	688.5	714.6
1968	47.8	117.2	264.9	426.7	511.6	595.0	675.9	721.0	739.6
1969	25.4	67.7	145.4	196.4	240.8	275.3	307.0	345.7	389.3
1970	30.6	81.9	164.5	289.4	404.4	454.5	506.1	528.3	575.2
1971	30.6	76.0	151.7	266.6	350.5	426.0	482.1	531.1	540.6
1972	30.6	73.1	170.7	284.6	397.1	502.5	546.0	576.5	608.4
1973	24.9	61.4	146.6	209.4	247.0	269.2	309.8	318.3	329.4
1974	22.1	55.6	127.8	241.9	332.6	402.2	422.7	443.3	467.0
1975	34.8	74.4	178.7	237.9	289.0	348.5	398.3	425.1	443.7
1976	30.0	65.1	128.7	209.0	226.0	264.7	311.9	326.1	341.1
1977	43.3	85.5	231.4	319.8	443.5	534.9	598.4	647.0	687.6
1978	38.4	70.2	149.7	263.7	365.6	464.5	556.1	622.1	695.2
1979	43.0	85.4	199.1	239.9	303.3	392.8	438.4	523.8	563.8
1980	39.4	79.8	194.0	291.1	363.0	410.9	433.2	456.8	468.9
1981	29.6	72.8	173.9	287.3	440.3	498.4	576.0	706.4	759.1
1982	41.7	93.8	201.9	285.2	354.1	422.3	506.5	574.8	615.6
1983	43.5	75.9	202.8	297.1	361.0	396.5	418.2	434.2	453.3
1984	38.8	79.6	152.5	253.6	335.3	411.3	448.9	506.6	567.8
1985	39.5	65.9	172.4	254.2	356.0	441.9	511.5	598.8	625.6
1986	29.7	76.8	189.0	287.2	382.4	445.2	516.5	551.1	574.2
1987	33.3	67.1	129.4	198.1	269.9	306.1	348.3	410.6	456.8
1988	40.3	99.4	264.9	377.1	529.4	595.8	675.7	700.7	724.5
1989	35.5	74.5	189.3	249.6	359.7	488.2	547.6	568.2	639.9
1990	48.2	77.6	169.5	256.0	368.8	466.4	560.4	626.9	699.2

Table B4.5 Probable Rainfall for Different Durations in the Project Catchment

Return Period (in years)	Duration of Rainy Days													
	1-days Rainfall (mm)	10-days Rainfall (mm)	20-days Rainfall (mm)	(Difference between 10-days and 20-days Rainfall) (mm)	30-days Rainfall (mm)	(Difference between 20-days and 30-days Rainfall) (mm)	40-days Rainfall (mm)	(Difference between 30-days and 40-days Rainfall) (mm)	50-days Rainfall (mm)	(Difference between 40-days and 50-days Rainfall) (mm)	60-days Rainfall (mm)	(Difference between 50-days and 60-days Rainfall) (mm)	70-days Rainfall (mm)	(Difference between 60-days and 70-days Rainfall) (mm)
1.01	20.5	91.1	136.1	(45.0)	155.8	(19.7)	218.3	(62.5)	236.0	(17.7)	264.8	(28.8)	290.3	(25.5)
2	38.7	162.5	242.1	(79.6)	313.7	(71.6)	428.3	(114.6)	482.6	(54.3)	524.5	(41.9)	556.8	(32.3)
5	49.7	205.2	305.4	(100.2)	408.2	(102.8)	553.9	(145.7)	630.0	(76.1)	679.8	(49.8)	716.1	(36.3)
10	56.9	233.5	347.4	(113.9)	470.7	(123.3)	637.0	(166.3)	727.6	(90.6)	782.6	(55.0)	821.6	(39.0)
20	63.8	260.6	387.6	(127.0)	530.7	(143.1)	716.7	(186.0)	821.3	(104.6)	881.2	(59.9)	922.8	(41.6)
30	67.8	276.2	410.7	(134.5)	565.2	(154.5)	762.6	(197.4)	875.1	(112.5)	937.9	(62.8)	981.0	(43.1)
40	70.6	287.2	427.0	(139.8)	608.3	(181.3)	794.9	(186.6)	913.1	(118.2)	977.9	(64.8)	1022.1	(44.2)
50	72.7	295.7	466.1	(170.4)	647.8	(181.7)	820.0	(172.2)	942.5	(122.5)	1008.8	(66.3)	1053.8	(45.0)
100	79.4	322.0	478.7	(156.7)	666.5	(187.8)	897.3	(230.8)	1033.3	(136.0)	1104.5	(71.2)	1151.9	(47.4)
200	86.1	348.2	517.5	(169.3)	724.5	(207.0)	974.3	(249.8)	1123.8	(149.5)	1199.8	(76.0)	1249.7	(49.9)
500	94.9	382.8	568.8	(186.0)	800.9	(232.1)	1076.0	(275.1)	1243.2	(167.2)	1325.5	(82.3)	1378.7	(53.2)
1000	101.6	408.9	607.6	(198.7)	858.7	(251.1)	1152.8	(294.1)	1333.4	(180.6)	1420.5	(87.1)	1476.2	(55.7)
10000	123.7	495.7	736.3	(240.6)	1050.6	(314.3)	1407.9	(357.3)	1632.9	(225.0)	1736.0	(103.1)	1799.9	(63.9)

Table B4.6 (1/2) Ratio of Rainfall in Subbasin to that in Project Catchment

No. of Day	Flood - 1 Nov. 1961 Flood (Oct. 4 - Dec. 2)					Flood - 2 Nov. 1963 Flood (Sep. 28 - Nov. 26)					Flood - 3 Apr. 1964 Flood (Mar 1 - Apr. 29)					Flood - 4 Nov. 1966 Flood (Sep. 21 - Nov. 19)				
	4F13	4FD3	4F19	4FA7	Rem. Area	4F13	4FD3	4F19	4FA7	Rem. Area	4F13	4FD3	4F19	4FA7	Rem. Area	4F13	4FD3	4F19	4FA7	Rem. Area
1	10.5	15.0	15.7	5.2	0.3	0.0	0.0	0.0	0.0	0.0	4.5	6.6	2.9	1.3	0.9	0.3	0.5	0.0	0.2	0.0
2	16.8	20.0	28.1	19.0	3.0	0.0	0.0	0.0	0.0	0.0	15.0	16.9	28.5	13.4	4.2	0.1	0.1	0.0	0.0	0.0
3	5.9	6.5	11.9	10.2	0.0	0.0	0.0	0.1	0.0	0.0	13.7	14.1	13.3	28.6	5.1	0.0	0.1	0.0	0.0	0.0
4	0.1	0.1	0.0	0.0	0.0	0.2	0.3	0.0	0.2	0.0	5.2	4.2	5.1	12.5	3.0	0.7	1.2	0.0	0.0	0.0
5	0.7	1.0	0.0	0.8	0.0	0.3	0.4	0.0	0.4	0.0	3.8	2.9	2.1	7.0	7.5	1.7	3.0	0.0	0.0	0.0
6	1.5	1.7	2.3	2.7	0.0	0.4	0.7	0.0	0.0	0.0	0.4	0.3	0.4	1.8	0.0	1.0	1.3	1.6	1.2	0.0
7	12.2	12.8	28.5	19.2	0.5	0.1	0.2	0.0	0.0	0.0	0.5	0.4	0.7	1.6	0.0	2.5	3.6	1.8	2.5	0.0
8	12.3	13.1	30.8	17.4	0.1	0.9	1.0	0.0	0.5	0.0	0.7	1.2	0.1	0.1	0.0	3.8	4.4	4.1	5.2	1.6
9	9.7	11.7	11.1	18.2	0.3	6.4	6.0	0.8	7.7	4.7	0.3	0.6	0.0	0.1	0.0	0.8	1.3	0.1	0.0	0.1
10	18.2	22.3	21.8	19.0	4.8	5.6	5.3	4.3	10.6	3.2	1.2	2.1	0.1	0.6	0.0	0.2	0.4	0.0	0.0	0.0
11	25.7	28.0	37.5	51.0	1.3	1.0	0.5	1.2	2.5	0.6	0.1	0.2	0.2	0.0	0.0	0.2	0.3	0.2	0.0	0.0
12	35.2	30.2	51.7	72.6	13.7	0.4	0.2	1.6	1.5	0.0	0.4	0.2	0.2	2.3	0.0	0.0	0.0	0.0	0.0	0.0
13	29.0	31.1	29.1	36.0	24.3	1.4	1.8	0.1	1.7	0.4	0.8	1.4	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
14	42.7	36.4	35.8	58.4	52.8	3.0	3.8	2.5	1.5	1.1	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.0	0.0
15	17.2	17.6	28.7	36.6	1.6	5.1	6.6	6.4	7.3	0.0	3.5	3.1	2.1	5.0	6.7	1.2	2.2	0.0	0.0	0.0
16	9.6	8.1	19.6	14.6	5.5	4.3	4.5	7.5	3.1	1.5	2.0	3.2	1.0	1.6	0.0	1.6	1.6	7.0	0.2	0.0
17	8.0	8.5	11.1	13.2	3.5	5.7	2.9	8.2	16.5	2.8	2.8	2.4	2.8	10.0	1.6	6.1	6.4	4.3	5.7	2.8
18	27.0	18.0	34.8	45.1	26.8	4.0	3.5	4.8	8.1	1.3	2.6	3.2	1.6	5.9	0.7	5.8	4.2	16.7	11.0	2.6
19	24.9	22.9	54.3	43.6	6.2	2.2	1.8	6.2	5.4	0.0	2.1	2.1	1.8	6.6	0.0	3.2	4.8	0.5	3.8	0.0
20	34.8	31.3	57.8	36.6	31.0	0.9	0.8	1.6	0.7	0.6	6.7	6.1	4.9	11.6	4.1	2.1	3.6	0.0	0.9	0.0
21	40.9	45.2	48.3	48.5	24.8	1.6	0.9	4.5	3.4	0.6	8.3	9.3	7.6	5.7	5.0	0.5	0.9	0.1	0.0	0.0
22	29.4	24.3	42.0	36.3	31.1	2.5	0.2	12.0	10.6	0.0	15.0	17.4	3.8	10.9	11.6	0.2	0.4	0.0	0.0	0.0
23	20.9	15.0	34.9	47.4	17.2	0.7	0.4	2.9	2.2	0.0	9.2	12.1	2.0	6.9	2.9	0.0	0.0	0.0	0.1	0.0
24	24.2	14.9	68.2	48.8	14.4	1.2	1.0	1.6	2.0	0.4	6.4	8.9	1.9	9.2	0.0	0.0	0.0	0.0	0.0	0.0
25	26.5	17.9	70.5	46.2	9.0	4.3	3.8	12.5	8.6	0.0	10.5	9.1	13.2	26.3	1.1	0.3	0.0	0.0	1.9	0.0
26	28.5	21.1	53.5	53.6	23.5	5.5	1.6	24.4	19.9	0.1	20.8	14.8	18.4	12.4	37.7	0.5	0.4	0.0	2.3	0.0
27	27.0	23.2	55.6	33.7	13.6	0.6	1.2	0.0	0.0	0.0	10.1	7.1	22.7	19.9	6.9	0.8	0.3	0.0	4.4	0.0
28	32.5	32.4	34.8	44.9	24.1	0.5	0.9	0.0	0.1	0.0	2.8	3.6	5.8	2.5	0.0	0.3	0.5	0.0	0.4	0.0
29	21.6	26.3	9.2	29.5	17.5	0.6	1.0	0.0	0.0	0.0	0.4	0.7	0.0	0.0	0.0	0.8	0.2	0.0	4.5	0.0
30	6.5	7.2	5.6	7.3	4.4	5.1	8.5	0.8	0.5	0.0	0.4	0.7	0.0	0.0	0.0	1.2	0.5	5.0	2.8	0.0
31	4.7	4.0	10.9	6.7	1.8	1.9	3.0	1.0	1.1	0.9	0.6	0.7	0.2	1.9	0.0	5.9	5.2	23.5	4.7	0.2
32	20.2	13.1	37.3	47.0	15.8	1.9	3.4	0.0	0.1	0.0	1.5	1.9	0.0	0.0	3.0	5.1	5.6	15.3	3.4	0.3
33	23.9	20.0	19.4	44.1	19.5	1.9	2.3	2.3	2.3	0.2	5.1	8.0	1.8	2.1	0.1	14.2	15.2	36.6	13.8	0.1
34	23.6	18.2	18.4	49.3	23.9	8.0	5.2	20.6	19.3	1.8	10.2	15.2	3.6	5.0	3.2	19.2	12.6	36.9	75.1	0.6
35	29.8	21.7	41.4	56.7	27.3	12.7	11.2	20.4	14.2	8.6	11.0	13.3	9.6	4.0	15.7	3.1	2.1	6.8	8.6	0.7
36	42.0	45.9	60.0	39.8	26.5	15.6	7.9	32.7	28.6	30.8	6.6	8.1	4.9	14.0	0.0	2.0	1.6	1.6	7.1	0.0
37	25.9	25.0	19.4	23.9	32.9	8.6	8.6	5.4	8.4	13.3	22.4	28.7	17.0	21.4	1.1	10.8	15.2	10.3	8.1	0.5
38	25.9	32.8	17.6	27.9	9.6	2.7	2.8	2.2	2.1	5.8	28.3	23.2	57.1	42.0	20.4	8.7	6.1	35.0	13.5	0.4
39	22.7	26.4	21.7	27.2	12.6	0.4	0.3	0.8	0.7	0.4	20.0	16.2	34.4	28.6	19.1	9.0	5.9	10.9	36.2	0.0
40	13.0	10.7	25.8	12.4	20.9	0.7	0.4	0.0	1.3	0.8	9.7	13.1	7.3	8.9	3.3	28.1	24.1	43.6	53.2	16.1
41	15.6	17.9	16.1	15.9	6.1	1.6	0.7	0.0	4.7	1.7	5.6	7.0	3.3	6.9	0.1	44.3	37.3	64.2	71.0	42.1
42	28.3	18.6	40.6	59.4	26.2	0.5	0.9	0.2	0.0	0.0	6.8	6.1	3.7	5.3	12.2	30.0	20.5	39.1	31.4	52.4
43	11.4	9.8	13.1	14.6	16.7	2.5	3.4	2.2	0.5	0.6	5.3	7.1	1.6	5.7	1.3	22.7	17.7	52.7	27.4	20.8
44	20.2	20.0	11.9	28.1	18.0	6.4	4.6	10.5	8.9	4.0	15.6	19.2	7.7	17.0	2.6	20.2	23.6	17.5	19.4	11.6
45	35.8	34.8	35.8	69.5	12.9	8.7	6.4	15.4	16.1	5.1	16.9	17.4	12.7	20.9	14.0	25.0	26.9	26.9	23.4	16.7
46	29.2	30.6	17.9	26.7	31.1	12.2	10.1	14.5	18.5	8.4	14.5	11.1	20.1	25.6	7.5	36.9	34.9	62.0	51.7	23.7
47	32.6	31.1	39.7	13.3	53.8	9.0	9.0	13.7	9.1	5.3	22.4	23.6	27.7	33.1	8.5	29.7	20.2	52.7	24.9	39.0
48	14.8	13.7	21.3	16.5	16.6	27.0	20.9	21.6	36.4	27.6	28.6	29.0	40.4	47.9	7.9	13.7	15.0	5.6	8.5	28.2
49	10.4	7.4	14.8	21.7	13.7	24.4	18.4	33.0	35.0	27.6	18.8	13.5	35.6	44.0	10.0	10.5	9.2	13.1	11.8	19.8
50	8.5	7.9	19.5	13.2	5.9	15.9	14.2	34.5	23.7	8.5	12.5	12.3	13.2	22.4	11.0	6.7	6.0	11.4	10.6	6.2
51	12.6	7.4	20.2	38.5	9.6	25.1	17.6	46.3	52.2	18.8	19.0	22.0	9.5	21.1	15.6	5.9	3.5	13.7	16.8	2.8
52	21.0	12.8	23.8	15.6	37.9	15.9	15.7	26.2	21.3	8.8	13.0	15.2	12.3	10.0	10.3	4.8	3.3	8.9	3.2	8.1
53	22.3	22.4	21.0	32.2	16.4	11.4	10.7	14.1	13.0	14.7	26.8	40.2	9.1	10.6	10.7	2.2	2.2	0.2	4.0	4.0
54	32.5	36.8	19.7	38.4	22.1	7.5	9.1	4.4	5.0	9.7	28.7	42.4	20.7	20.3	1.3	1.2	0.4	0.3	6.3	0.3
55	27.6	37.1	19.1	23.0	5.2	5.3	3.5	18.7	14.0	0.0	18.0	25.5	10.8	15.2	2.3	0.7	1.0	0.4	0.6	0.0
56	13.8	15.8	12.6	6.4	7.8	2.5	2.6	6.8	4.1	0.0	7.1	6.8	13.9	8.5	4.1	1.3	1.7	1.0	2.8	0.0
57	7.1	6.6	3.9	6.9	14.3	1.6	2.7	0.8	0.8	0.0	6.0	7.9	1.7	0.4	8.8	2.8	1.3	15.4	4.8	0.0
58	3.5	4.3	2.2	2.2	6.3	1.8	1.7	3.9	4.5	0.1	7.4	5.9	5.0	14.2	5.0	1.3	1.2	2.3	1.3	0.7
59	1.6	2.8	0.0	0.4	0.0	2.7	3.4	4.1	3.0	0.1	9.5	7.7	0.7	3.4	25.3	0.6	0.3	1.5	2.4	0.0
60	0.9	0.6	0.9	4.8	0.0	7.5	5.9	12.0	10.0	4.4	6.7	6.1	2.5	5.5	13.6	0.9	0.9	1.1	2.6	0.0
Total																				
60-day	1181.4	1120.0	1559.2	1697.9	866.7	308.4	266.4	472.3	473.9	224.4	554.8	609.3	531.3	669.8	337.0	403.6	363.2	651.9	595.7	302.4
(Ratio to 4F13)		(0.95)	(1.39)	(1.44)	(0.73)		(0.86)	(1.77)	(1.54)	(0.73)		(1.10)	(0.87)	(1.21)	(0.61)		0.9	1.8	1.5	(0.75)
10-day	206.8	191.8	230.7	278.9	201.0	108.2	88.6	145.6	152.9	88.8	147.0	146.3	166.0	228.8	75.1	239.7	211.3	345.2	280.1	260.5
(Ratio to 4F13)		(0.93)	(1.20)	(1.35)	(0.97)		(0.82)	(1.64)	(1.41)	(0.82)		(1.00)	(1.13)	(1.56)	(0.51)		(0.88)	(1.63)	(1.17)	(1.09)

Table B4.6 (2/2) Ratio of Rainfall in Subbasin to that in Project Catchment

No. of Day	Flood - 5 May 1967 Flood (Mar. 25 - May 23)					Flood - 6 Nov. 1968 Flood (Oct. 17 - Dec. 15)					Flood - 7 Apr. 1970 Flood (Mar 9 - May 7)					Flood - 8 May 1971 Flood (Apr. 4 - Jun. 2)				
	4F13	4FD3	4F19	4FA7	Rem Area	4F13	4FD3	4F19	4FA7	Rem Area	4F13	4FD3	4F19	4FA7	Rem Area	4F13	4FD3	4F19	4FA7	Rem Area
1	0.1	0.1	0.0	0.0	0.0	19.8	12.4	51.5	47.1	9.1	1.7	2.0	1.4	2.7	0.5	2.0	2.3	1.5	3.8	0.0
2	0.3	0.5	0.0	0.4	0.0	14.5	12.0	26.1	32.2	3.7	1.2	1.8	1.2	0.5	0.0	2.6	3.0	4.1	3.8	0.2
3	0.3	0.5	0.0	0.5	0.0	1.7	2.4	1.7	1.4	0.1	0.3	0.4	0.1	0.1	0.3	4.0	5.9	1.6	4.3	0.8
4	0.1	0.1	0.0	0.0	0.0	1.4	1.4	1.2	2.8	0.0	0.8	1.5	0.0	0.0	0.0	9.7	8.6	25.0	18.8	0.1
5	0.9	0.9	0.2	3.5	0.0	3.7	4.3	5.2	4.3	0.9	1.9	3.4	0.0	0.0	0.0	8.5	9.4	4.6	16.2	1.5
6	9.0	8.8	30.9	5.3	1.7	4.3	3.6	10.6	8.7	1.7	4.4	6.1	1.1	3.1	3.6	17.8	14.6	54.3	26.6	3.5
7	10.9	7.5	12.2	33.6	9.6	8.5	3.1	23.8	31.3	3.1	5.0	3.5	8.0	18.0	0.1	13.3	10.0	24.6	23.8	12.2
8	2.0	1.5	7.0	2.7	0.0	1.5	1.3	1.5	4.7	0.1	2.3	1.2	5.8	9.1	0.0	8.1	9.0	5.1	13.6	3.1
9	16.9	17.8	32.8	20.8	5.2	12.1	14.2	7.5	19.8	0.0	0.0	0.1	0.0	0.0	0.0	10.3	7.1	21.5	27.2	0.5
10	13.9	8.3	15.8	45.4	7.0	19.0	23.9	20.0	23.0	1.7	0.4	0.8	0.0	0.0	0.0	7.1	5.1	13.5	16.2	3.0
11	4.7	4.5	4.1	14.3	0.3	9.9	8.6	14.2	23.3	4.8	0.6	1.0	0.0	0.5	0.0	4.5	3.7	3.8	15.0	2.0
12	2.4	3.4	1.4	0.7	2.3	3.0	4.8	1.4	2.2	0.0	1.3	1.7	0.0	2.2	0.1	7.4	8.9	2.5	13.8	1.9
13	2.2	2.6	2.1	4.5	0.0	2.1	1.5	4.6	4.3	0.6	2.1	3.4	0.8	0.8	0.1	10.7	13.1	5.2	22.4	0.6
14	3.4	3.2	8.1	3.6	3.8	13.0	10.2	29.9	24.6	1.6	3.3	4.7	0.5	2.5	2.4	23.8	27.2	11.3	26.2	19.5
15	2.2	1.2	1.9	0.7	7.0	9.0	3.7	25.0	28.4	5.6	2.1	2.7	0.0	3.8	0.2	30.6	23.9	39.2	42.0	28.6
16	1.4	1.8	1.5	1.6	0.0	4.8	4.2	11.3	2.8	1.8	4.5	5.7	2.4	2.9	2.4	21.6	14.9	60.6	35.5	8.5
17	18.1	16.1	6.6	21.8	33.2	10.9	10.4	14.7	5.5	15.8	17.8	16.1	7.1	37.9	6.3	10.1	9.5	6.9	11.2	14.5
18	7.8	6.9	12.1	5.1	8.4	10.4	12.3	5.3	7.9	9.4	20.0	17.2	25.8	21.6	24.1	10.6	8.8	15.6	7.9	14.4
19	12.2	8.8	15.1	9.1	25.8	6.2	9.5	2.3	4.7	0.1	26.6	21.5	23.8	36.6	35.6	4.2	4.7	2.7	10.9	0.3
20	11.8	9.9	20.2	9.7	12.0	7.8	11.7	0.4	3.1	3.0	20.0	22.1	18.3	9.0	16.3	1.9	1.8	0.3	6.8	0.0
21	9.7	9.3	7.6	5.9	14.6	7.2	7.6	5.0	2.1	16.4	19.2	14.2	19.8	22.7	31.5	5.4	9.2	0.1	2.3	0.0
22	12.4	14.4	10.4	9.9	13.8	10.7	11.8	13.5	9.4	4.0	14.6	15.1	10.2	14.1	16.7	14.1	18.1	6.0	8.0	14.4
23	9.6	12.4	2.5	7.2	5.7	15.6	10.7	25.6	30.7	12.0	17.2	17.3	13.3	19.9	16.4	29.4	21.1	60.0	30.5	41.2
24	12.8	14.3	16.8	12.4	7.5	9.9	6.1	14.2	8.8	18.3	7.6	10.1	2.6	6.4	1.3	6.2	7.1	3.3	6.5	4.1
25	9.1	9.0	8.8	15.0	4.6	8.3	4.4	10.5	11.0	19.0	8.4	12.3	4.1	8.6	0.3	7.1	10.5	4.5	4.9	0.2
26	4.6	3.9	4.7	3.7	8.9	4.6	2.3	6.7	6.6	6.6	11.0	13.7	8.5	18.2	0.0	11.2	12.1	5.7	11.2	4.8
27	4.0	1.2	9.0	9.9	4.9	11.4	11.2	9.2	13.7	14.2	14.3	16.5	29.7	10.4	3.6	14.3	16.1	16.2	11.1	10.9
28	3.4	0.6	5.4	0.5	6.2	10.8	12.7	12.8	4.7	11.1	14.9	18.9	14.1	17.3	0.2	19.5	18.1	18.1	25.0	25.2
29	1.1	0.9	1.4	0.2	4.0	3.0	4.1	5.6	0.8	0.1	16.6	15.4	25.9	25.5	9.6	25.4	26.8	23.0	32.9	14.7
30	5.5	8.8	2.2	1.9	0.4	4.1	6.8	0.5	2.0	0.0	30.6	27.0	25.9	50.3	25.7	8.6	12.0	4.5	8.8	2.1
31	20.1	24.2	37.2	21.5	0.3	2.5	3.2	3.8	2.6	0.1	29.3	18.7	38.2	72.9	26.7	2.5	2.9	2.1	5.7	0.0
32	30.3	25.2	44.9	85.6	2.1	10.4	9.7	14.4	11.7	7.1	4.9	8.2	0.3	1.0	0.0	2.0	3.5	0.2	0.3	0.0
33	14.8	15.5	19.1	25.0	5.0	16.7	8.4	32.9	32.5	17.7	3.8	5.0	2.1	2.5	0.6	4.5	6.3	2.2	4.7	0.8
34	4.6	5.4	1.6	3.5	1.9	18.0	13.5	23.4	24.2	24.0	3.4	2.9	3.3	2.3	5.0	9.0	12.6	1.5	4.1	3.3
35	3.5	3.4	5.3	7.6	0.0	39.5	29.1	46.2	54.8	55.1	2.4	2.1	3.3	1.1	3.5	2.7	3.9	2.0	2.8	0.0
36	12.3	14.1	7.8	20.2	3.0	47.8	39.9	61.0	59.8	61.1	6.8	5.8	7.9	7.5	7.5	7.5	12.5	0.5	4.7	0.0
37	34.0	27.8	52.0	46.5	38.9	29.9	26.9	34.6	38.0	28.5	6.8	5.3	15.1	11.2	4.4	2.5	3.6	1.9	2.7	0.0
38	6.1	8.8	4.3	6.1	0.3	23.8	17.0	40.3	32.0	27.3	1.7	1.1	3.2	3.1	3.6	4.2	5.4	2.1	5.7	0.0
39	5.6	5.7	3.3	10.9	2.8	23.3	21.2	24.6	32.9	16.0	1.6	1.7	3.1	0.5	2.2	9.4	11.3	6.2	11.0	4.6
40	16.0	16.0	26.8	30.6	3.4	34.8	24.9	51.6	54.3	35.0	2.6	2.7	0.8	5.6	1.5	10.7	13.1	6.4	11.6	4.6
41	35.6	37.1	76.5	42.8	7.9	16.6	11.1	30.0	25.4	16.9	2.3	3.6	1.8	0.6	0.0	6.4	9.5	1.3	4.3	1.7
42	34.1	40.4	38.7	48.4	0.9	14.5	9.2	26.1	26.3	17.5	10.4	15.2	6.5	11.7	0.0	4.8	7.8	0.9	3.2	0.0
43	35.1	33.1	55.9	84.5	2.1	10.1	6.6	19.5	20.5	7.7	7.7	8.4	7.2	17.4	0.2	10.6	13.2	7.8	17.9	1.3
44	32.6	44.9	30.4	21.2	4.8	8.7	5.7	15.2	18.7	4.6	23.9	31.0	11.4	31.6	6.3	14.1	15.5	3.4	13.4	22.6
45	25.9	30.5	15.8	31.0	14.8	9.3	11.8	8.8	6.4	1.7	28.4	33.4	16.5	29.2	13.5	11.9	12.2	17.9	19.0	2.9
46	35.3	43.0	37.1	41.9	3.9	15.0	15.2	9.6	11.5	18.4	29.6	38.5	21.9	20.2	12.0	8.3	10.9	1.5	7.5	5.0
47	38.4	46.8	34.5	37.8	12.3	32.4	39.1	17.7	17.8	30.7	13.6	12.3	16.4	19.7	15.4	10.7	14.5	1.2	3.8	10.2
48	31.3	31.1	64.5	39.8	9.6	37.7	34.5	38.7	41.1	40.8	1.5	2.1	1.2	1.9	0.0	6.8	11.1	0.2	3.2	1.0
49	10.8	11.3	7.2	17.3	5.2	22.3	22.4	23.8	21.8	13.3	4.6	5.9	1.7	0.6	5.2	2.3	3.0	0.1	0.9	3.9
50	4.3	6.8	1.3	2.8	0.0	12.7	9.9	14.8	21.3	15.0	5.8	8.6	0.6	1.7	3.9	0.3	0.5	0.0	0.1	0.0
51	2.7	3.7	1.8	3.1	0.0	3.2	2.5	3.1	9.3	0.4	2.6	4.1	0.1	1.4	0.5	0.1	0.1	0.0	0.0	0.0
52	2.0	2.3	0.4	1.7	3.5	3.6	3.6	1.5	5.2	1.9	3.0	3.4	1.2	1.3	6.1	0.9	0.8	0.5	3.6	0.0
53	1.8	2.9	0.3	0.0	0.4	3.7	3.3	2.8	8.6	3.7	0.0	0.0	0.0	0.0	0.0	2.5	4.1	0.1	1.0	0.0
54	4.0	4.8	0.4	0.6	3.1	1.6	2.2	1.3	1.6	0.0	9.6	13.4	7.7	12.1	0.0	1.0	1.1	0.3	2.5	0.0
55	2.3	3.8	0.1	1.8	0.0	1.1	1.4	1.8	0.7	0.1	4.0	6.7	1.5	0.8	0.0	0.7	0.6	0.0	3.0	0.0
56	2.2	3.7	0.1	1.3	0.0	2.3	1.6	7.9	1.7	0.9	5.4	8.2	3.4	4.1	0.7	0.3	0.5	0.0	0.1	0.0
57	3.5	5.4	2.8	2.5	0.0	1.6	1.6	4.0	1.8	0.6	6.7	11.5	0.3	3.0	0.0	1.7	3.0	0.0	0.2	0.0
58	3.2	4.7	0.4	2.4	2.4	3.1	2.2	6.3	8.7	1.0	2.0	3.5	0.0	0.2	0.2	0.4	0.7	0.0	0.2	0.0
59	2.1	3.5	0.0	0.7	0.3	1.2	0.4	1.7	1.3	5.9	0.9	1.7	0.0	0.0	0.0	0.4	0.7	0.3	0.2	0.0
60	3.4	4.5	0.0	1.1	1.1	0.8	1.2	0.5	0.3	0.0	2.7	4.7	0.1	0.4	0.0	0.9	1.3	1.1	0.6	0.0
Total																				
60-day	650.7	689.6	811.3	890.1	316.9	697.4	612.5	929.7	964.7	617.8	498.7	547.1	427.2	610.3	316.3	490.1	528.8	507.0	625.2	294.7
(Ratio to 4F13)		(1.06)	(1.18)	(1.37)	(0.49)		(0.88)	(1.52)	(1.38)	(0.89)		(1.10)	(0.78)	(1.22)	(0.63)		(1.08)	(0.96)	(1.28)	(0.60)
10-day	283.4	325.0	361.9	367.5	61.5	179.3	165.5	204.2	210.8	166.6	127.8	159.0	85.2	134.6	56.5	76.2	98.2	34.3	73.3	48.6
(Ratio to 4F13)		(1.15)	(1.11)	(1.30)	(0.22)		(0.92)	(1.23)	(1.18)	(0.93)		(1.24)	(0.54)	(1.05)	(0.44)		(1.29)	(0.35)	(0.96)	(0.64)

Table B4.7 Estimated Probable Floods at Existing and Planned Dam Sites

(1) In case without the Masinga and Kiambere Reservoirs

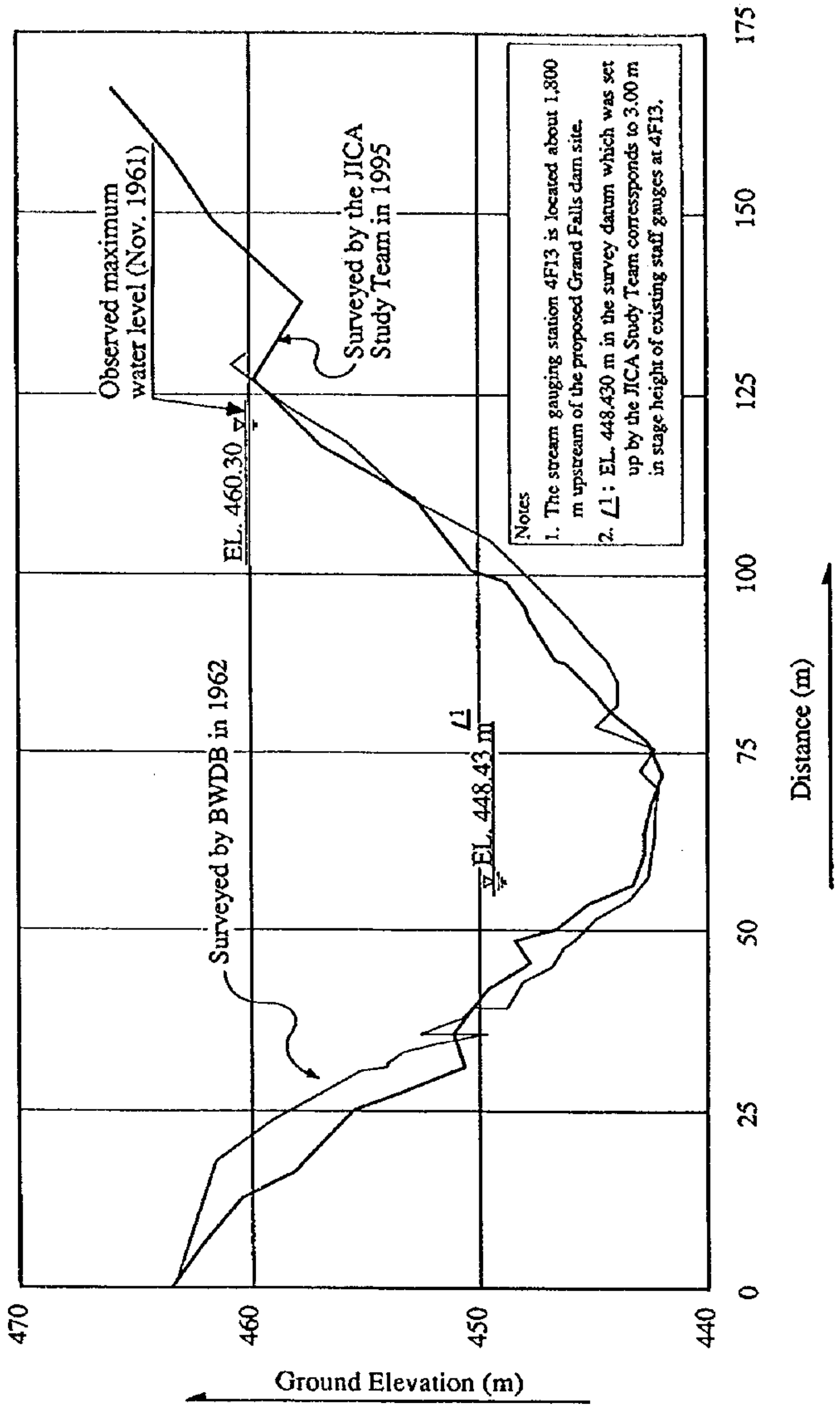
(Unit : m3/sec)

Return Period (Years)	Mutonga	Grand Falls
1.01	470	530
2	1,200	1,400
5	1,600	1,800
10	1,800	2,100
20	2,000	2,400
50	2,400	2,800
100	3,000	3,400
200	4,000	4,500
500	6,400	7,200
1000	8,000	9,300
10000	10,900	12,800

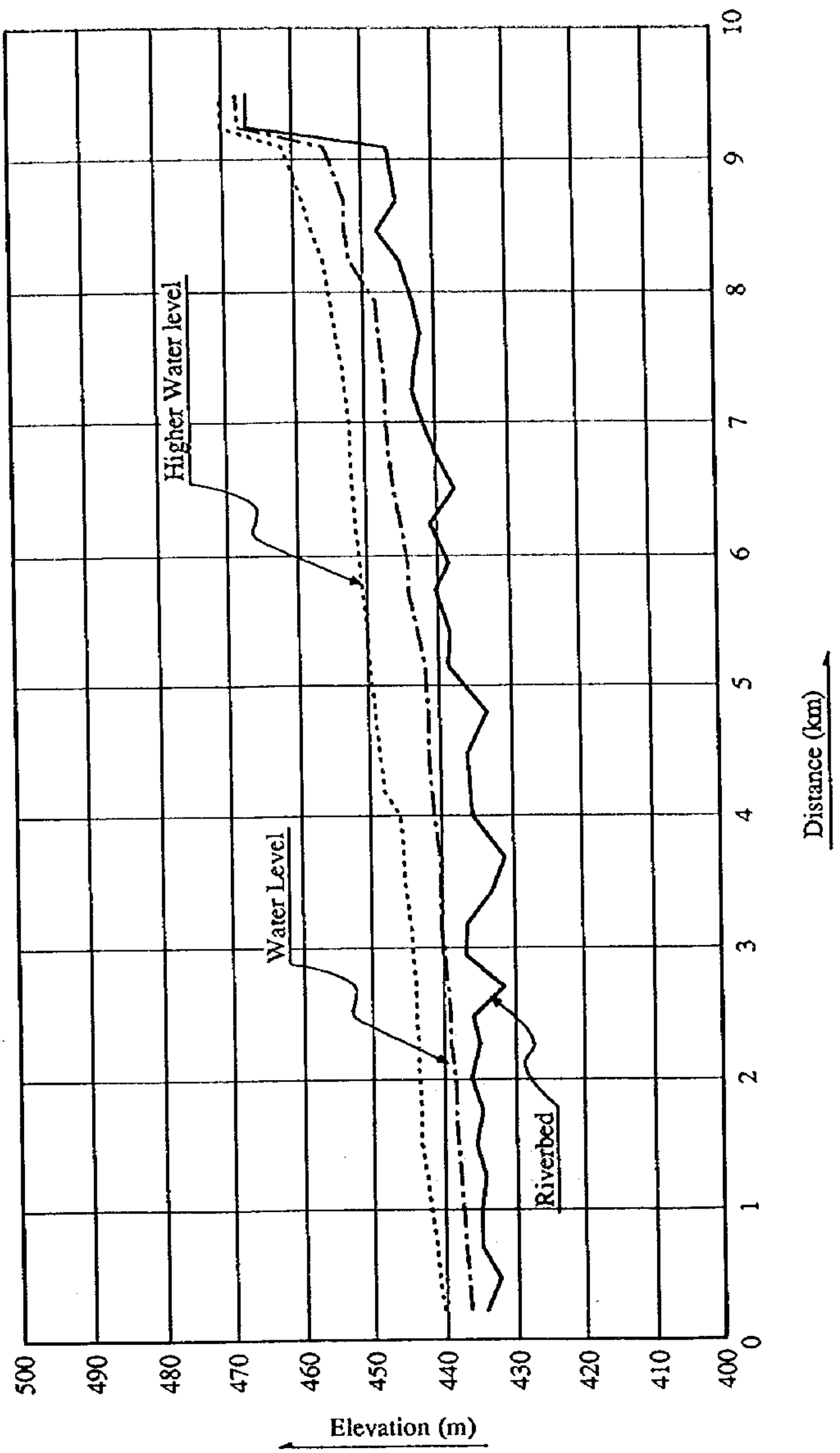
(2) In case with the Masinga and Kiambere Reservoirs

(Unit : m3/sec)

Return Period (Years)	Mutonga	Grand Falls
1.01	330	390
2	780	980
5	1,020	1,300
10	1,200	1,500
20	1,400	1,700
50	1,600	2,000
100	1,900	2,400
200	2,600	3,100
500	4,500	5,400
1000	6,000	7,300
10000	8,900	10,800

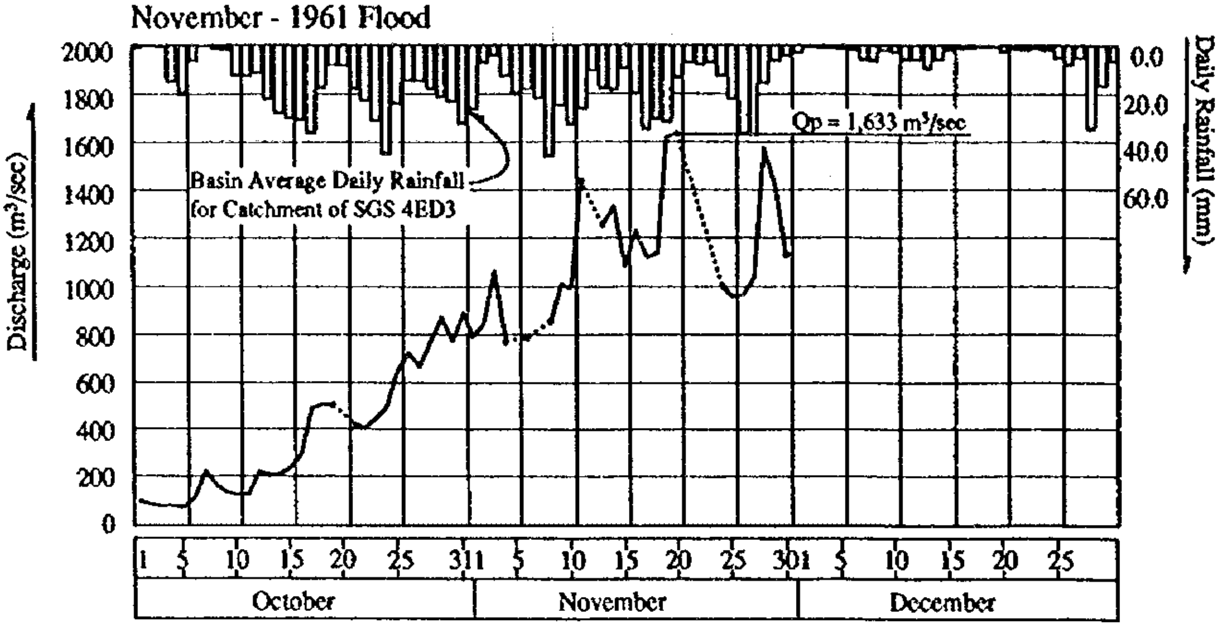


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Comparison of River Cross Sections at Stream Gauging Station 4F13	Fig. No. B4.1

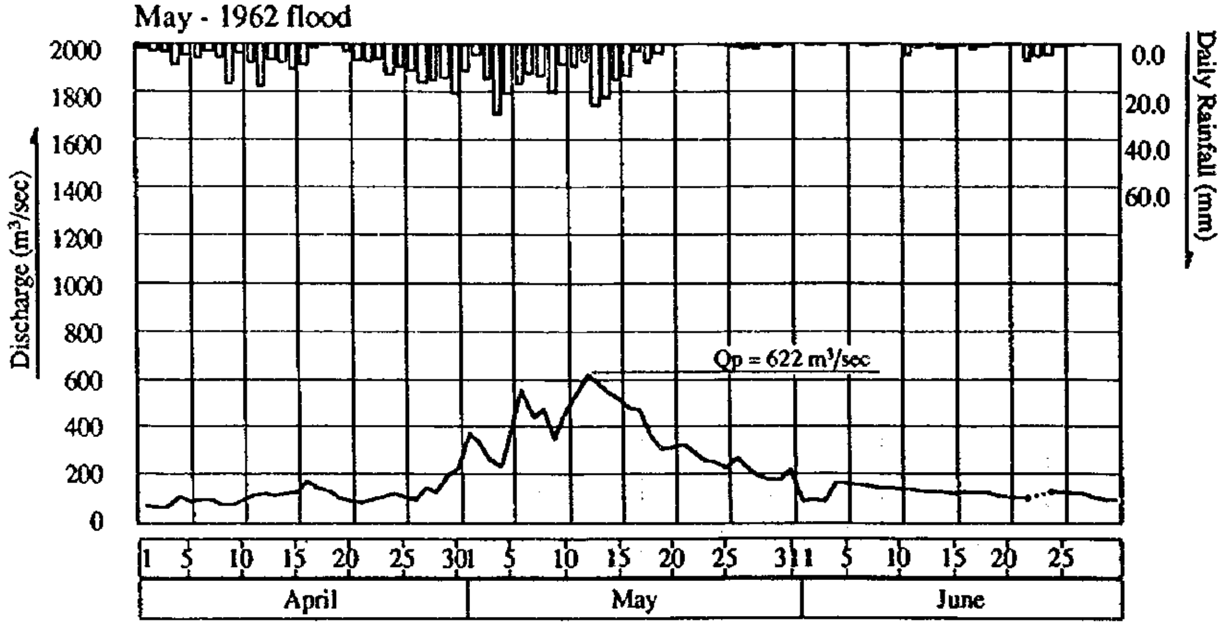


JAPAN INTERNATIONAL COOPERATION AGENCY	River Bed Profile in a Reach Adjacent to SGS 4F13	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.2

November - 1961 Flood

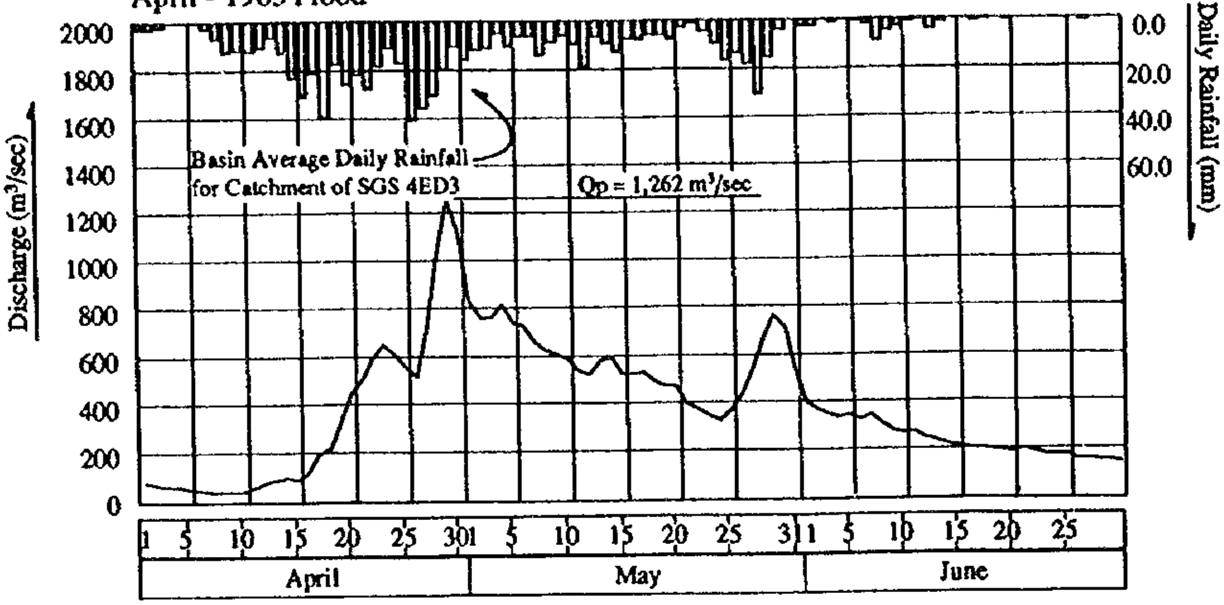


May - 1962 flood

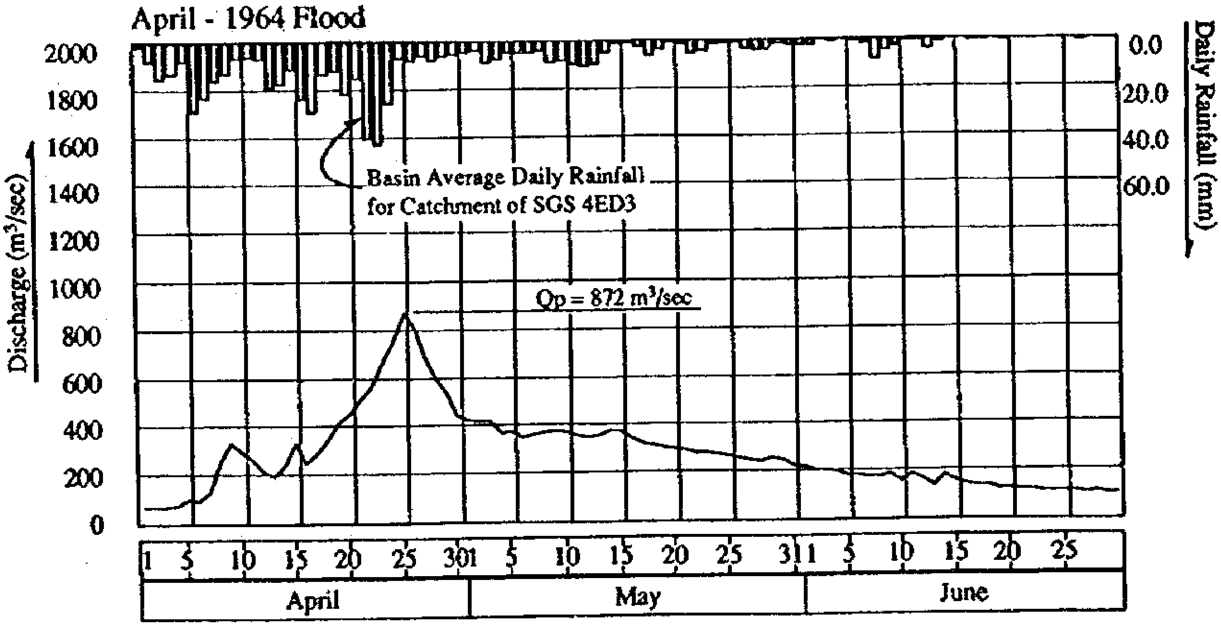


JAPAN INTERNATIONAL COOPERATION AGENCY	Flood Hydrographs Observed at SGS 4ED3	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.3 (1)

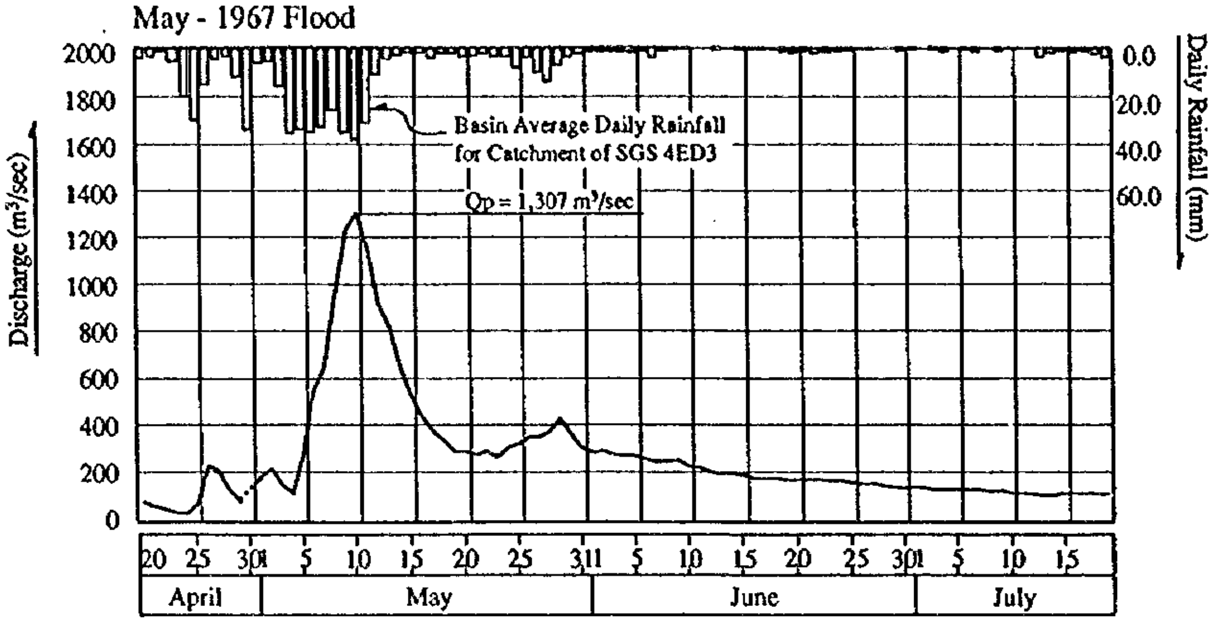
April - 1963 Flood

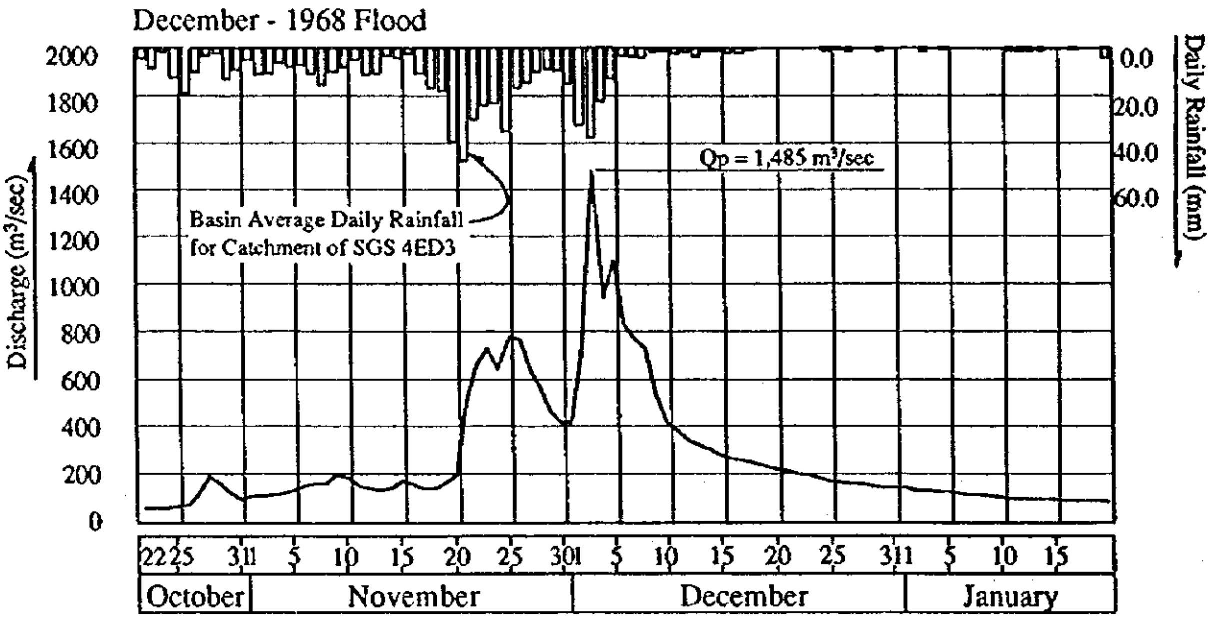


April - 1964 Flood

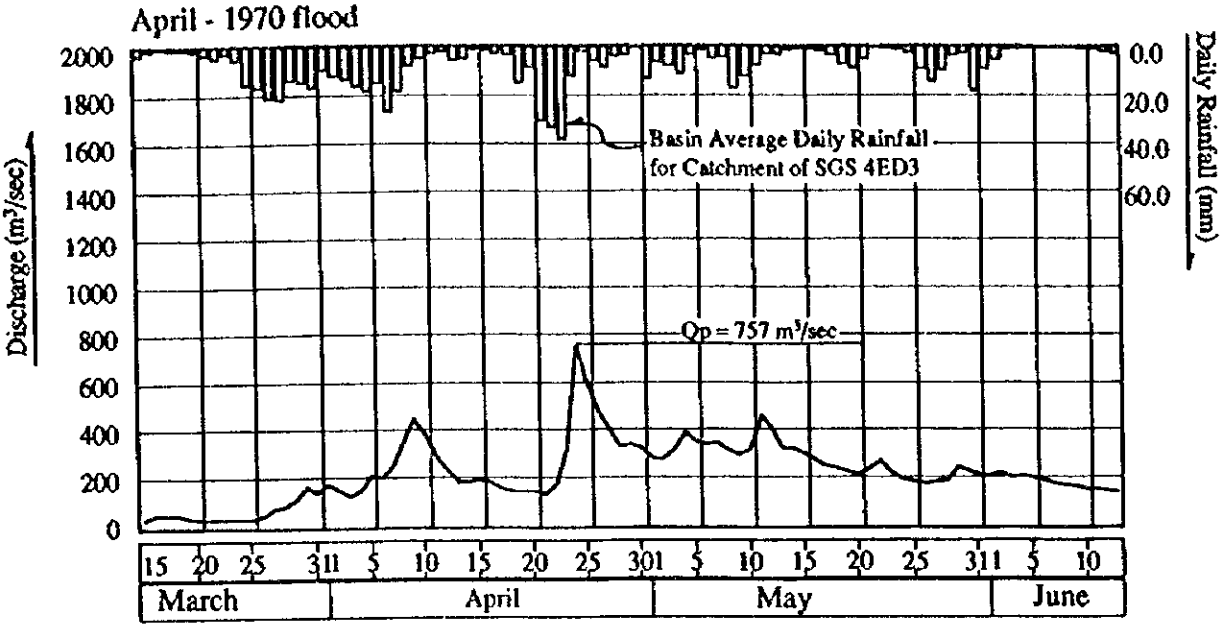


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Flood Hydrographs Observed at SGS 4ED3	Fig. No. B4.3 (2)

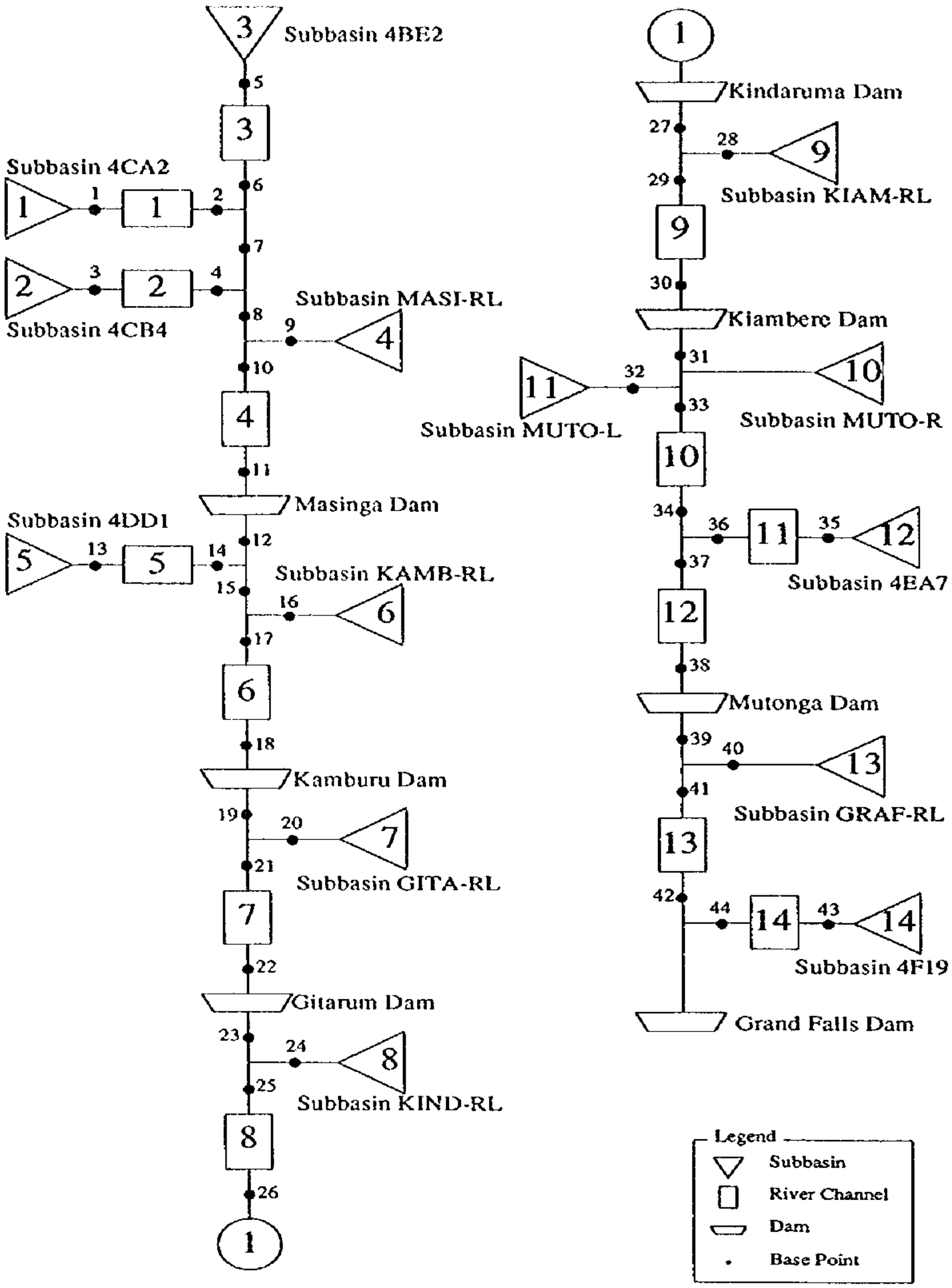




JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Flood Hydrographs Observed at SGS 4ED3	Fig. No. B4.3 (3)

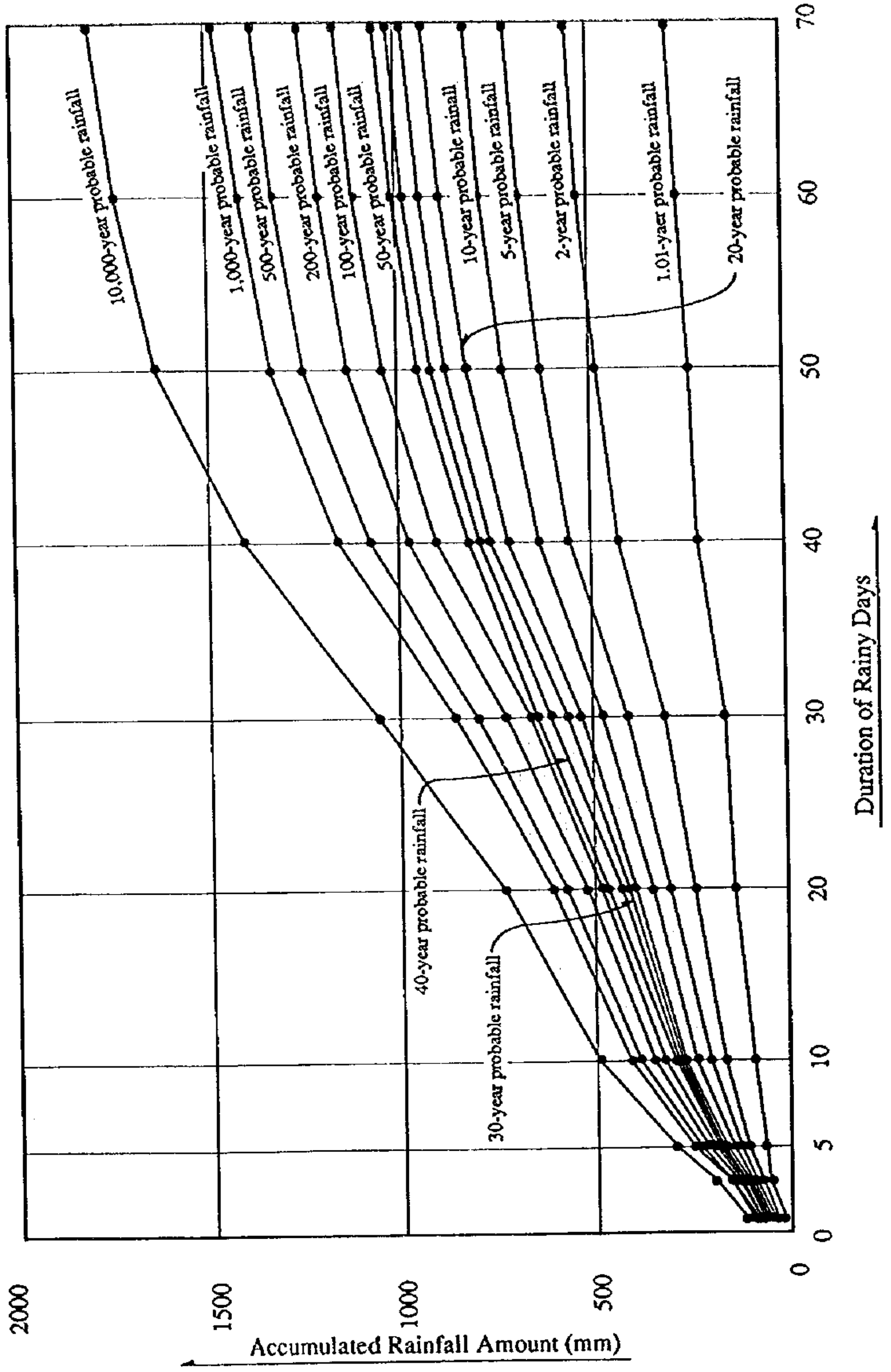


JAPAN INTERNATIONAL COOPERATION AGENCY	Flood Hydrographs Observed at SGS 4ED3	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.3 (4)



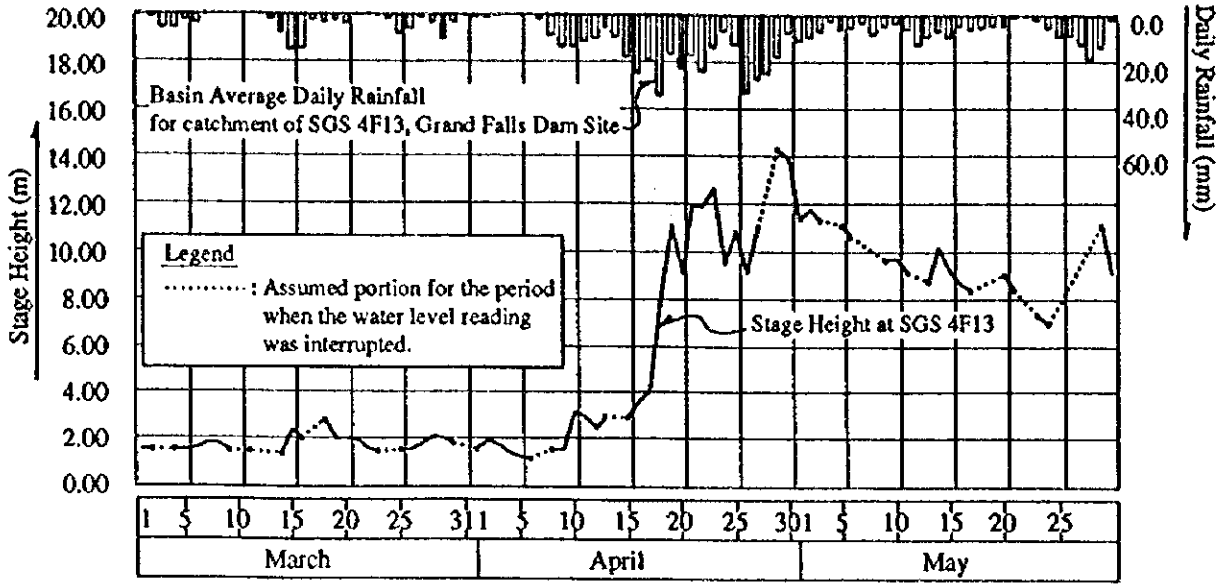
Note
The locations of subbasins are shown in Fig. B3.1

JAPAN INTERNATIONAL COOPERATION AGENCY	Simulation Model for Project Catchment, Used for Storage Function Model	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.4

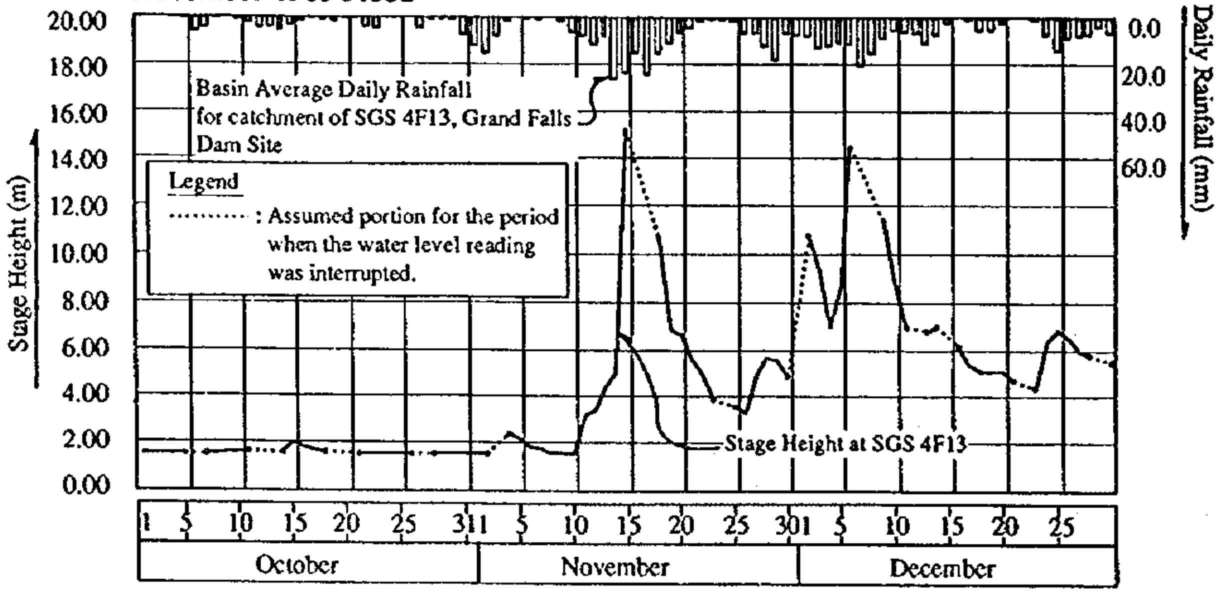


JAPAN INTERNATIONAL COOPERATION AGENCY	Probability of Basin Average Rainfall for Project Catchment	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.5

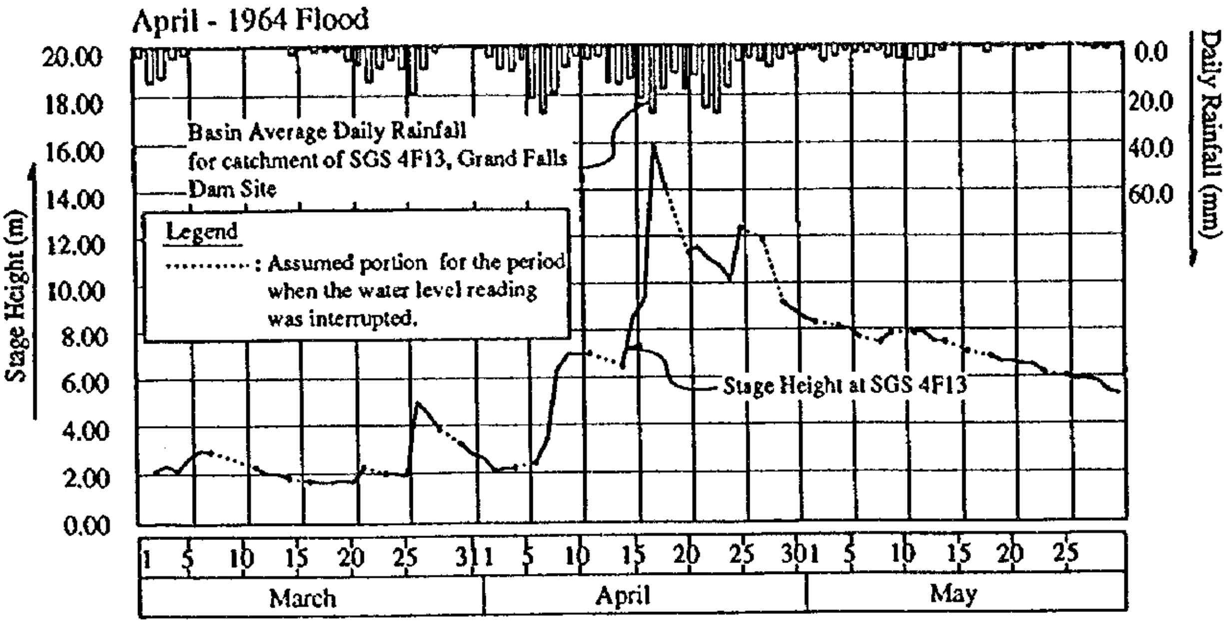
April-1963 Flood

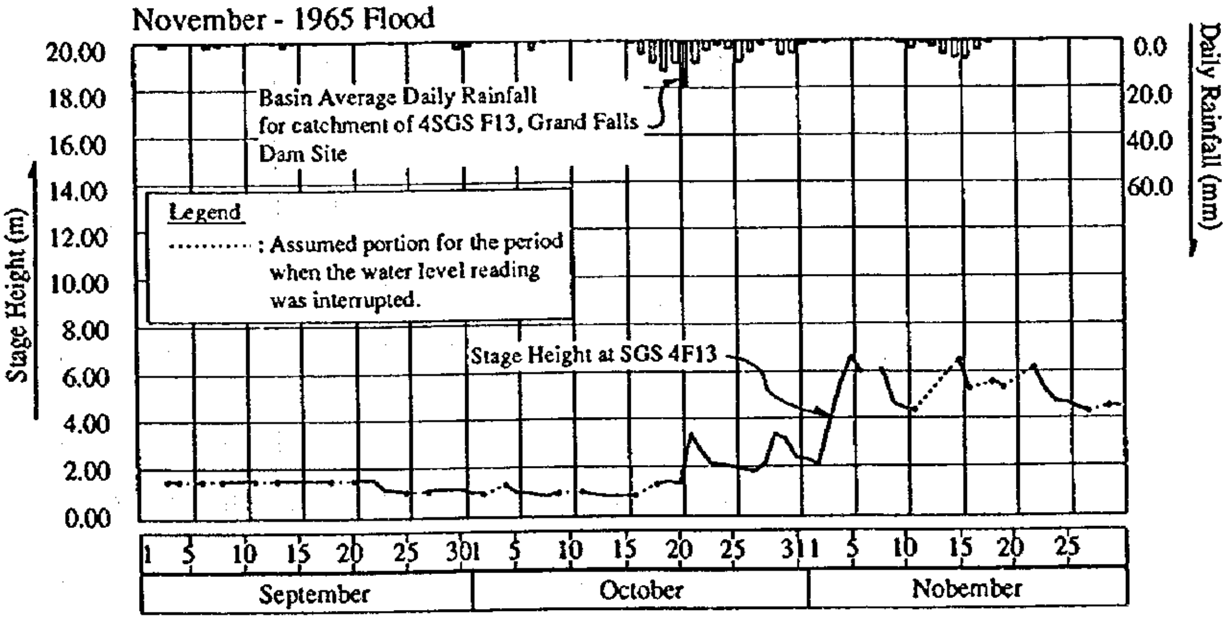


November-1963 Flood

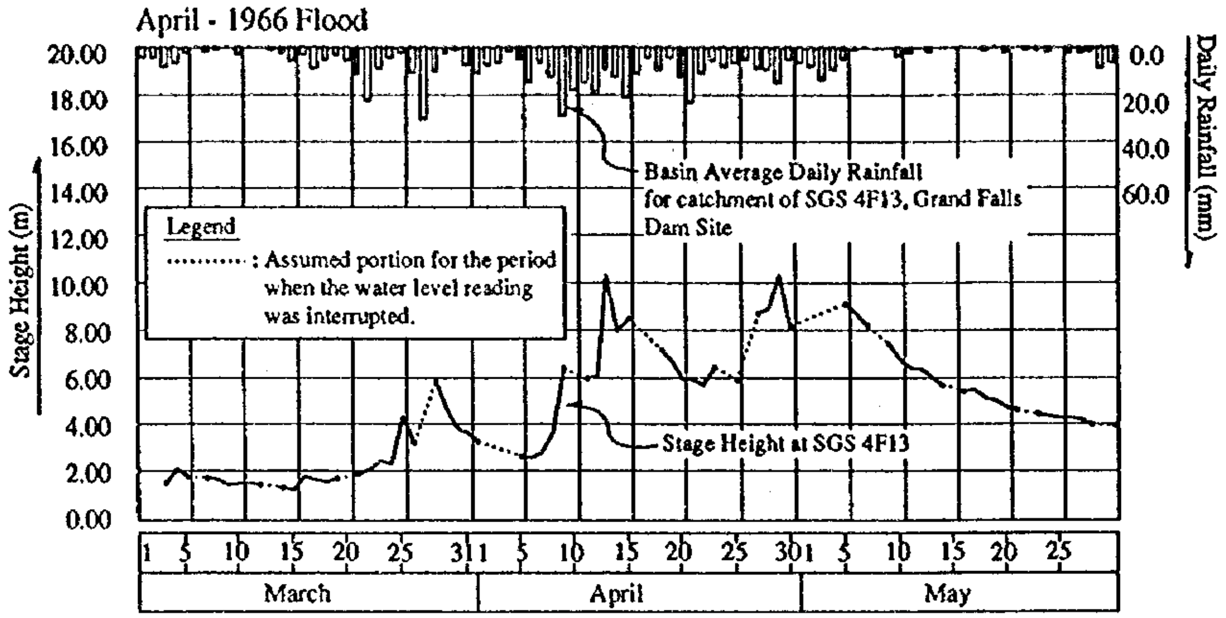


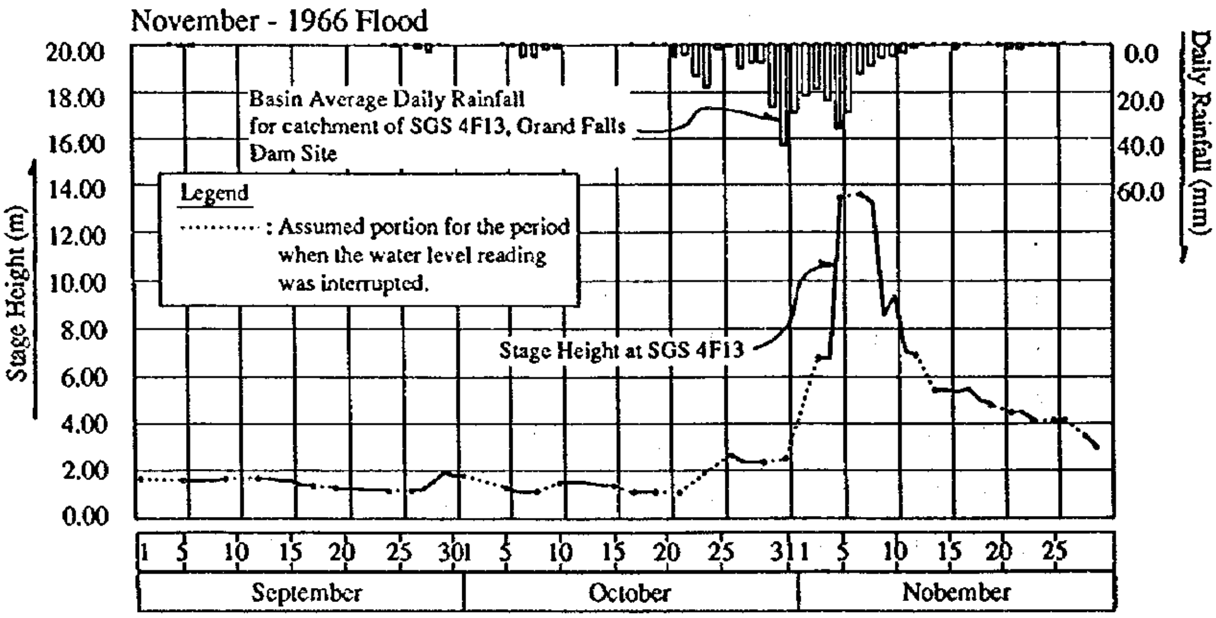
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Major Flood Records at SGS 4F13, Grand Falls Dam Site	Fig. No. B4.6 (1)



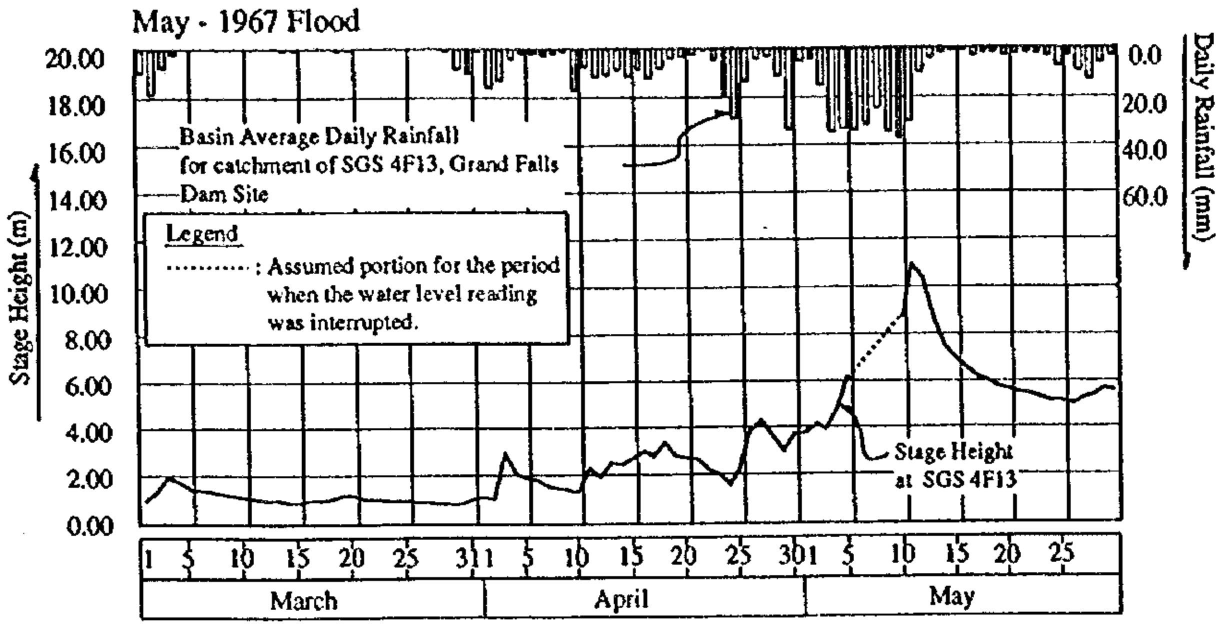


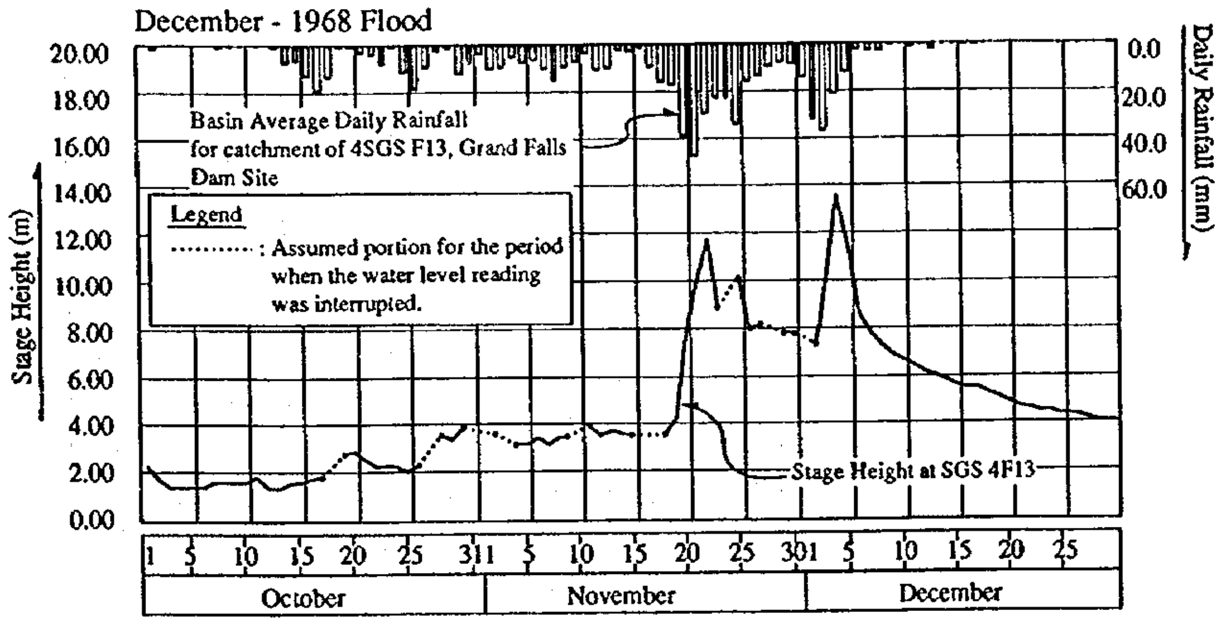
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Major Flood Records at SGS 4F13, Grand Falls Dam Site	Fig. No. B4.6 (2)



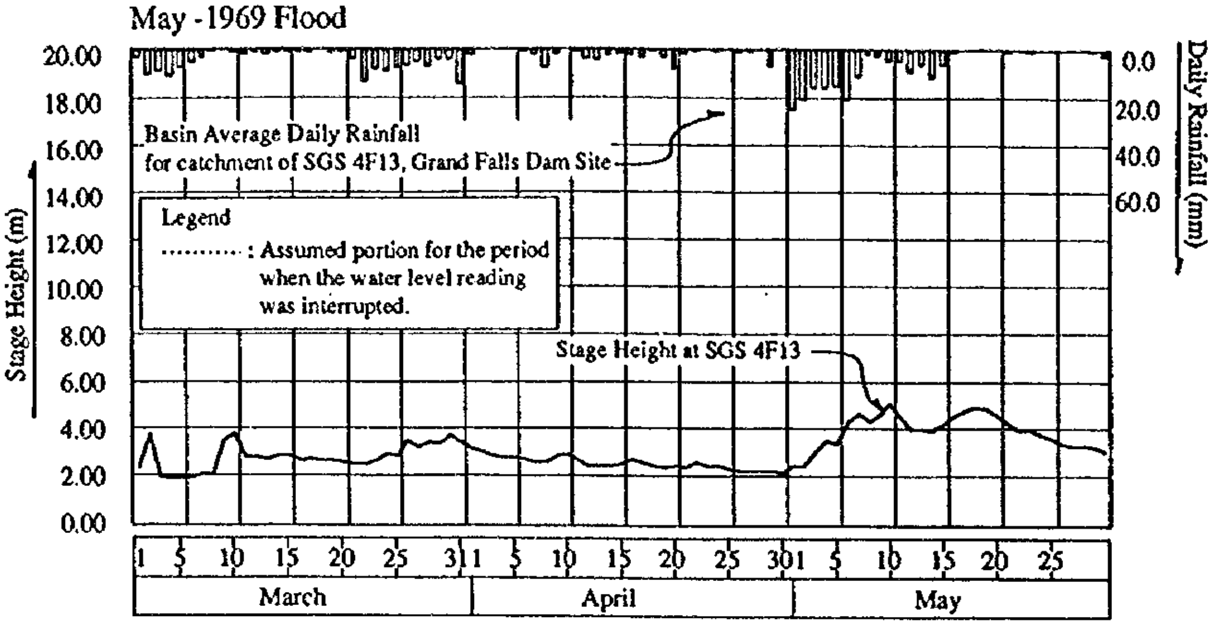


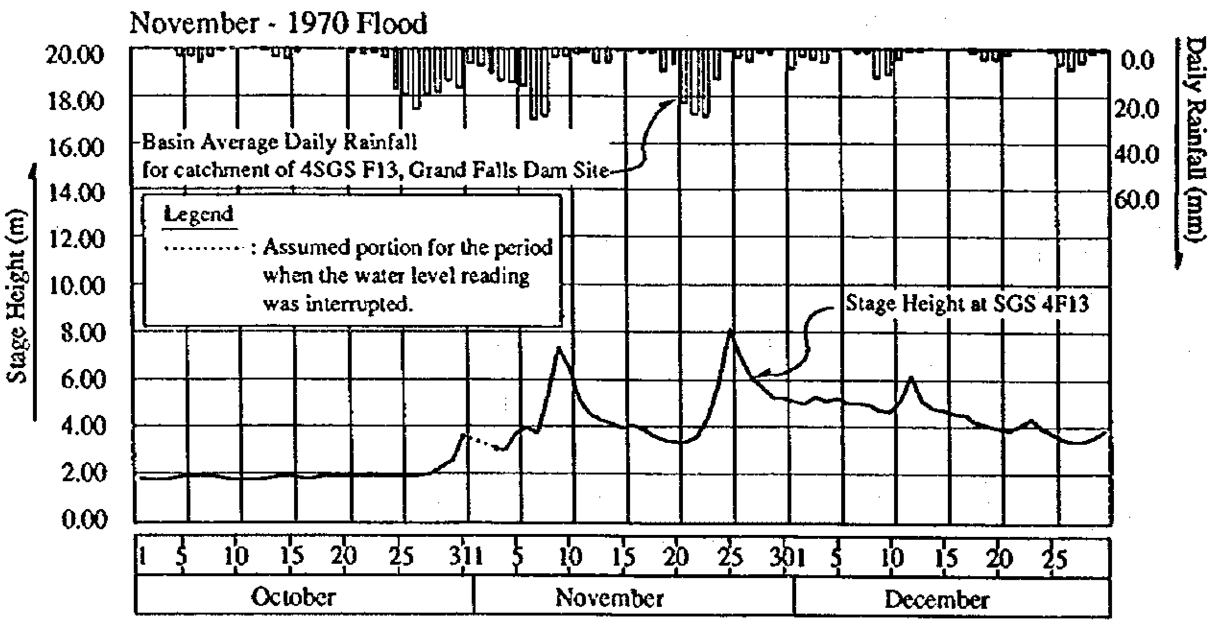
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Major Flood Records at SGS 4F13, Grand Falls Dam Site	Fig. No. B4.6 (3)



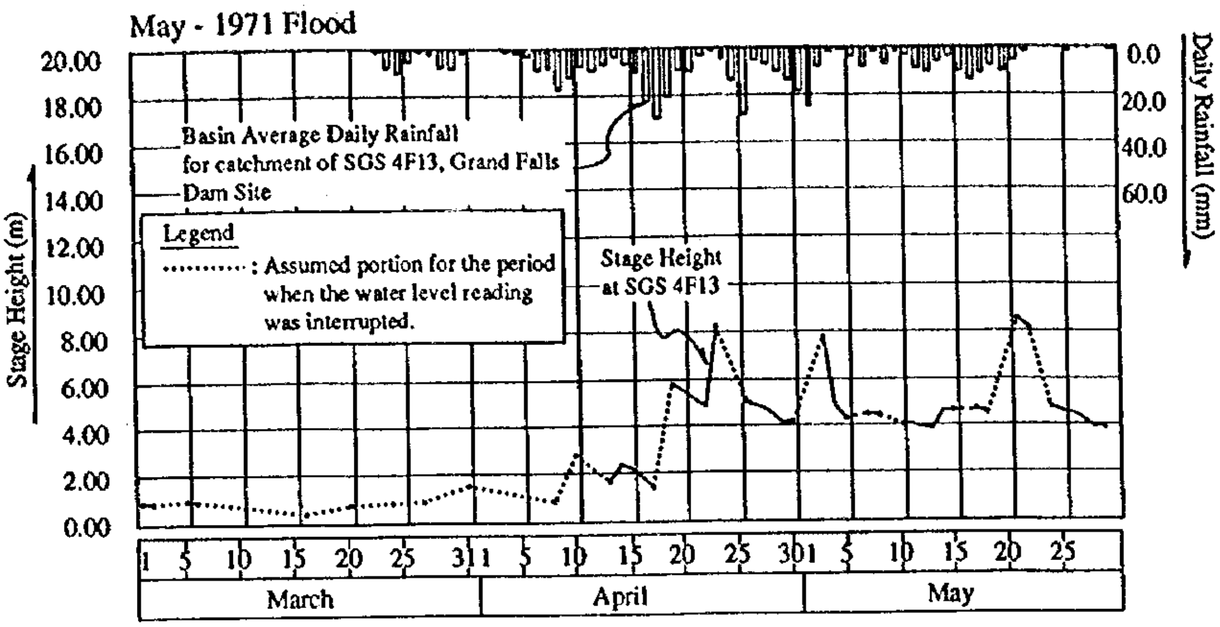


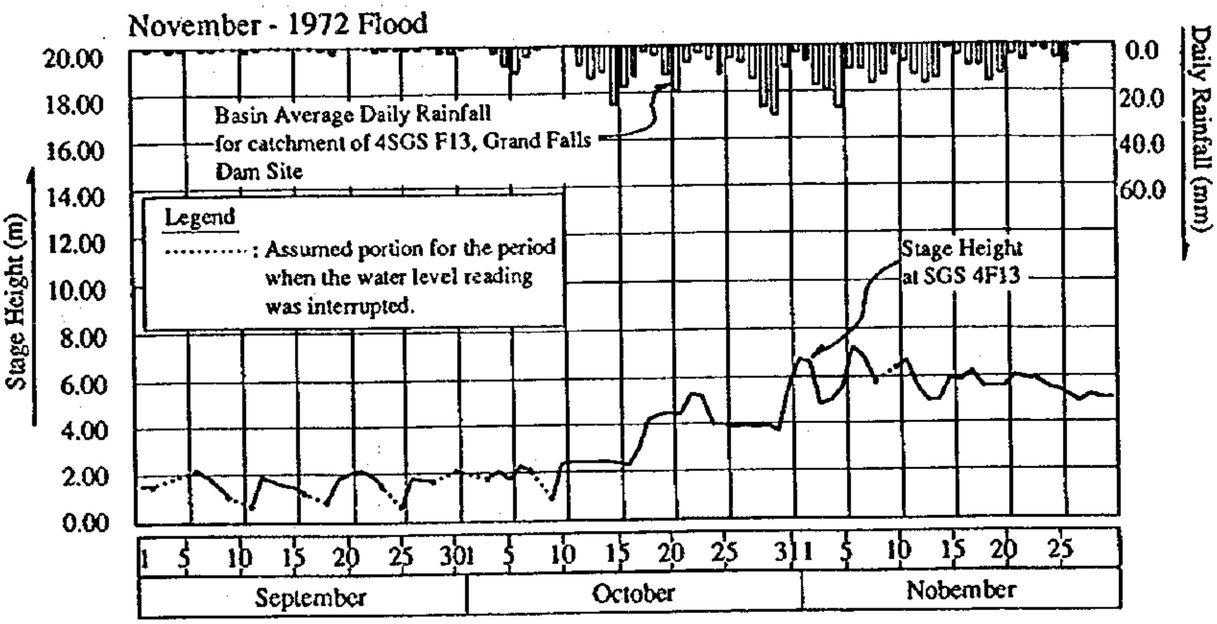
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Major Flood Records at SGS 4F13, Grand Falls Dam Site	Fig. No. B4.6 (4)



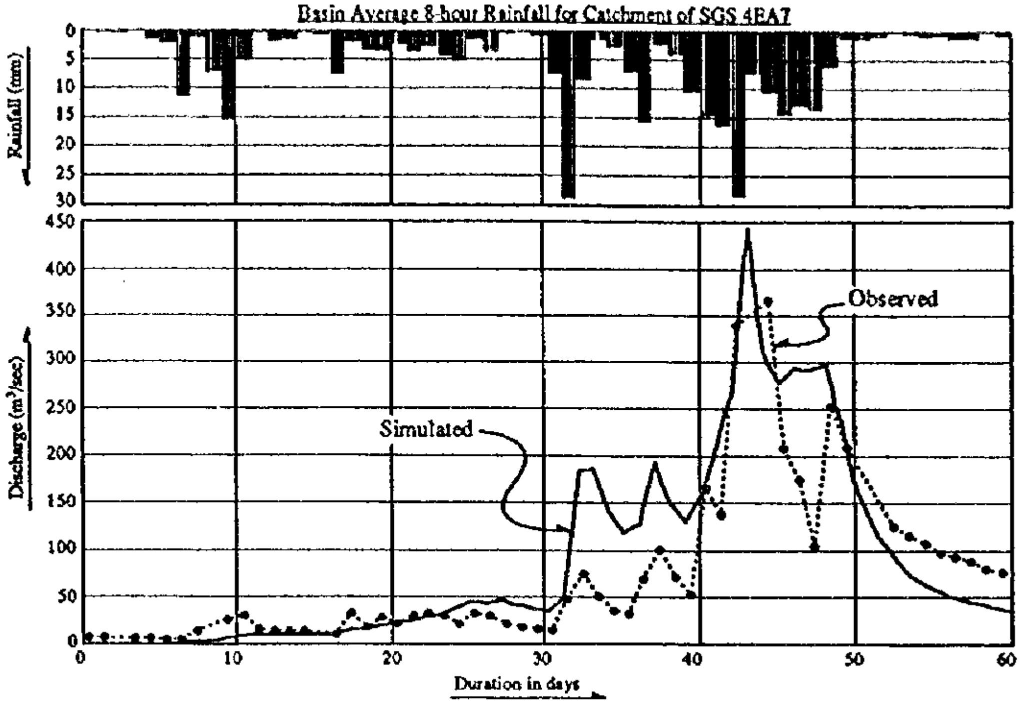


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Major Flood Records at SGS 4F13, Grand Falls Dam Site	Fig. No. B4.6 (5)

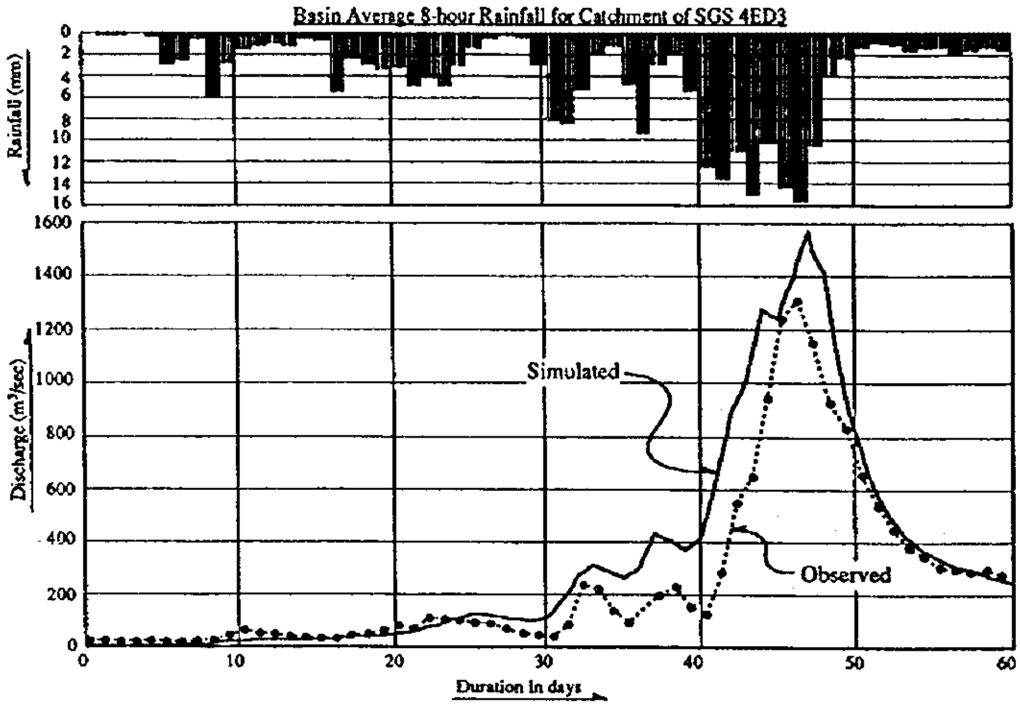




JAPAN INTERNATIONAL COOPERATION AGENCY	Major Flood Records at SGS 4F13, Grand Falls Dam Site	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.6 (6)

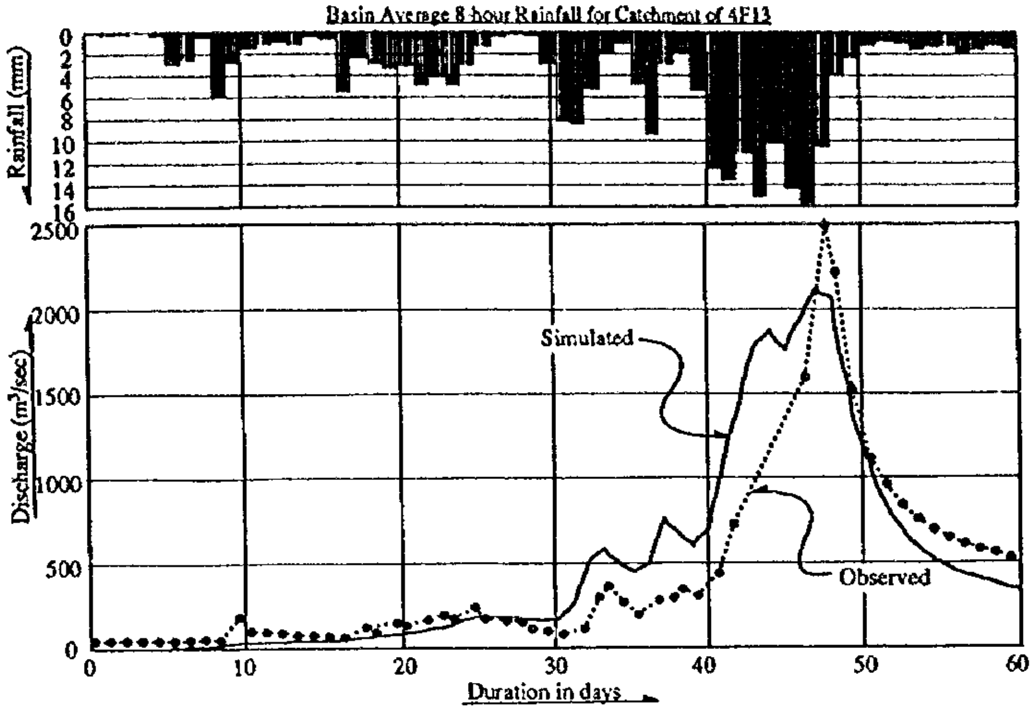


Hydrograph of 1967 Flood at SGS 4EA7 on the Mutonga River

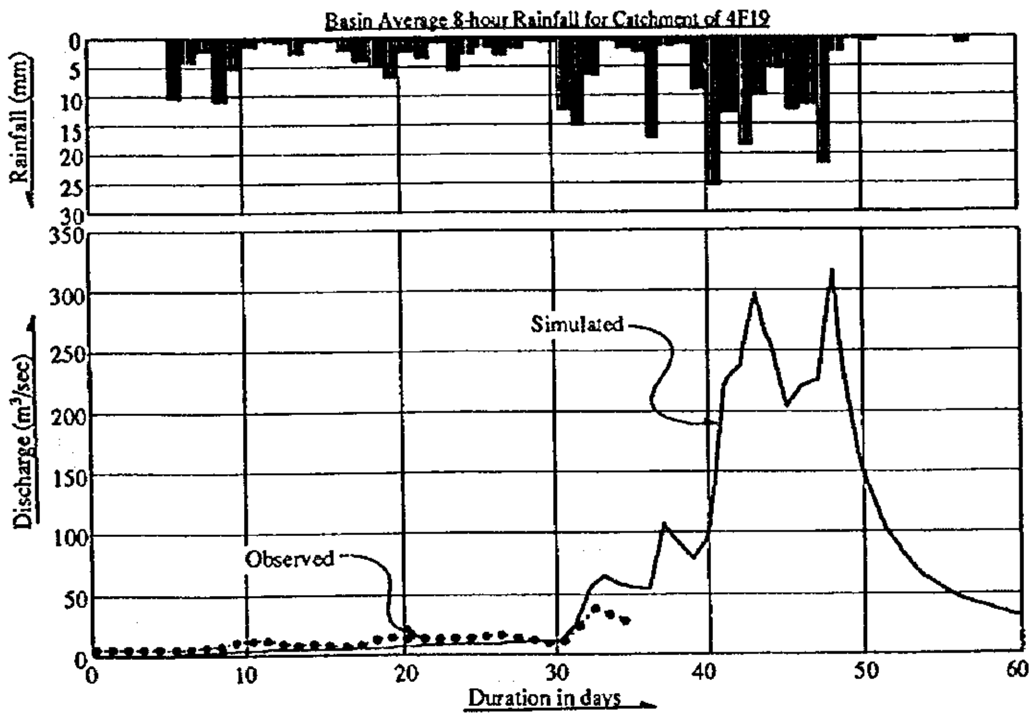


Hydrograph of 1967 Flood at SGS 4ED3 on the Tana Mainstream

JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Observed and Simulated Hydrographs of the 1967 Flood	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.7 (1)

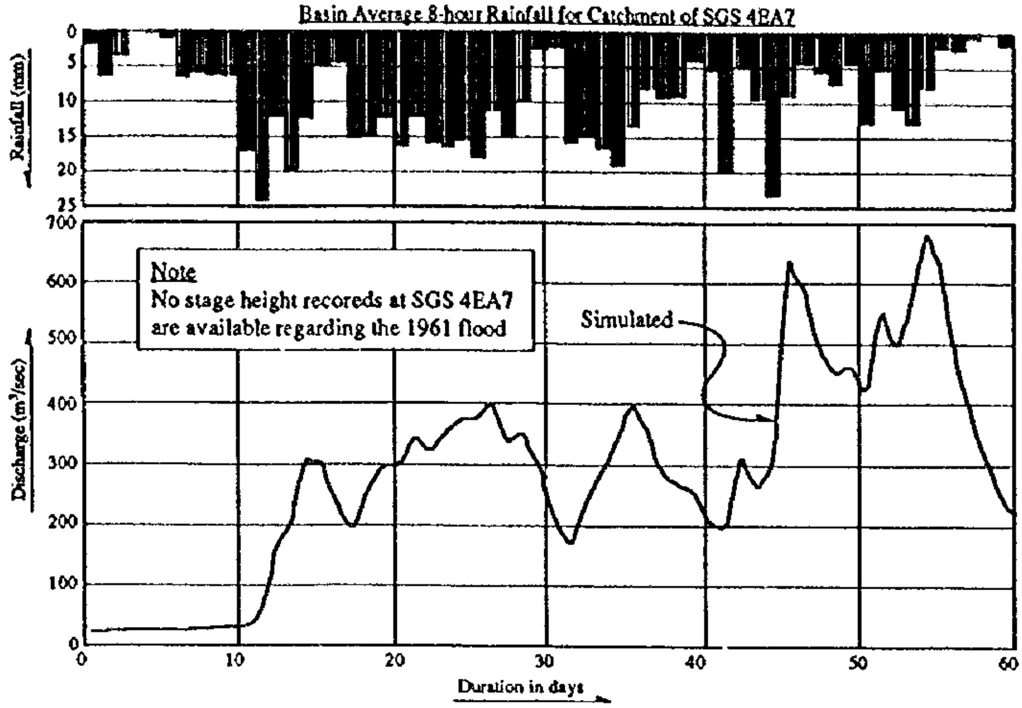


Hydrograph of 1967 Flood at SGS 4F13 on the Tana Mainstream

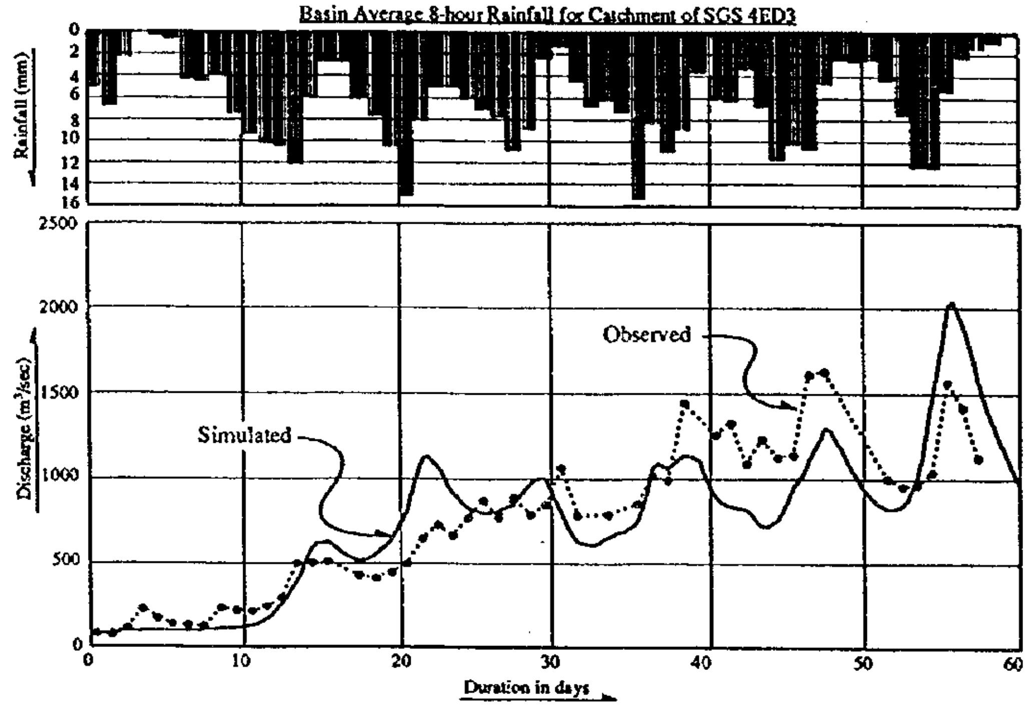


Hydrograph of 1967 Flood at SGS 4F19 on the Mutonga River

JAPAN INTERNATIONAL COOPERATION AGENCY	Comparison of Observed and Simulated Hydrographs of the 1967 Flood	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.7 (2)

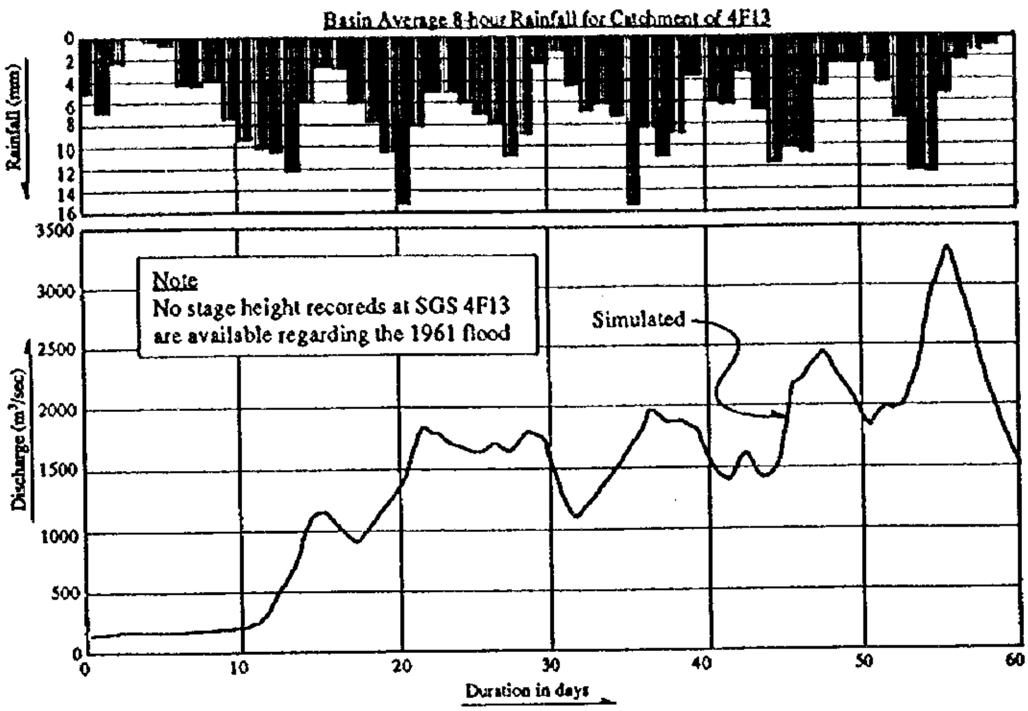


Hydrograph of 1961 Flood at SGS 4EA7 on the Mutonga River

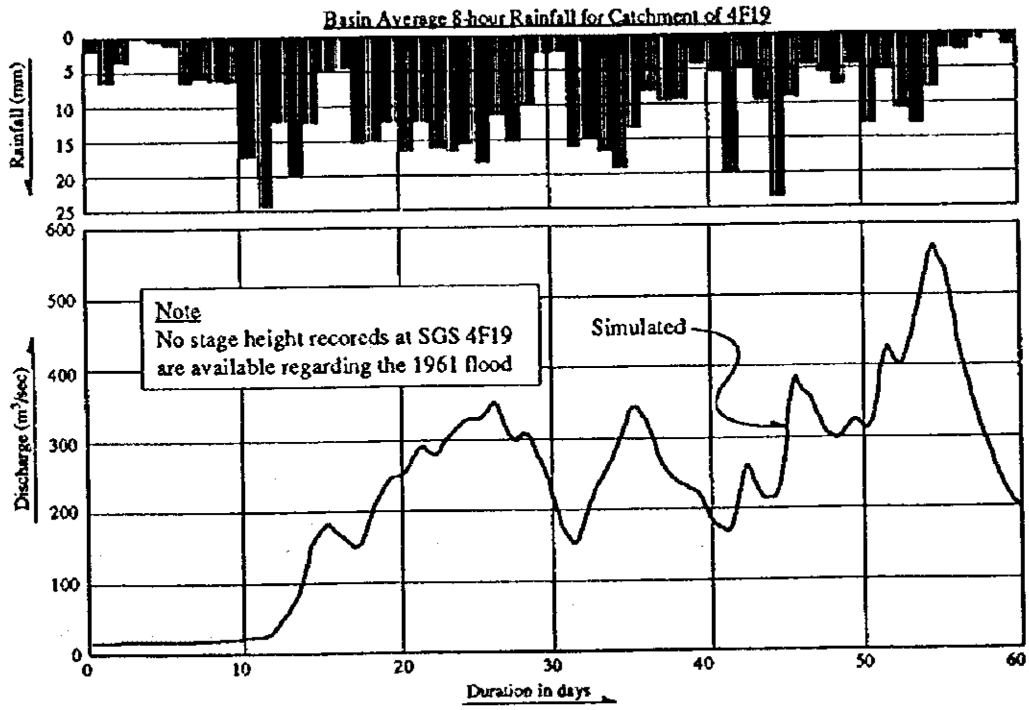


Hydrograph of 1961 Flood at SGS 4ED3 on the Tana Mainstream

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Comparison of Observed and Simulated Hydrographs of the 1961 Flood	Fig. No. B4.8 (1)

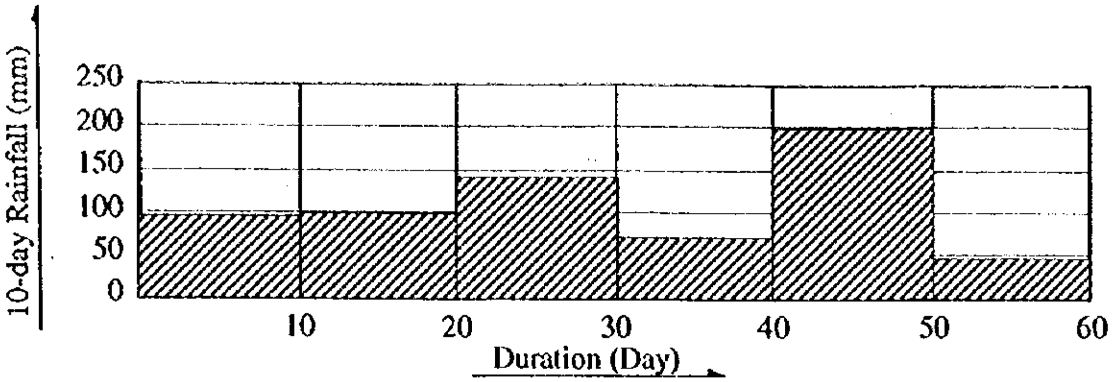


Hydrograph of 1961 Flood at SGS 4F13 on the Tana Mainstream

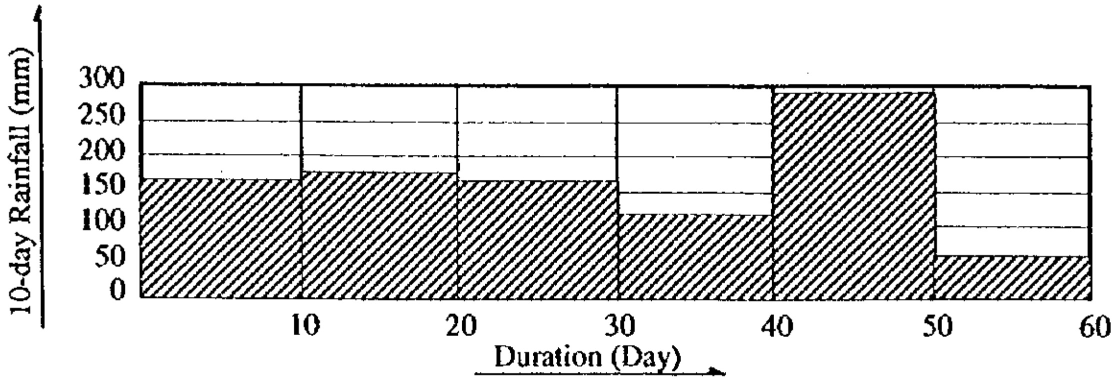


Hydrograph of 1961 Flood at SGS 4F19 on the Mutonga River

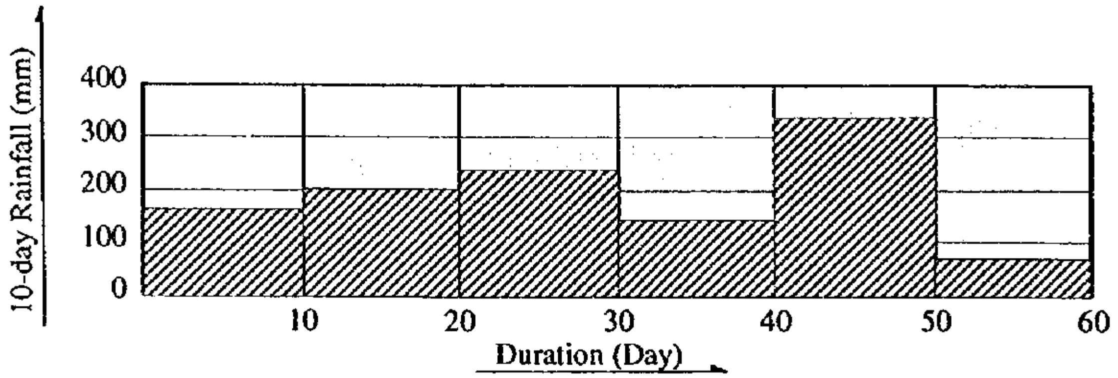
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Comparison of Observed and Simulated Hydrographs of the 1961 Flood	Fig. No. B4.8 (2)



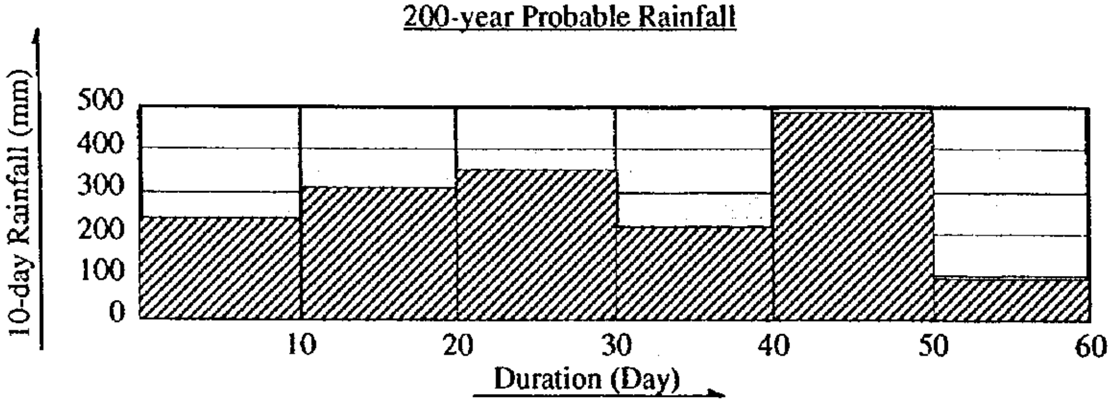
5-year Probable Rainfall



50-year Probable Rainfall

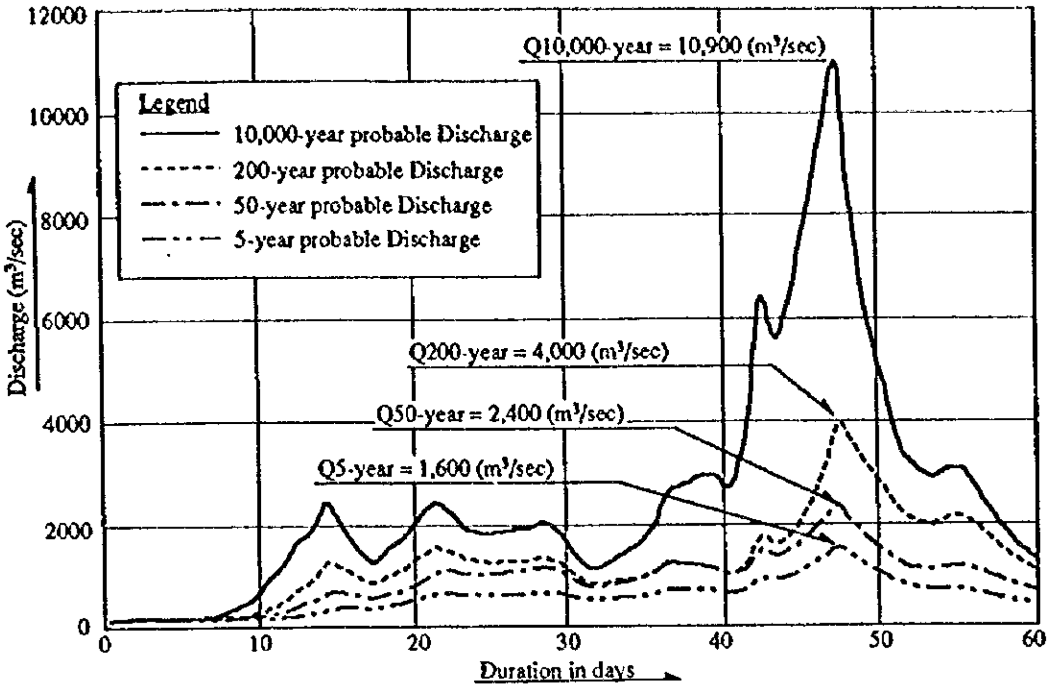


200-year Probable Rainfall

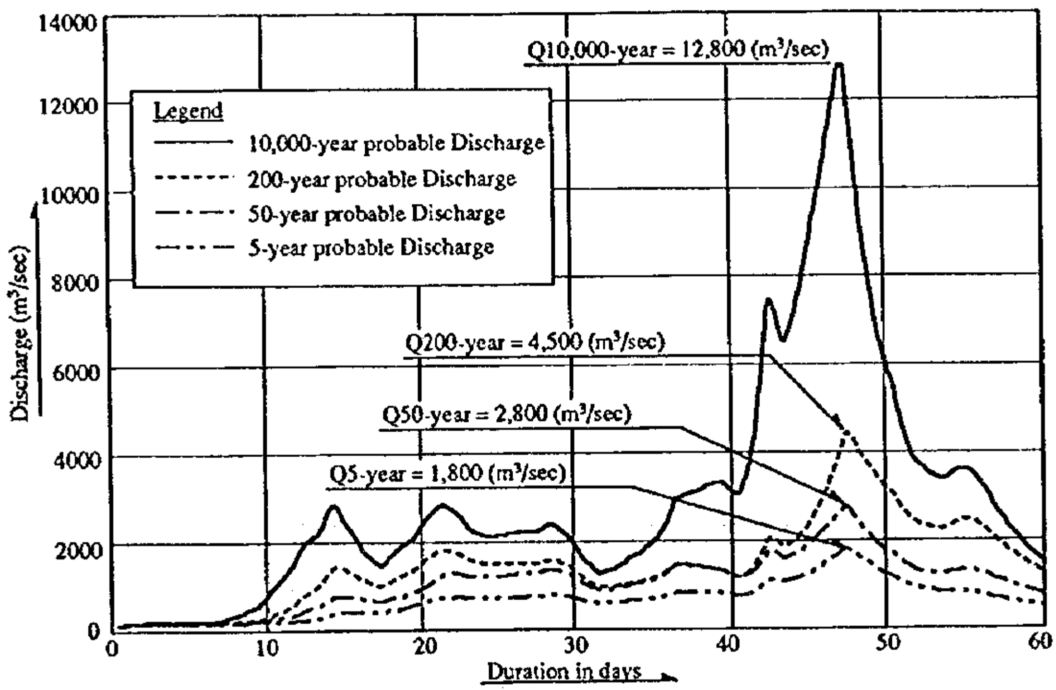


10,000-Probable Rainfall

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Design Rainfall Pattern	Fig. No. B4.9

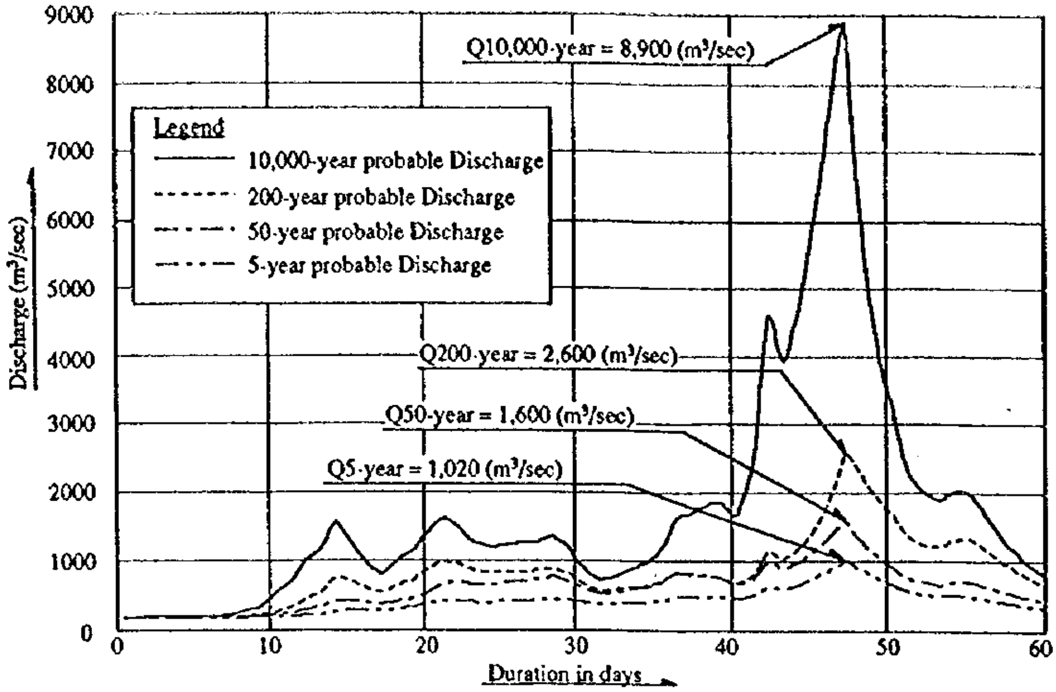


Hydrographs of Probable Floods at Mutonga Dam Site

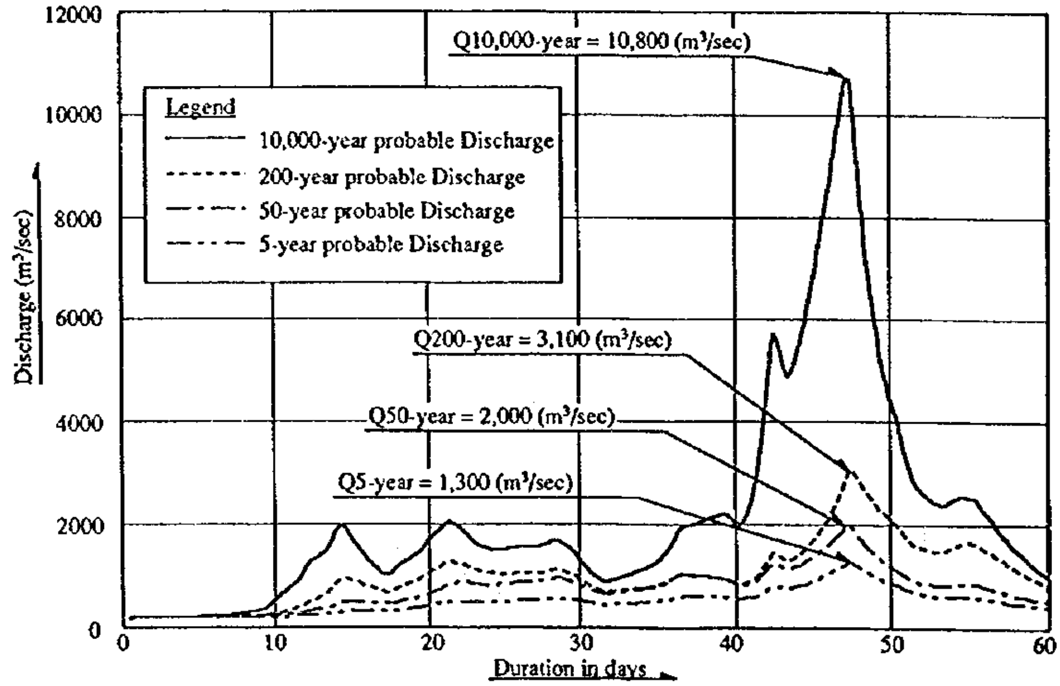


Hydrographs of Probable Floods at Grand Falls Site

JAPAN INTERNATIONAL COOPERATION AGENCY	Estimated Flood Hydrographs at Mutonga and Grand Falls Dam Site (on the without upstream Reservoirs Condition)	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B4.10



Hydrographs of Probable Floods at Mutonga Dam Site



Hydrographs of Probable Floods at Grand Falls Site

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Estimated Flood Hydrographs at Mutonga and Grand Falls Dam Site (on the with upstream Reservoirs Condition)	Fig. No. B4.11

B5 SEDIMENTATION STUDY

B5.1 General

In the Tana river basin, most of the sloped lands are subject to erosion of surface soils. It is foreseen that the high sediment transport occurs in the high mountainous areas around the Mt. Kenya where the high annual rainfall of more than about 1,500 mm/year takes place. In the moderately sloped areas, the lands are utilized for cultivation of paddy and other crops. Besides, new irrigation projects are planned to be developed in the upper Tana Basins. The irrigated paddy field would help to avoid an intrusion of the eroded materials into the river. On the other hand, it has to be noted that in general the sediment transport rate will increase with development of lands in the catchment. Therefore, the sedimentation study needs to be carried out taking into consideration increase of erosion rate attributed to expansion of land uses in future.

Since the Mutonga/Grand Falls hydropower project is planned to be developed as a reservoir type project, the sedimentation study aims ultimately at determining the sediment volume transported into the planned reservoirs and it's deposition rate therein. The sedimentation study on these projects was made primarily based on the results of the suspended load measurements. The water sampling for the suspended load analysis was carried out at SGS 4F13, the Grand Falls dam site as well as at SGS 4F19, in the course of the present environmental survey. Those suspended load data were incorporated in analyzing the sediment yield at the proposed dam site.

Besides, the gross sediment yield at the Grand Falls dam site, which was derived based on the results of the suspended load measurements, were allocated to catchment of Masinga dam and intervening catchments of other existing four (4) dams based on the estimated rate at 4F19 on the Kathita river and that adopted in the Kiambere hydroelectric development project. The net sediment transports at the Mutonga/Grand Falls dam sites were determined in consideration of the sediment volumes trapped by the upstream reservoirs.

B5.2 Suspended Load Yield

The sediment load is broadly divided into suspended and bed loads. Usually, the suspended load contained in stream flow can be quantified by the load measurement, while it is not possible to accurately measure the bed load in natural river. In the usual estimate, the rate of bed load transport is assumed to be equivalent to 10 to 20% to the suspended load. Aiming at making it's estimate conservative, 20% is adopted as the ratio for the Mutonga/Grand Falls project. Unit weight of sediment load is assumed at 1.4 ton/m^3.

Tables B5.1 and B5.2 show the results of laboratory tests for the suspended load analysis. On the basis of the results of the suspended load measurement, a rating curve of the suspended load was plotted on log-log axis as shown in Figures B5.1 to B5.4, and summarized below:

Kiambere Downstream Point

The surveyed data have a good correlation on log axis between the flow discharge and the suspended load yield as shown in Figure B5.1. The following equation is adopted.

$$S = 1.0933 \cdot Q^{1.204}$$

where, S : Suspended load in ton/day

Q : Mean daily discharge in m^3/sec

SGS 4EA7 at the Mutonga River

Three MOWD data as in Figure B5.2 are discarded for establishing the rating curves because those data would provide low estimate. The suspended load data, which were measured on 14 to 20 November 1995 by the JICA Study Team, suggest the daily suspended load weight of more than 100,000 ton. However, the measurement at the downstream SGS 4F13 never indicates so much load transportation. Therefore, the three JICA data are as well discarded. Thus, the rating curve is established as follows.

$$S = 0.024 \cdot Q^{2.8299}$$

SGS 4F19 at the Kathita River

The measured data are scattered widely as shown in Figure B5.3. The rating curve shall be established to the safe side to the dam design. Then, many of MOWD data are discarded for establishing the curve but JICA data are employed as in Figure B5.3. The following equation is adopted.

$$S = 0.64194 \cdot Q^{2.5606}$$

SGS 4F13 at the Grand Falls dam site

The measured data are scattered in narrow range as shown in Figure B5.3. The average rating curve is adopted at this site as follows.

$$S = 0.0010578 \cdot Q^{2.7988}$$

The daily river flow series of the Mutonga and Kathita rivers and the simulated daily outflow series from the Kiambere dam are applied for the above equations, and the suspended load quantity is estimated. The average monthly load is tabulated in Table B5.3 to B5.6 and shown in Figure B5.5. The results are summarized as follows.

Estimated mean annual sediment yield

(Unit: 10^6 m^3/year)

Classification	Kiambere	Mutonga	Kathita	Total	4F13 (GF)
Suspended load	0.09	1.32	0.79	2.20	2.00
Bed load	0.00	0.26	0.16	0.42	0.40
Total	0.09	1.58	0.95	2.62	2.40

As seen in the above table, the total sediment load from the Kiambere dam, Mutonga and Kathita rivers is estimated at 2.62 10^6 m^3/year, while the transported sediment load at SGS 4F13 is estimated at 2.40 10^6 m^3/year. Those figures are different, however, the bigger sediment load of 2.62 10^6 m^3/year is adopted to be on the safe side for the dam design.

According to the report on Feasibility Study for the Kiambere Hydroelectric Development, the sediment transport at Grand Falls was estimated by TRDA in the past to be approximately 7 million ton/year or 5 million m^3/year based on the data surveyed in 1962 to 1965. The larger estimate come from that the upstream dams had not been constructed in those years.

B5.3 Sediment Deposition in the Proposed Reservoirs

In the stage of detailed design for the Kiambere hydroelectric development project, a 50-year sediment deposition of 55 million m^3 was adopted for planning the reservoir. On the other hand, the design code in Japan specifies that the reservoir life is taken at 100 years, unless the facilities for flushing sediments deposited in the reservoir are provided in the dam body or its appurtenant structures. In this study, the sediment deposition volume in the planned reservoirs is estimated adopting the reservoir life of 50 years with the condition to provide sand flushing facility.

The sediment trapping efficiency of the proposed reservoirs is assumed by applying the Bruneis curve shown in Figure B5.6.

	Sediment Trapping Efficiency
Mutonga reservoir	66 %
Low Grand Falls reservoir	92 %
High Grand Falls reservoir	98 %

The estimated sediment volume in the proposed reservoirs is shown in Figure B5.5 and summarized as follows.

Estimated Sediment Deposition for the Reservoir Life

Name of dam	Sediment Inflow (10^6 m^3/yr)	Trap efficiency (%)	Sediment Deposition: Annual Sediment (10^6 m^3/yr)	Sediment Deposition: For 50-year life (10^6 m^3)	Sediment Level (El m)	Sediment Outflow (10^6 m^3/yr)
Mutonga dam	1.67	66	1.10	55	540.35	0.57
Low Grand Falls dam	1.52	92	1.40	70	477.79	0.12
High Grand Falls dam	2.62	98	2.57	128	482.53	0.05

Table B5.1 Suspended Load Sampling Records (1)

Kindaruma

D	M	Yr.	Q (m3/s)	Dens. (ppm)	W (t/day)
7	9	95	117	37	373
9	9	95	71	34	206
11	9	95	99	38	326
13	9	95	111	42	408
15	9	95	114	38	370
17	9	95	75	37	237
19	9	95	72	33	204
21	9	95	72	55	340
23	9	95	84	51	370
25	9	95	90	32	247
27	9	95	111	38	363
29	9	95	114	36	357
1	10	95	99	36	305
3	10	95	72	38	236
5	10	95	108	36	333
29	10	95	120	62	643
31	10	95	120	66	684
2	11	95	114	40	394
4	11	95	120	38	394
6	11	95	105	28	254
8	11	95	114	24	236
10	11	95	120	28	290
12	11	95	117	48	485
14	11	95	117	34	344
16	11	95	120	60	622
18	11	95	120	28	290
20	11	95	120	32	332
22	11	95	123	46	489
24	11	95	106	28	256
26	11	95	114	32	315

Kiambere

D	M	Yr.	Q (m3/s)	Dens. (ppm)	W (t/day)
7	9	95	73	39	249
9	9	95	78	34	227
11	9	95	75	35	224
13	9	95	75	34	219
15	9	95	75	31	204
17	9	95	81	32	223
19	9	95	74	30	192
21	9	95	78	30	200
23	9	95	84	30	215
25	9	95	79	31	209
27	9	95	84	39	283
29	9	95	75	34	218
1	10	95	83	30	212
3	10	95	83	32	230
5	10	95	75	32	208
29	10	95	84	18	132
31	10	95	76	22	145
2	11	95	76	30	196
4	11	95	85	26	193
6	11	95	76	22	146
8	11	95	96	30	250
10	11	95	102	42	371
12	11	95	77	38	256
16	11	95	112	38	371
19	11	95	150	38	494
21	11	95	158	32	438
23	11	95	182	34	539
25	11	95	190	44	724
27	11	95	194	32	537

Mutonga (4EA7)

D	M	Yr.	Q (m3/s)	Dens. (ppm)	W (t/day)
6	9	79	14	8	10
6	10	79	23	70	140
17	10	79	14	51	62
27	2	80	9	10	8
25	3	80	8	12	8
25	8	80	13	27	30
24	12	80	24	89	185
23	1	81	15	22	29
11	6	81	52	593	2,663
9	9	95	15	31	40
11	9	95	16	37	52
13	9	95	16	31	42
15	9	95	15	33	42
17	9	95	14	33	41
19	9	95	14	30	36
21	9	95	14	32	38
23	9	95	13	31	35
25	9	95	13	35	38
27	9	95	12	52	53
29	9	95	12	34	35
1	10	95	11	35	34
3	10	95	11	35	35
5	10	95	11	31	30
27	10	95	184	41,720	663,244
29	10	95	51	227	1,002
31	10	95	153	4,392	58,068
2	11	95	60	304	1,573
4	11	95	55	313	1,488
6	11	95	52	323	1,449
8	11	95	46	321	1,280
10	11	95	39	283	948
12	11	95	53	218	996
14	11	95	165	7,067	100,635
16	11	95	69	1,090	6,497
18	11	95	81	15,687	110,194
20	11	95	64	349	102,903
22	11	95	74	371	2,382
24	11	95	55	469	2,206

Note:

Q : Flow Disvharge (m3/s)
Dens. : Suspended Load Density (ppm)
W : Daily Suspended Load Weight (ton/day)

Data in 1994 and 1995 are the results of JICA survey. Other data are obtained from MOWD.

Table B5.2 Suspended Load Sampling Records (2)

Kathita (4F19)

D	M	Yr.	Q (m3/s)	Dens. (ppm)	W (t/day)
1	9	79	10	6	5
28	11	79	22	31	59
14	12	79	17	69	101
21	12	79	18	29	45
26	2	80	8	3	2
26	3	80	6	15	8
16	4	80	9	67	52
22	5	80	13	51	57
8	8	80	5	96	41
22	8	80	5	43	19
22	9	80	4	28	10
23	2	81	6	45	23
9	3	81	5	25	11
22	4	81	31	272	729
21	5	81	42	398	1,444
25	5	81	37	156	499
28	5	81	33	2,459	7,011
8	6	81	24	110	228
22	6	81	19	49	80
2	7	81	15	631	818
23	7	81	13	1,070	1,202
29	3	82	6	331	172
23	4	82	25	38	82
31	5	82	25	153	330
29	10	82	31	1,992	5,335
24	11	83	7	79	48
8	9	95	7	27	16
10	9	95	7	29	18
12	9	95	7	26	16
14	9	95	7	29	17
16	9	95	6	39	20
18	9	95	6	30	15
20	9	95	6	24	12
22	9	95	5	37	18
24	9	95	5	28	13
26	9	95	5	21	10
28	9	95	5	22	9
30	9	95	5	21	9
2	10	95	5	30	13
4	10	95	5	47	21
6	10	95	5	21	10
28	10	95	21	20,208	36,664
30	10	95	69	4,904	29,149
1	11	95	22	712	1,329
3	11	95	15	548	692
5	11	95	11	212	203
7	11	95	13	144	155
9	11	95	10	297	249
11	11	95	10	122	107
13	11	95	60	28,437	147,170
15	11	95	48	3,500	14,429
17	11	95	30	1,604	4,117
19	11	95	27	701	1,629
21	11	95	21	1,149	2,104
23	11	95	23	2,095	4,181
25	11	95	21	254	465

Grand Falls (4F13)

D	M	Yr.	Q (m3/s)	Dens. (ppm)	W (t/day)
19	10	79	105	21	194
26	2	80	48	24	98
27	3	80	64	18	99
28	4	80	60	10	53
22	8	80	95	37	300
29	9	80	66	31	174
19	11	80	214	490	9,052
21	1	81	111	91	875
28	4	81	256	2,212	48,920
5	11	94	679	7,793	457,383
9	11	94	733	4,048	256,190
10	11	94	1,066	5,100	469,898
12	11	94	711	3,031	186,196
14	11	94	1,493	4,165	537,373
17	11	94	724	2,183	136,630
19	11	94	494	522	22,266
21	11	94	579	1,852	92,647
23	11	94	579	771	38,570
25	11	94	653	387	21,848
29	11	94	634	374	20,377
1	12	94	811	571	39,990
3	12	94	544	317	14,889
8	9	95	101	31	275
10	9	95	104	44	391
12	9	95	103	36	318
14	9	95	102	43	382
16	9	95	100	52	448
18	9	95	98	39	326
20	9	95	99	41	348
22	9	95	100	38	323
24	9	95	98	39	331
26	9	95	96	42	349
28	9	95	100	35	303
30	9	95	97	35	296
2	10	95	91	38	297
4	10	95	102	31	275
8	10	95	102	98	868
28	10	95	330	1,501	42,785
30	10	95	362	1,993	62,017
1	11	95	269	988	22,956
3	11	95	280	168	4,063
5	11	95	236	163	3,315
7	11	95	217	847	15,888
9	11	95	212	176	3,224
11	11	95	225	321	6,246
13	11	95	242	293	6,118
15	11	95	443	555	21,247
17	11	95	303	489	12,802
19	11	95	312	667	17,971
21	11	95	280	113	2,731
23	11	95	415	149	5,339
25	11	95	391	173	5,857

Note:

Q : Flow Disvharge (m3/s)

Dens. : Suspended Load Density (ppm)

W : Daily Suspended Load Weight (ton/day)

Data in 1994 and 1995 are the results of JICA survey. Other data are obtained from MOWD.

Table B5.3 Estimated Suspended Sediment Yield, Kiambere Outflow

(Unit : 1,000 ton)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1957	9	8	9	8	20	16	5	8	9	9	5	5	110
1958	6	5	9	5	22	24	12	10	9	9	6	5	122
1959	5	4	9	5	5	5	5	6	7	9	5	5	69
1960	5	4	5	5	5	5	5	5	5	6	5	5	57
1961	5	4	5	5	5	5	5	5	7	20	157	68	289
1962	29	10	10	10	38	12	7	9	9	9	7	5	154
1963	5	7	9	10	64	25	9	9	9	9	6	5	169
1964	12	8	9	31	44	13	6	9	9	9	8	5	164
1965	8	8	9	7	5	5	5	5	5	8	6	5	74
1966	7	8	9	10	25	10	6	9	9	9	14	5	121
1967	6	6	9	5	35	26	9	10	9	12	19	16	162
1968	10	8	9	27	44	23	12	11	9	9	14	51	227
1969	13	10	10	10	8	5	5	7	9	9	6	6	97
1970	6	5	6	10	16	12	6	9	9	9	7	5	100
1971	5	4	5	5	5	5	5	6	9	9	5	5	68
1972	5	4	5	5	5	5	5	5	5	8	11	11	71
1973	10	8	9	9	7	6	5	6	7	9	5	5	86
1974	6	6	6	5	5	5	7	10	9	9	7	5	77
1975	6	6	7	6	8	6	5	6	5	6	5	5	70
1976	5	4	6	5	6	6	5	6	5	6	5	5	64
1977	5	4	6	8	24	15	6	9	9	9	12	16	124
1978	11	8	9	51	40	10	6	9	9	9	8	6	176
1979	7	8	9	16	46	34	10	9	9	9	8	5	171
1980	6	7	9	6	5	5	5	6	9	9	10	7	83
1981	8	8	9	21	46	15	6	9	9	9	7	5	153
1982	6	6	9	5	17	21	6	9	9	11	11	16	125
1983	10	8	9	9	21	12	6	9	9	9	6	5	112
1984	5	6	6	5	5	5	5	5	5	7	5	7	63
1985	7	6	6	7	18	13	5	9	9	9	6	5	99
1986	5	5	6	5	16	19	6	9	9	9	6	7	101
1987	7	7	9	6	6	7	5	7	9	9	6	5	83
1988	5	5	8	11	57	12	6	9	9	9	12	9	153
1989	9	8	9	10	13	10	5	8	9	9	14	16	122
1990	21	9	14	47	41	15	7	10	9	10	10	12	203
Min.	5	4	5	5	5	5	5	5	5	6	5	5	57
Avg.	8	7	8	11	21	12	6	8	8	9	12	10	121
Max.	29	10	14	51	64	34	12	11	9	20	157	68	289

Table B5.4 Estimated Suspended Sediment Yield, Mutonga River

(Unit : 1,000 ton)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1957	3	0	0	30	160	13	0	0	0	0	30	87	323
1958	7	0	0	21	286	27	1	0	0	0	29	168	539
1959	20	1	0	1	43	4	0	0	0	0	24	43	135
1960	4	0	3	41	10	0	0	0	0	6	21	6	92
1961	1	0	0	32	70	5	0	0	0	1,481	11,683	2,418	15,690
1962	49	3	1	28	200	19	1	0	0	4	5	1	311
1963	0	0	0	332	498	31	2	0	0	0	144	207	1,216
1964	78	4	4	338	168	6	1	0	0	0	3	118	719
1965	26	2	0	8	53	4	1	0	0	0	161	48	304
1966	3	1	12	384	171	11	3	2	1	376	1,331	22	2,317
1967	3	1	1	25	2,501	65	9	4	3	89	1,101	642	4,443
1968	23	8	166	941	780	64	19	8	3	19	2,434	5,831	10,296
1969	83	23	45	16	140	18	5	3	1	3	80	27	444
1970	5	2	9	538	168	13	5	2	1	3	10	2	758
1971	1	0	0	58	114	13	4	2	1	1	7	7	205
1972	2	1	0	1	18	9	3	1	0	1	110	23	168
1973	10	2	1	20	12	4	1	1	0	1	19	4	76
1974	1	0	2	190	42	4	7	2	1	7	53	9	317
1975	2	0	0	81	49	5	1	1	0	7	53	4	205
1976	0	0	0	5	10	4	1	0	0	2	22	15	60
1977	4	1	5	304	336	109	8	1	0	0	439	167	1,374
1978	20	5	148	1,521	1,023	31	8	3	1	74	220	273	3,327
1979	115	243	30	656	518	64	10	3	1	4	690	24	2,356
1980	5	2	1	13	51	8	2	1	1	2	256	37	379
1981	4	1	48	997	299	56	10	3	2	7	46	14	1,488
1982	3	1	0	185	277	48	9	3	2	346	708	222	1,804
1983	30	4	1	551	311	15	4	2	1	4	91	18	1,029
1984	10	2	1	6	4	1	0	0	0	44	106	47	223
1985	6	3	7	264	286	23	7	2	1	5	25	18	646
1986	3	1	2	85	264	19	4	1	1	4	351	424	1,158
1987	16	2	1	5	10	9	2	1	0	0	37	10	94
1988	2	1	6	1,632	1,111	30	4	2	1	36	459	322	3,604
1989	149	5	7	131	73	15	4	1	1	160	2,550	875	3,973
1990	91	5	127	1,326	213	26	4	1	1	83	334	448	2,659
Min.	0	0	0	1	4	0	0	0	0	0	3	1	60
Avg.	23	10	19	317	302	23	4	2	1	81	695	370	1,845
Max.	149	243	166	1,632	2,501	109	19	8	3	1,481	11,683	5,831	15,690

Table B5.5 Estimated Suspended Sediment Yield, Kathita River

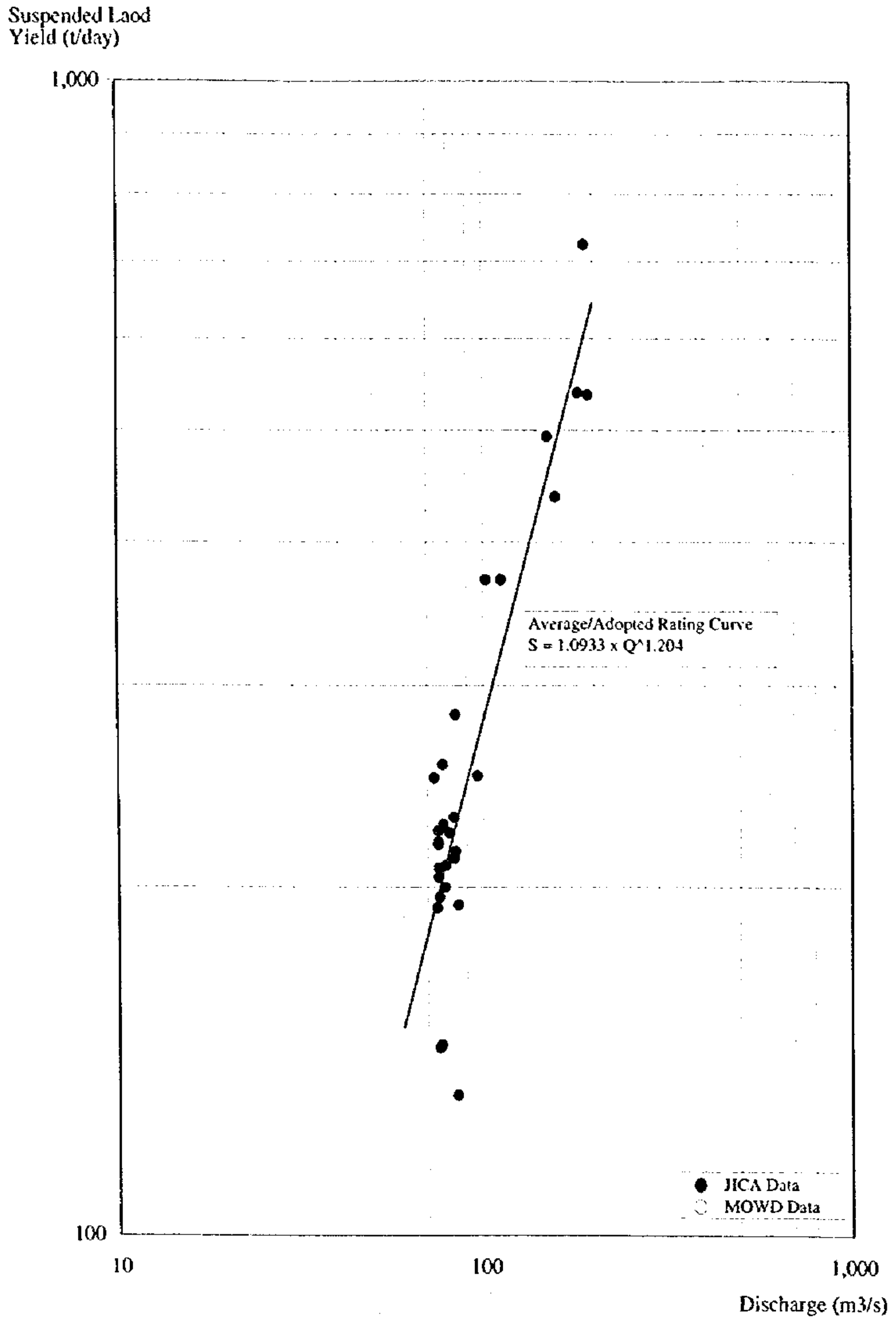
(Unit : 1,000 ton)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1957	11	3	3	9	113	12	3	2	2	4	146	248	554
1958	13	11	5	39	153	11	5	4	3	3	25	63	333
1959	14	6	3	4	69	7	3	2	2	2	49	116	277
1960	10	3	16	169	43	5	3	3	2	15	43	13	324
1961	5	2	2	69	68	6	3	2	2	646	5,156	1,035	6,996
1962	60	19	14	44	307	29	12	10	8	15	18	17	553
1963	9	6	6	140	368	25	11	8	6	6	150	403	1,139
1964	178	17	13	238	144	15	11	9	7	16	61	290	998
1965	77	16	10	26	37	9	7	6	5	22	159	36	411
1966	8	6	15	1,298	497	24	10	5	2	12	1,142	62	3,081
1967	7	3	2	33	1,092	73	15	10	8	69	648	436	2,396
1968	24	19	153	586	437	89	38	25	15	28	536	1,171	3,122
1969	115	60	79	152	200	31	15	10	5	12	70	36	786
1970	10	6	11	162	21	10	5	3	3	3	15	4	254
1971	2	1	1	132	26	5	3	2	2	4	22	13	214
1972	3	2	4	4	60	7	3	1	1	89	466	59	698
1973	22	3	2	14	4	2	1	1	1	1	270	4	325
1974	1	1	69	188	46	6	3	2	1	1	58	127	501
1975	2	1	1	491	9	3	1	1	0	7	83	9	608
1976	3	1	0	9	7	6	1	1	0	0	15	43	86
1977	6	2	10	116	139	30	21	13	9	5	202	328	882
1978	92	27	1,123	1,405	441	66	23	12	8	474	141	442	4,253
1979	167	145	182	117	409	49	18	11	5	6	201	19	1,330
1980	7	4	3	16	13	4	3	2	2	2	69	14	138
1981	6	3	96	132	196	30	16	8	4	40	42	14	585
1982	10	6	4	46	73	21	9	125	3	86	201	157	742
1983	42	15	8	49	81	11	7	5	4	3	37	16	278
1984	8	2	2	2	3	1	1	1	1	75	454	183	733
1985	7	5	18	225	139	24	9	6	5	5	27	56	525
1986	7	3	3	96	85	17	9	5	4	3	286	243	761
1987	28	6	5	176	13	8	4	2	1	1	91	63	398
1988	5	2	4	585	227	22	5	5	2	108	360	276	1,601
1989	82	7	15	78	52	22	11	7	4	27	312	276	892
1990	90	24	80	246	81	31	28	12	6	37	297	116	1,048
Min.	1	1	0	2	3	1	1	1	0	0	15	4	86
Avg.	33	13	58	209	166	21	9	9	4	54	349	188	1,112
Max.	178	145	1,123	1,405	1,092	89	38	125	15	646	5,156	1,171	6,996

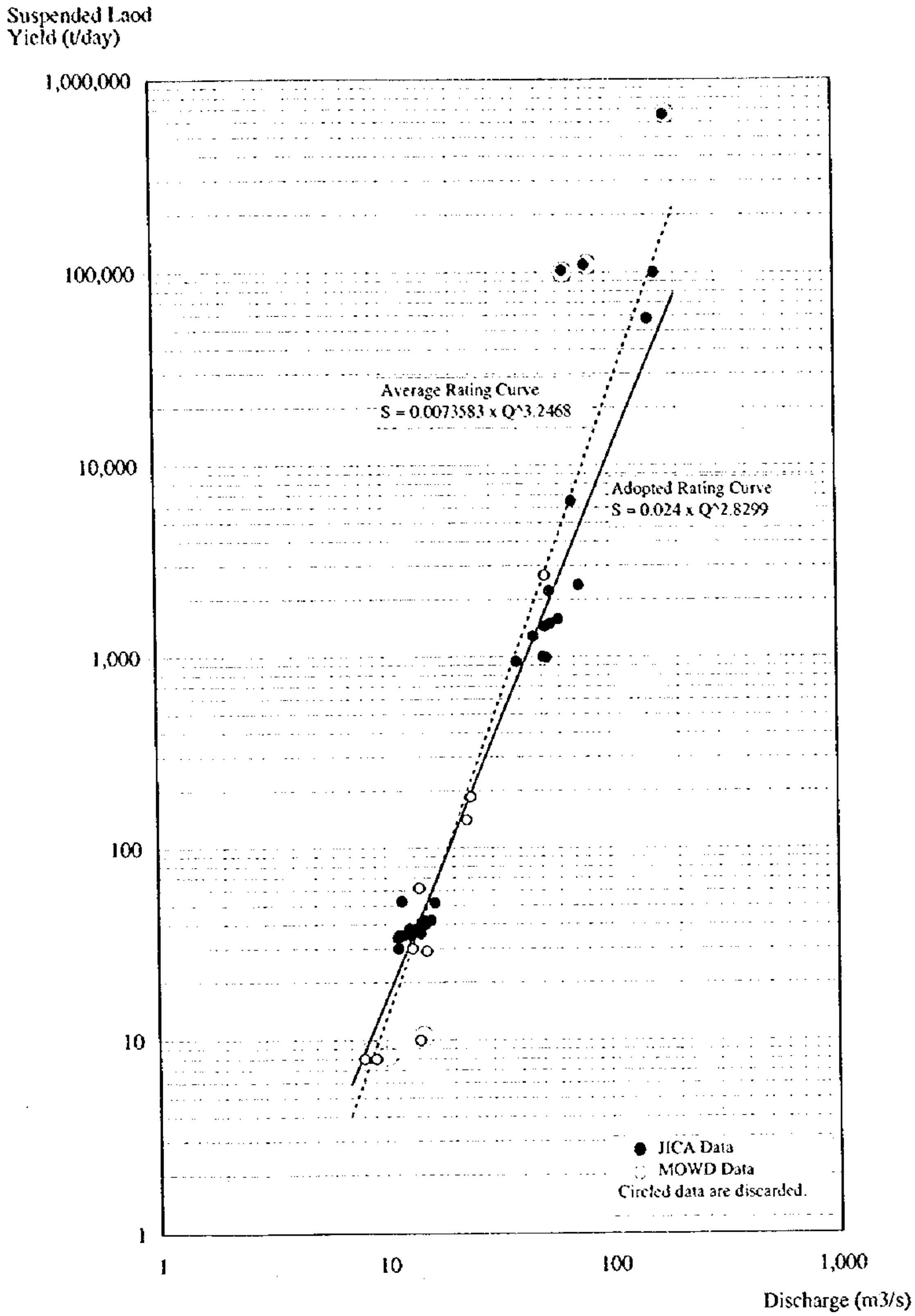
Table B5.6 Estimated Suspended Sediment Yield at 4F13

(Unit : 1,000 ton)

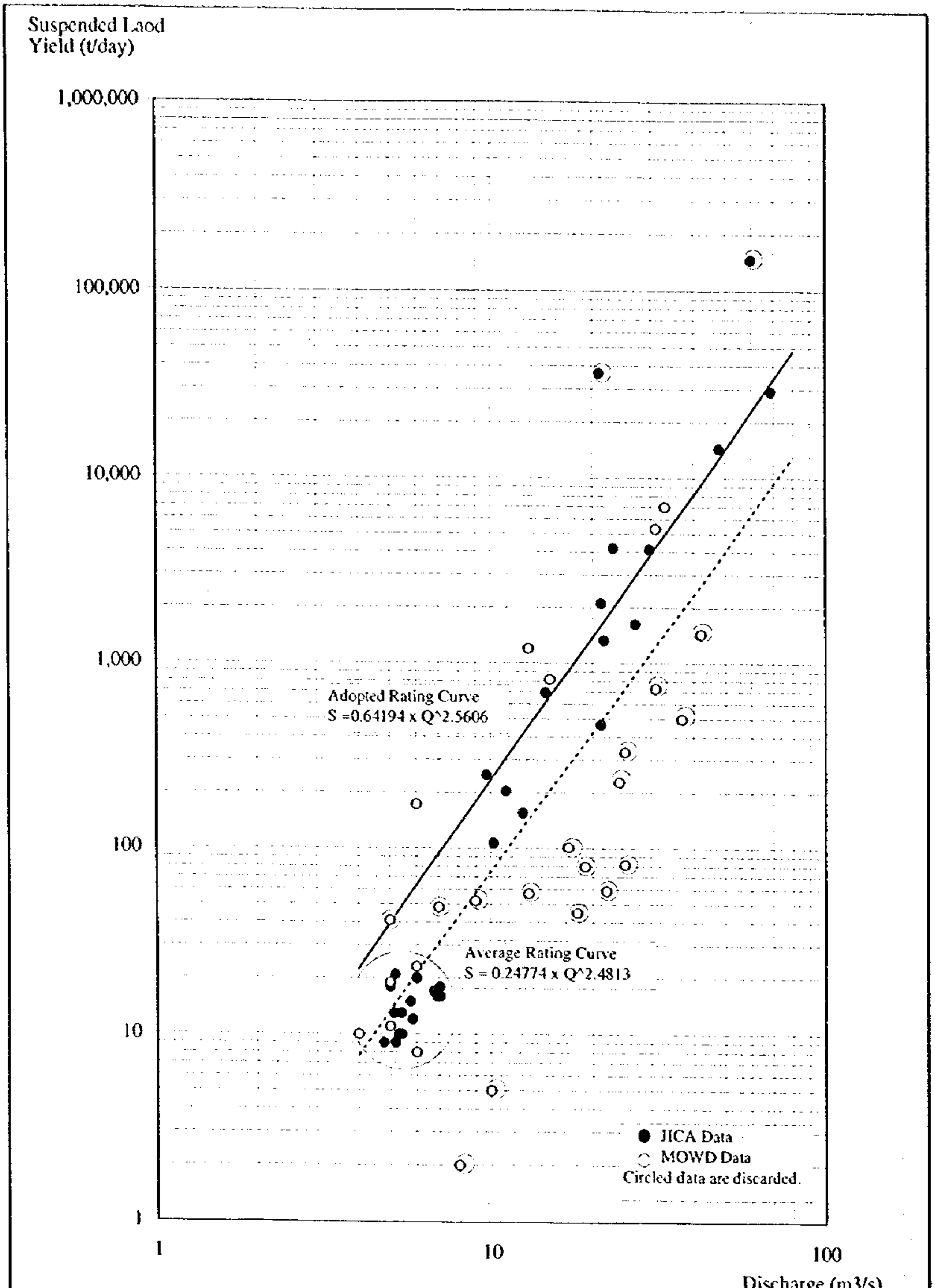
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1957	28	19	18	31	345	127	7	16	16	18	30	54	708
1958	18	9	20	17	514	284	39	24	17	18	27	49	1,034
1959	16	7	19	7	27	9	7	8	11	18	20	31	179
1960	10	5	10	34	15	6	5	5	4	15	20	11	141
1961	7	5	5	24	33	9	6	5	11	934	32,217	5,795	39,050
1962	477	43	31	57	1,178	73	15	23	20	28	26	9	1,980
1963	9	15	21	230	3,181	338	30	23	20	21	54	93	4,034
1964	138	30	28	1,630	1,350	71	14	24	20	23	29	58	3,416
1965	44	26	23	22	26	9	7	6	5	22	68	25	284
1966	19	23	32	234	646	47	14	24	21	59	597	23	1,739
1967	13	13	21	19	1,832	446	39	35	29	97	701	443	3,686
1968	52	33	108	1,401	1,810	335	70	50	29	41	629	4,968	9,527
1969	131	68	70	69	95	17	11	17	23	27	36	25	589
1970	17	11	14	215	187	63	14	25	21	25	24	8	626
1971	6	5	5	28	34	13	11	12	20	22	14	11	181
1972	8	6	6	7	18	11	8	6	4	23	119	64	278
1973	42	24	21	34	25	13	8	9	10	21	23	9	239
1974	8	8	12	56	23	9	17	28	19	23	46	16	265
1975	10	8	12	59	37	13	8	9	6	10	23	10	205
1976	6	4	6	13	17	14	8	8	6	8	14	16	120
1977	10	7	11	110	518	158	21	26	21	22	242	259	1,404
1978	68	32	135	3,226	1,896	66	19	30	24	64	101	101	5,760
1979	68	107	62	383	1,653	696	51	29	22	26	165	22	3,286
1980	17	16	22	17	22	10	8	10	18	22	125	38	325
1981	23	22	48	586	1,467	166	19	28	23	30	34	15	2,459
1982	13	11	19	46	374	267	20	38	22	139	249	258	1,456
1983	58	29	24	104	349	67	13	24	21	25	41	15	773
1984	14	11	11	9	8	5	5	5	4	38	56	46	213
1985	19	13	15	93	325	100	14	25	22	26	25	20	696
1986	9	9	10	30	232	175	17	23	20	24	71	109	730
1987	28	19	23	25	17	22	10	15	18	19	25	14	234
1988	9	9	24	518	3,032	88	13	25	21	44	202	128	4,113
1989	79	29	32	83	119	56	13	23	22	72	534	379	1,440
1990	324	36	151	2,006	1,007	118	22	31	22	65	161	197	4,139
Min.	6	4	5	7	8	5	5	5	4	8	14	8	120
Avg.	53	21	31	336	659	115	17	20	17	61	1,081	392	2,803
Max.	477	107	151	3,226	3,181	696	70	50	29	934	32,217	5,795	39,050



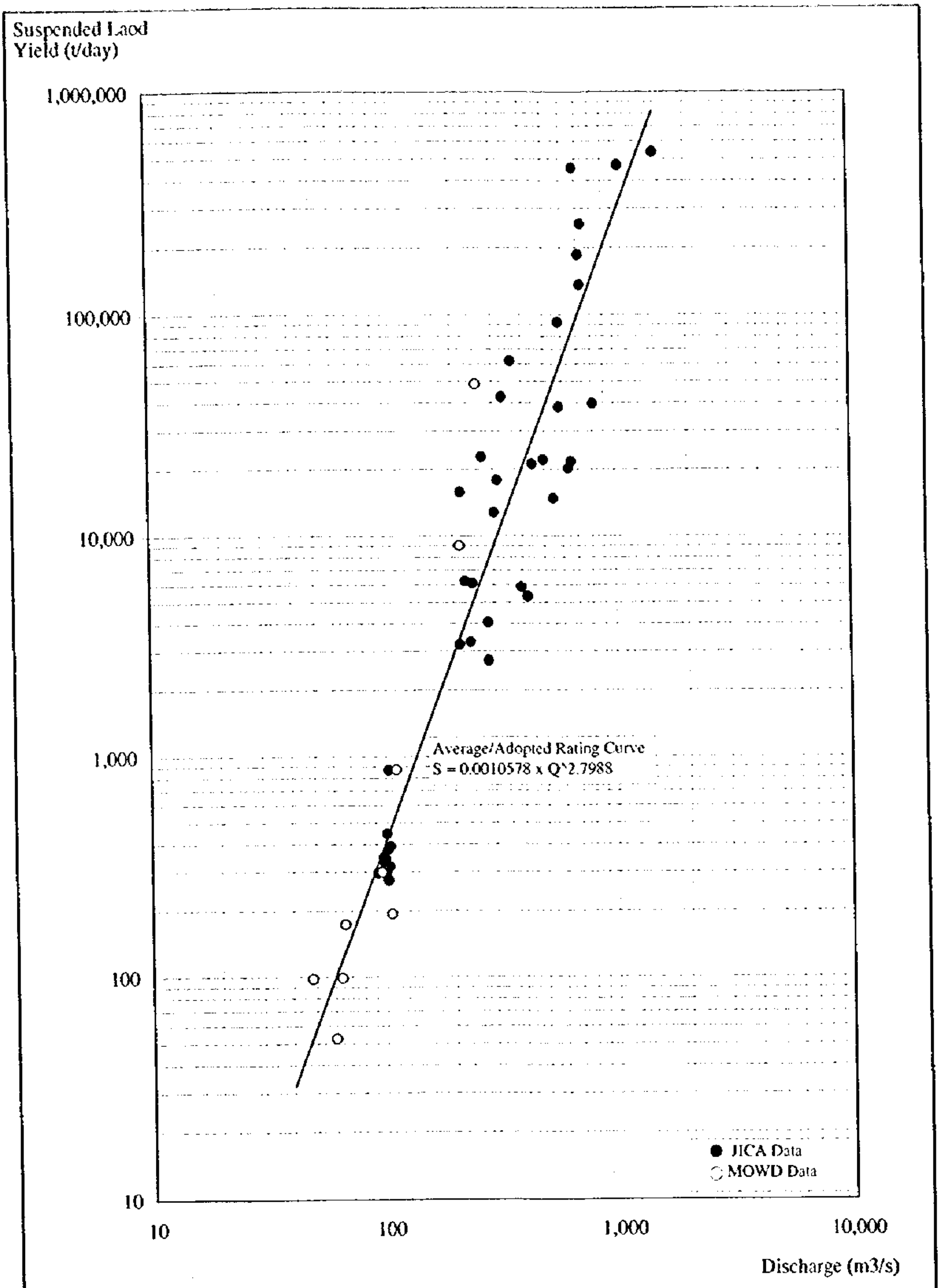
JAPAN INTERNATIONAL COOPERATION AGENCY	Suspended Load Density Curve at the Kiambere Dam downstream point	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B5.1



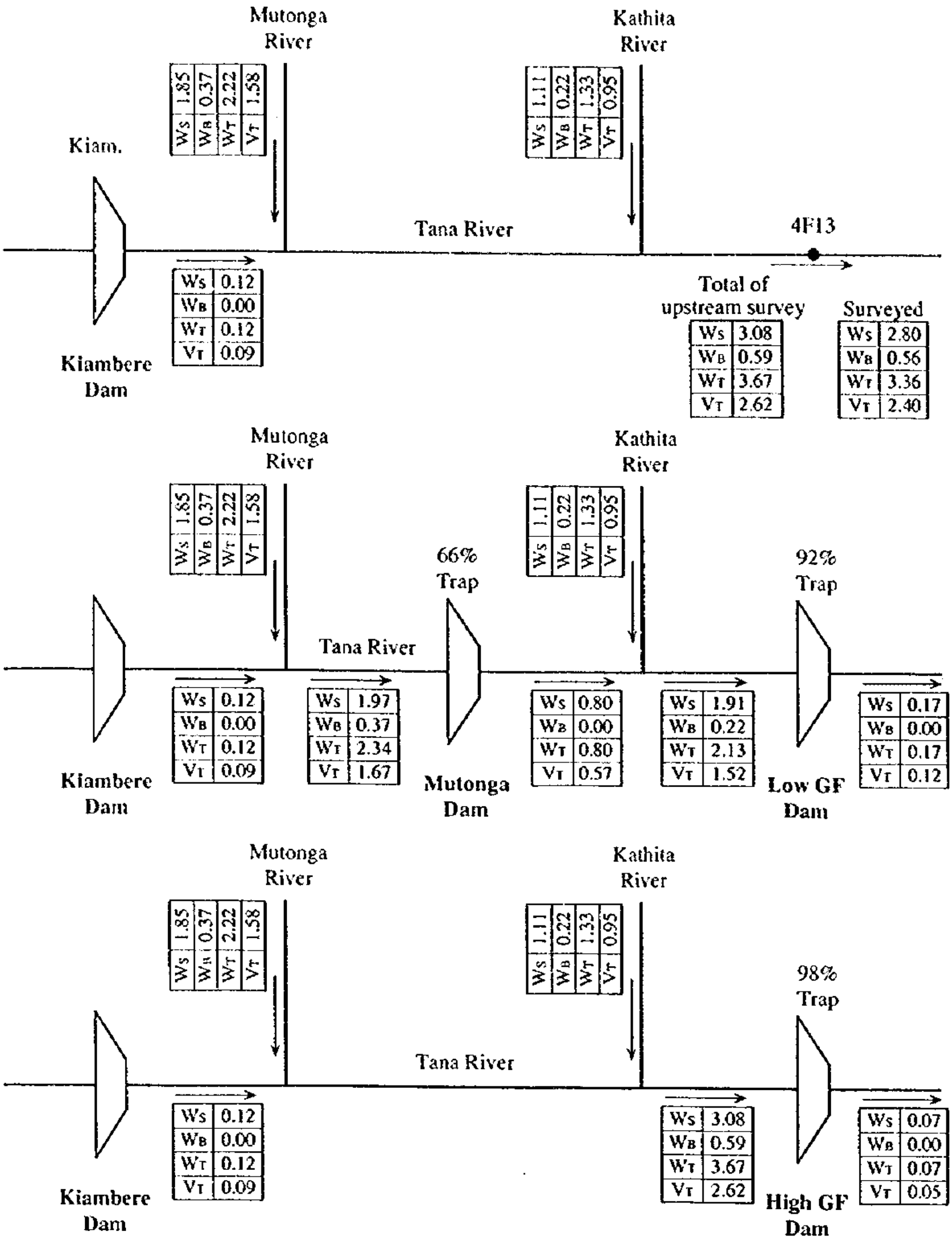
JAPAN INTERNATIONAL COOPERATION AGENCY	Suspended Load Density Curve at SGS 4EA7 of Mutonga Rive	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B5.2



JAPAN INTERNATIONAL COOPERATION AGENCY	Suspended Load Density Curve at SGS 4F19 of Kathita Rive	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B5.3

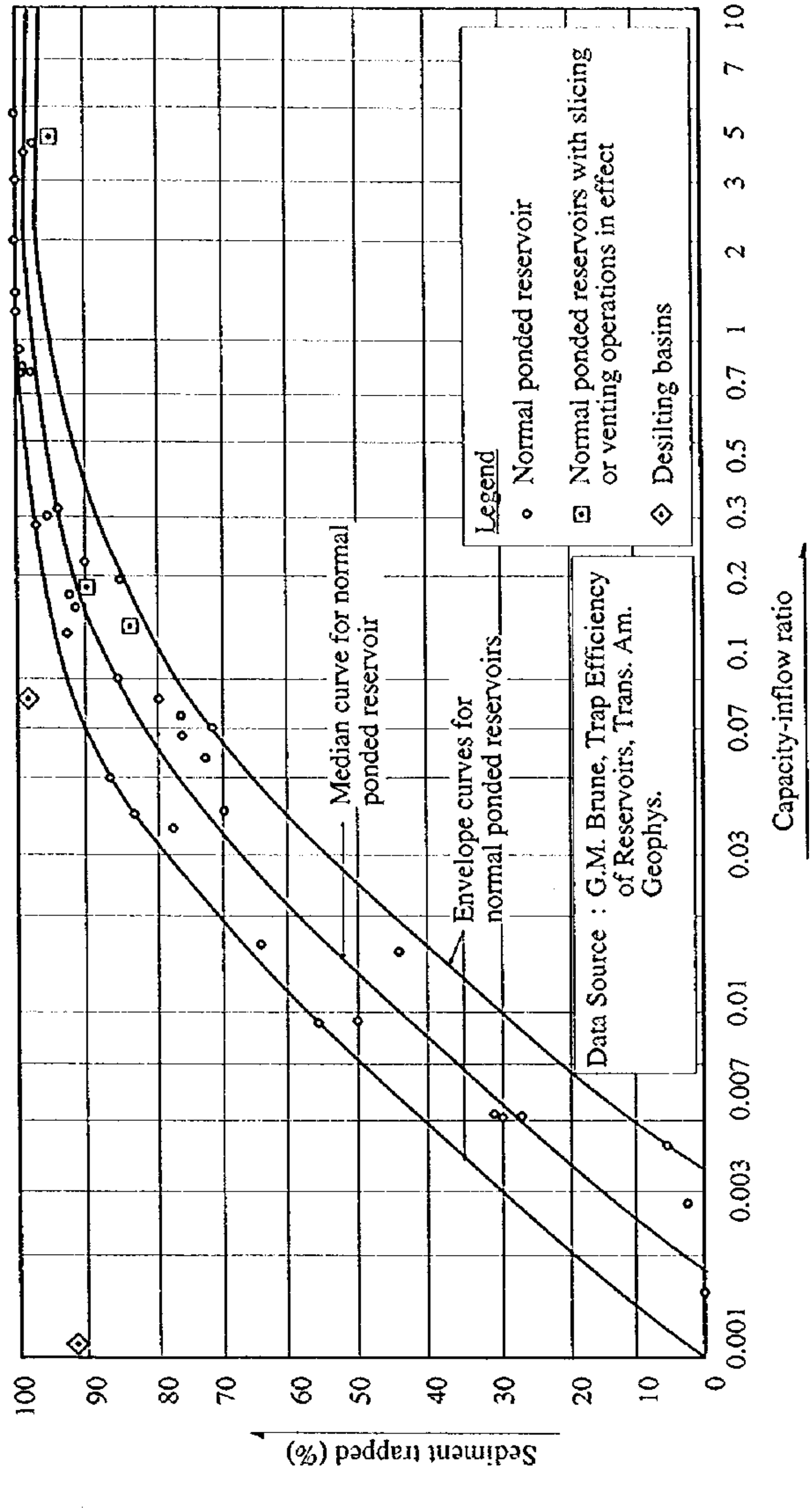


JAPAN INTERNATIONAL COOPERATION AGENCY	Suspended Load Density Curve at SGS 4F13 at Grand Falls	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B5.4



Legend :
WS : Weight of Suspended Load (10^6ton/year)
WB : Weight of Bed Load (10^6ton/year)
WT : Weight of Sediment Load (10^6ton/year)
VT : Volume of Sediment Load (10^6m^3/year)

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Estimate of Annual Sediment Transportation	Fig. No. B5. 5



JAPAN INTERNATIONAL COOPERATION AGENCY	Reservoir-trap Efficiency as a Function of the Capacity-inflow Ratio	Fig. No.
REPUBLIC OF KENYA		
MUTONGA/GRAND FALLS HYDROPOWER PROJECT		B5.6