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DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT
MINISTRY OF PUBLIC WORKS
REPUBLIC OF INDONESIA

JRATUNSELUNA BASIN UPDATED DEVELOPMENT PLAN

PART I

TUNTANG/JRAGUNG RIVERS BASINS
INTEGRATED DEVELOPMENT PLAN

PART II

TUNTANG AND RELATED RIVERS BASINS
DEVELOPMENT PLAN

APPENDIX A

HYDROLOGY

MAY 1980

SUBMITTED BY

PRC ENGINEERING CONSULTANTS, INC.
ENGLEWOOD, COLORADO, U.S.A. SEMARANG, INDONESIA

DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT
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PREFACE

The Directorate General of Water Resources Development (DGWRD) of the ministry of Public Works, Government of Indonesia (GOI) contracted PRC Engineering Consultants, Inc. (PRC/ECI) to provide consulting engineering service for preparing an integrated development plan for the Tuntang/Jragung Rivers in the Jratunseluna Basin. The study for the preparation of the plan started on May 16, 1979 and was originally scheduled to be completed on November 30, 1979.

An interim report on the study was submitted by PRC/ECI on August 15, 1979 which was reviewed by all the concerned agencies and later discussed on September 24, 1979 in a meeting held by the DGWRD at Jakarta. In that meeting and in subsequent discussions between PRC/ECI and DGWRD, it was the consensus of opinion of all the participants that it would be very beneficial if the study on the Tuntang/Jragung Rivers could be modified by including the entire Jratunseluna Basin in certain aspects of the study. In that modified study the interrelationships of the existing, proposed and the potential development works of the Tuntang/Jragung subbasins and those of the adjoining subbasins within the Jratunseluna Basin should be examined. Thus, the master plan for the development of the Jratunseluna Basin which was prepared earlier by NEDECO in the year 1973, would be reviewed and updated. The changes in criteria and constraints which have occurred and the large amount of new data which have become available since preparation of the original master plan would be incorporated in the modified study for formulating a conceptual optimized development plan. The original contract between GOI and PRC/ECI for the engineering services was, therefore, amended to include the revised scope of work for the modified study.

For the preparation of the integrated development plan for the Tuntang/Jragung Rivers, as contemplated originally, a report was prepared on Hydrology for supporting the proposed plan. That report is being produced as Part I Appendix A - Hydrology, related to the Tuntang/Jragung Rivers Basins Integrated Development Plan.

The above mentioned modified study to update the Master Plan for the Jratunseluna Basin was started in December 1979 and completed in May 1980. The results of that study pertinent to the hydrological investigations done by the consultant to support the proposed plan are reported in this document as Part II Appendix A - Hydrology, related to the Tuntang and Related Rivers Basins Development Plan.

Semarang, May 1980 PRC Engineering Consultants, Inc.

PART I

TUNTANG/JRAGUNG RIVERS BASINS
INTEGRATED DEVELOPMENT PLAN

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TUNTANG/JRAGUNG RIVERS BASINS

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APPENDIX A - PART I

HYDROLOGY

A.1. DESCRIPTION OF WATERSHEDS

A.1.1. General

The Tuntang and Jragung watersheds are adjacent basins having their headwaters on the slopes of the chain of volcanoes, Merbabu, Telomoyo and Ungaran (Figure A-1). Streams drain down from the volcanoes' upper slopes flowing out in a radial pattern, incising their beds into the volcanic debris.

The Rawa Pening subbasin is a natural depression at the upper end of the Tuntang River watershed. Surface runoff and groundwater from the subbasin flow into Rawa Pening lake which forms the source of the Tuntang River as it drains from the lake to the northeast.

Downstream from the Rawa Pening subbasin, a large part of the Tuntang River catchment is drained by two major tributaries: the Senjoyo River having a drainage area of 120 km^2 and the Bancak or Ngromo River with a drainage area of 140 km^2. These tributaries join the Tuntang River immediately upstream from the Gunung Wulan damsite.

Within the Jragung watershed upstream from the proposed damsite, the Klampok and Trimo Rivers combine to form the Jragung River. The drainage area of the Klampok River is 60 km^2 and that of the Trimo River is 30 km^2. At the damsite, the catchment area of the Jragung River is 94 km^2.

Subsurface flows within the Tuntang and Jragung River systems may be complicated, particularly in the upper Tuntang watershed where springs feed into Rawa Pening. Since nothing is known about the movement of groundwater in the area, it has been necessary to assume that there is no transfer of groundwater to or from the adjacent catchments. In other words, the boundaries of the subsurface drainage system are assumed to be coincident with the boundaries of the surface drainage system. For the purposes of this report, the area within the drainage system boundaries is referred to as the watershed, basin, catchment or drainage area.

The catchment areas of the subbasins are:

Tuntang River at Glapan Weir	796 km^2
Tuntang River at Gunung Wulan damsite	669 km^2
Tuntang River at Jelok Weir (also referred to as Rawa Pening watershed)	282 km^2
Jragung River at Jragung damsite	94 km^2

A map of the Tuntang and Jragung catchments is given in Figure A-1. A summary of the values describing the hydrology of the catchments is given in Table A-1.

A.1.2. Geology

A study of the surficial geology of the upper watersheds of the Jragung, Tuntang, and Serang Rivers was made to aid in the interpretation of sediment yield data. The information was obtained from geologic maps prepared by the Geological Survey of Indonesia.

A.1.2.a. Jragung Catchment

Only the upstream 65 km^2 of the Jragung catchment upstream from the Borangan Bridge is shown on the 1:100,000 scale geologic map [1]. The map indicates that the soils are formed from the following rock types.

Map Unit	Percent of Area
Volcanic products	
Young lahar and lava flows	2
Lava flow from Ungaran	65
Sedimentary rocks	
Volcanic bre	21
Marine beds	10
Intrusive rocks	2
	100

Other factors being equal, it is the marine beds which produce the most products of erosion. These are interbedded claystone, marl, sandstone, conglomerate, volcanic breccia and limestone. Claystone predominates and is, in part, calcareous and marl.

The marine beds are mapped as areas of landslides and talus deposits.

A.1.2.b. Rawa Pening Catchment

The geology of the Rawa Pening catchment has been mapped at the 1:100,000 scale [1]. This area includes the lake and the alluvial plains to the west and east of the lake. The areas are given below:

Map Unit	Percent of Area
Volcanic products	
Lava from Ungaran	12
Lava from Merbabu	27
Volcanic rocks from other volcanoes	20
Undifferentiated young lahar and lava flows	3
Sedimentary rocks	
Volcanic breccia	16
Marine beds and others	1
Intrusive rocks	1
Alluvium	13
Lake	7
	100

In general, the soil produced from volcanic rock is permeable and resistant to erosion when moist. The soil erodibility values obtained for volcanic soils are the lowest of all soils reported by the research group in Bogor [2].

A.1.2.c. Tuntang Catchment

The geology of the drainage area upstream from the Glapan damsite, but excluding Rawa Pening, has been mapped at the 1:500,000 scale [3]. Estimates of the areas of the surficial geologic units are as follows.

Map Unit	Percent of Area
Volcanic products	
Undifferentiated	43
Young quarternary	1
Volcanic facies	
Pleistocene	19
Sedimentary facies	
Pleistocene	2
Pleiocene	2
Miocene	33
	100

In the Tuntang catchment upstream from the Glapan damsite, 37 percent of the area is soil originating from sedimentary rock and is considered much more erodible than soils formed from volcanic products.

A.1.2.d. Kedungombo Catchment

The drainage area upstream from the Kedungombo damsite on the Serang River is 614 km^2. This catchment is adjacent to and east of the Rawa Pening and Tuntang catchments.

The sediment yield at the Kedungombo damsite has been estimated from measurements [4] so the area is of interest in this study.

The surficial geology of the area has been mapped at the 1:500,000 scale [3]. The areas are as follows.

Map Unit	Percent of Area
Volcanic products	
Undifferentiated	23
Young quarternary	1
Volcanic facies	
Pleistocene	37
Sedimentary facies	
Pleiocene	3
Miocene	36
	100

The percent of area with sedimentary rocks is almost the same for the Kedungombo and Tuntang catchments. The Tuntang has 20 percent more of its area covered with volcanic products.

On the basis of only geology, the sediment yield from the Tuntang area should be similar to that from the Kedungombo catchment.

A.1.3. Land Use

The land use pattern in 1975 in the Tuntang watershed upstream from Glapan was presented by NEDECO in the Glapan Dam Feasibility Study [5]. Their values are reproduced as follows:

Land Use	Percent of Area
Rice fields	
Technical irrigation	4.3
Semi-technical irrigation	1.8
Simple irrigation	8.1
Rain dependent	6.3
Dry fields	30.8
Home yards	20.7
Plantations	4.2
Forests	19.7
Others	4.1
	100.0

The forests are located on top of the Gunung Merbabu (mahogany), on top of the Gunung Telomoyo (pine), on top of the Gunung Ungaran (mahogany), and below elevation 150 m in the lower watershed (teak).

In the Jragung Dam Upgraded Feasibility Study by Engineering Consultants, Inc. [6], the land use on the Jragung watershed was determined from 1:500,000 scale land use maps prepared from site surveys conducted in September 1969. The land use for the watershed upstream from the Jragung damsite was as follows.

Land Use	Percent of Area
Rice fields	44
Dry fields	17
Villages	10
Teak forests	20
Rubber plantations	9
	100

A.1.4. River Profiles

The profiles of the Tuntang, Jragung, Klampok and Trimo Rivers are shown in Figure A-1. The slope of the Tuntang River at the Gunung Wulan damsite is approximately 5 m/km; at the Glapan damsite the slope is approximately 0.5 m/km. On the Jragung River at the proposed damsite, the slope of the riverbed is approximately 4 m/km.

A.1.5. Damsites

The Gunung Wulan damsite on the Tuntang River is situated immediately downstream of the point where the eastward flowing Tuntang River is joined by the northward flowing Bancak River and the Tuntang turns north. The river channel at the damsite section is approximately 80 m wide.

The proposed damsite at Glapan is located at the end of a straight reach of the Tuntang River approximately one kilometer upstream from the Glapan Weir. The river bends from north to east then north again along the dam axis. The Tuntang River channel at this point is approximately 50 m wide.

On the Jragung River, the proposed Jragung damsite is located approximately 2.5 kilometers downstream of the confluence of the Klampok and Trimo Rivers. At this point the northwestward flowing Jragung River bends to the northeast cutting through a 70-meter high ridge. The proposed dam would close the gap in this ridge.

TABLE A-1

SUMMARY OF HYDROLOGIC DATA
TUNTANG AND JRAGUNG CATCHMENTS

	Unit	Tuntang River at Glapan Weir	Tuntang River at Gunung Wulân Damsite	Tuntang River at Jelok River	Jragung River at Jragung Damsite
Area					
Catchment Area	km^2	796	669	282	94
Rainfall					
Mean annual rainfall	mm	2,630	2,700	2,720	2,640
Maximum monthly rainfall	mm	600	608	612	950
Minimum monthly rainfall	mm	0	0	0	0
Maximum daily station rainfall	mm	400	400	400	306
Probable maximum 24-hr catchment rainfall	mm	577	598	612	680
Runoff					
Mean annual runoff	mm	1,120	1,150	1,420	1,280
Mean annual volume of runoff	$10^6 m^3$	892	770	400	121
Mean annual discharge	m^3/s	28.3	24.4	12.6	3.82
Floods					
Mean annual flood peak	m^3/s	540	450	360	280
25-year flood peak	m^3/s	940	800	640	560
Flood volume for the 25-year flood peak	$10^6 m^3$	37	25	15	5.6
Probable maximum flood peak	m^3/s	-	6,700	5.600	3.000

A.2. RAINFALL

A.2.1. Annual Catchment Rainfall

The mean annual rainfall on the catchments are as follows.

Catchment	Annual Rainfall mm
Rawa Pening upstream from Jelok Weir	?,720
Tuntang upstream from Glapan damsite	2,640
Tuntang upstream from Gunung Wulan damsite	2,700
Jragung upstream from Jragung damsite	2,640

The values for the Rawa Pening and Tuntang catchments upstream from the Glapan damsite are for the combined periods 1916/17 through 1942/43 and 1950/51 through 1972/73. The values were determined by NEDECO, using one Thiessen polygon per catchment applied to monthly rainfall data [5]. The yearly rainfall totals for the different gages were checked by double mass analysis and, for some of the stations, correction factors were applied to the monthly and annual rainfall values to make their records homogeneous.

To arrive at the mean annual rainfall for the Tuntang catchment upstream from the Gunung Wulan damsite, the lower end of the Thiessen polygon used for the Glapan damsite catchment was adjusted and then applied to the same fifty-year period of record. The resulting mean annual rainfall on the Gunung Wulan damsite catchment is 2,700 mm.

For the Glapan damsite catchment, the wettest water year on record is 1957/58 with 3,356 mm of rain, while the driest is 1962/63 with 2,160 mm.

The wettest water year for the Rawa Pening catchment was 1967/68 with 3,478 mm and the driest was 1960/61 with 2,186 mm.

On the catchment upstream from Gunung Wulan damsite, the wettest water year was 1957/58 with 3,431 mm; the driest was 1965/66 with 2,136 mm.

The mean annual rainfall on the Jragung catchment above the Jragung damsite is 2,640 mm based on 52.5 years of record. This mean was obtained from the records of eight raingage stations for the period 1916 to 1972 and five raingages for the period 1972 to 1979, as described in the Jragung Dam Upgraded Feasibility Study by Engineering Consultants, Inc. in 1976 [6] and a subsequent update of rainfall records. The wettest water year on record for the Jragung catchment is 1957/58 with 3,653 mm of rainfall and the driest is 1976/77 with only 1,918 mm.

A.2.2. Monthly Catchment Rainfall

Monthly rainfall data from selected raingage stations have been Thiessen-averaged to arrive at monthly catchment rainfall for each of the catchments. The values of monthly catchment rainfall on the Tuntang catchments upstream from the Glapan and Gunung Wulan damsites are presented in Tables A-2 and A-3, respectively. In Table A-4 the monthly rainfall over the Rawa Pening catchment upstream from the Jelok Weir is given. The monthly rainfall for the Jragung catchment upstream from the Jragung damsite are shown in Table A-5. The Thiessen polygons used to derive these monthly catchment rainfall values for the Glapan, Gunung Wulan, Rawa Pening and Jragung catchments are presented in Table A-6.

The mean monthly values for the Rawa Pening, Gunung Wulan and Glapan damsite catchments are as follows.

Long-Term Monthly Rainfall
(mm/%)

Rawa Pening Catchment

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
143	247	351	380	350	380	312	235	127	84	58	57	2,724
5.2	9.1	12.9	14.0	12.8	14.0	11.4	8.6	4.7	3.1	2.1	2.1	100.0

Gunung Wulan Damsite Catchment

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
154	256	341	387	345	384	296	215	116	81	59	63	2,697
5.7	9.5	12.6	14.4	12.8	14.2	11.0	8.0	4.3	3.0	2.2	2.3	100.0

Glapan Damsite Catchment

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
156	258	339	378	336	369	284	209	111	77	57	64	2,638
5.9	9.8	12.9	14.3	12.7	14.0	10.8	7.9	4.2	2.9	2.2	2.4	100.0

The long-term values for the Jragung catchment is very similar to those monthly rainfall figures given above.

On the average, January is the wettest month with about 380 mm of rainfall on the Tuntang catchments and 422 mm of rain on the Jragung catchment. August is the driest month with an average of less then 60 mm of rainfall on each of the catchments. The largest monthly rainfalls recorded in the Tuntang catchments upstream from the Glapan damsite, the Gunung Wulan damsite and the Jelok Weir were 600 mm in January 1931, 606 mm in January 1931, and 612 mm in March 1928, respectively. On the Jragung catchment upstream from the Jragung damsite, the largest monthly rainfall was 950 mm which occurred in January 1965. Many dry season months have had zero rainfall

A.2.3. Daily Rainfall

Daily rainfall data are published by the Institute of Meteorology and Geophysics in their yearly "Rain Observations in Indonesia". Presently, raingages in Indonesia are read each morning at 0700 hours, so the value recorded for a given day is actually the rainfall total from 0700 hours of the previous day to 0700 on the day of the reading. Some historical records of daily rainfall are based on readings taken at 0600 hours. Interestingly, instructions to raingage readers around the turn of the 20th century allowed observers to choose their own times for taking the daily reading, as long as they remained consistent. Nearly all raingages during that time were read between 0600 and 1200 hours.

The daily rainfall values for the six raingages in the Jragung catchment for the period from 1 January 1976 to 30 June 1979 are given in Appendix H.

A.2.3.a. Maximum Daily Station Rainfall

From the forty raingage stations in or near the Tuntang catchment upstream from Glapan which were screened for monthly and annual rainfall averages, NEDECO selected twelve stations with long periods of reliable records for frequency analysis of maximum daily rainfall in their Glapan feasibility report [5]. Stations requiring correction factors were excluded from the frequency calculations. In the present analysis of maximum daily rainfall, two additional stations were included.

The annual maximum daily rainfall values for each of the raingages for the period of record were transcribed from the original files of daily and monthly rainfall data published by the Institute of Meteorology and Geophysics (L.M.G.) in Jakarta [8]. The raingage stations' periods of record ranged from 31 to 85 years, dating as far back as 1879. The maximum daily rainfalls recorded at these raingages are given in Table A-7. The mean of these maximum values is 251 mm.

On the Jragung catchment, values of maximum daily rainfall for raingage stations in the vicinity of the catchment were compiled by Engineering Consultants, Inc. [6]. These data are reproduced in Table A-8. The mean of these values is 241 mm.

A.2.3.b. Daily Basin Rainfall

The maximum recorded daily rainfall over the Tuntang catchment upstream from the Glapan damsite and over the Rawa Pening catchment upstream from Jelok Weir were calculated by NEDECO using the available fifteen years of record, but only for the months November through July. The Glapan damsite catchment had a maximum daily rainfall of 132 mm on 2 July 1959. The Rawa Pening catchment upstream from Jelok Weir has a maximum recorded daily rainfall of 113 mm on the same day. It was noted that generally heavy rainfall during severe storms is localized over part of the catchment only, with normal to low rainfall over the remainder of the catchment.

NEDECO determined that the largest recorded daily basin-averaged rainfall on the Jragung catchment was 180 mm based on eighteen years of records [9].

A.2.4. Probable Maximum Rainfall

The probable maximum 24-hour rainfalls over the Tuntang and Jragung catchments were estimated by using Hershfield's method [10]. The annual maximum daily recorded rainfall values for selected raingage stations within and near the catchments were compiled for analysis. The probable maximum daily rainfall at each station was calculated as follows:

$$PMP = \bar{x}\,(1 + 15\,C_v)$$

in which PMP = probable maximum daily rainfall
$\bar{x}$ = mean annual maximum daily rainfall at the station
C_v = coefficient of variation for the annual maximum daily rainfall at the station.

For the Tuntang catchment, data from fourteen raingage stations having an average period of record of 57 years, were used to arrive at an estimate of probable maximum daily station rainfall within the catchment. In Table A-9, a summary of the analysis is presented. The estimate for probable maximum daily rainfall is 626 mm. This value is for a daily period with fixed time limits from 0700 to 0700 hours. To convert to a 24-hour period with floating time limits, a factor of 1.11 has been applied which gives a probable maximum 24-hour point rainfall of 695 mm. This factor was derived by Snowy Mountains Engineering Corporation [4] from daily and automatic rainfall records for the Kunti station in the adjacent Serang River basin.

The raingage stations used in the analysis are well distributed over the Tuntang catchment area with six stations within or near the Rawa Pening catchment. In order to arrive at an estimate of probable maximum 24-hour rainfall over an entire catchment, different areal reduction factors were applied depending on the area of the particular catchment being investigated. The reduction factors to convert point rainfall to rainfall over an area were derived from a survey of areal reduction factors being used in Java. The values of basin-averaged probable maximum 24-hour rainfall are 612 mm for the Rawa Pening catchment, 598 mm for the catchment upstream from Gunung Wulan damsite and 577 mm for the catchment upstream from Glapan damsite.

On the Jragung catchment, the probable maximum 24-hour rainfall has been estimated by Engineering Consultants, Inc. [6] in 1976 using the same method. The records of eight raingages in or adjacent to the catchment above Jragung damsite were used. The probable maximum 24-hour point rainfall was estimated as 750 mm. By applying an areal reduction factor of 0.91, a value of 680 mm was obtained for the probable maximum 24-hour rainfall over the Jragung catchment upstream from the Jragung damsite.

A.2.5. Annual Service Area Rainfall

The designated Project service area has an estimated total net irrigable area of approximately 35,000 hectares. The mean annual rainfall on this area is 2,208 mm. This value was obtained by employing the records of seven raingages to form a Thiessen network over the entire area (Table A-6). The period of record was 1952 to 1973, which coincides with the period used for the reservoir operation studies. Missing data were simulated by averaging values measured at adjacent raingages.

The annual station rainfall for the seven raingages varies from 1,171 mm to 4,108 mm during the period of record. The annual rainfall over the Project service area varies from 1,722 mm to 2,762 mm.

A.2.6. Monthly Service Area Rainfall

The Thiessen averaged values of monthly rainfall over the Project service area, based on seven raingage stations within the area, are presented in Table A-10. The stations used in the analysis are listed in Table A-6. The mean monthly values are as follows.

Average Monthly Rainfall
(mm/%)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
127	229	297	415	322	252	197	138	60	57	52	63	2 208
5.8	10.4	13.4	18.8	14.6	11.4	8.9	6.2	2.7	2.6	2.4	2.8	100.0

On the average, January is the wettest month with 415 mm of rain and August is the driest with only 52 mm in the period 1952 to 1973.

A.3. STREAMFLOW

A.3.1. Tuntang River at Glapan Weir

In 1859, the construction of the Glapan Weir and the Glapan Timur (East) and Barat (West) canals was completed on the Tuntang River at Glapan.

The Glapan Weir is 100 meters long with an ogee crest. The discharge capacity of the Glapan Timur canal is 16 m^3/s. The canal intake, situated 100 meters upstream from the weir on the right bank, consists of six 3-meter wide undershot gates. The Glapan Barat main canal takes off from the left bank of the Tuntang River about 400 meters upstream from the weir. The intake structure, reconstructed in 1971, consists of two gated openings, each 2.46 meters wide. The discharge capacity of the Glapan Barat canal is 10 m^3/s.

The surface drainage area upstream from the weir is 796 km^2, including the 282 km^2 Rawa Pening drainage area upstream from the Jelok Weir. Streamflow of the Tuntang River is influenced by the Rawa Pening subbasin as runoff is first stored in the lake before being discharged over the Jelok Weir. The drainage area upstream from Glapan Weir but uncontrolled by Rawa Pening is 514 km^2.

Water level observations and computed discharges over the weir and in the irrigation canals are available since January 1, 1952. In 1975, NEDECO upgraded all of the discharge records for the period January 1, 1952 to September 30, 1973 using revised rating curves at the weir and canal intake and the observed water levels.

For the 22 years of daily streamflow data reported by NEDECO [11], the mean annual discharge of the Tuntang River at Glapan, including diversions to the Glapan Timur and Glapan Barat canals, is 28.3 m^3/s. This value corresponds to an average annual runoff of 1,120 mm over the total drainage area upstream from the Glapan Weir.

In Table A-11, monthly discharges[1/] of the Tuntang River at Glapan for the period of record, 1952 through 1973 are presented. Those long-term monthly streamflows are summarized below.

Long-Term Monthly Streamflow at Glapan
(m^3/s and %)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
10.1	21.7	35.6	44.5	44.4	48.4	44.3	32.9	17.7	17.1	13.2	9.5	28.3
3.0	6.4	10.5	13.1	13.1	14.3	13.0	9.7	5.2	5.0	3.9	2.8	100.0

A.3.2. Tuntang River at Jelok Weir

The Tuntang River is the only surface outlet for runoff from the Rawa Pening catchment. Jelok Weir is situated approximately one kilometer downstream from the source of the Tuntang River, which flows from the northeast side of Rawa Pening lake.

The lake is fed by 19 small rivers and rivulets and six springs [12]. The springs flow all year. Muncul Springs, located on the southern end of the lake is the largest, yielding approximately 2.5 m^3/s continuously with little variation in flow throughout the year. At present, the maximum storage level of the lake is at elevation 463.4 m on S.P. which corresponds to a storage capacity of 48×10^6 m^3. The surface area of the lake at this elevation is 27 km^2.

The existing Jelok Weir, built in 1937, has five gated openings each 5 meters wide, and one gated opening 3 meters wide. The weir diverts flow from the Tuntang River to the Jelok and Timo powerplants. Discharges over the weir and through the Jelok powerplant have been recalculated by NEDECO [11] for the period January 1, 1952 through September 30, 1973 so as to have simultaneous streamflow data with that at Glapan.

1/ Mean monthly values derived from streamflows generated from rainfall data for the period of record (1952 thru 1973)

The mean annual discharge of the Tuntang River at Jelok Weir for the 22-year period of interest is 12.6 m^3/s. This discharge is equivalent to an average of 1,420 mm of runoff over the Rawa Pening catchment annually. The average monthly discharges of the Tuntang River at Jelok for the period 1952 through 1973 are given in Table A-12. A summary is as follows.

Long-term Monthly Streamflow at Jelok Weir
(m^3/s and %)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
7.6	9.3	12.2	14.5	15.5	15.0	16.1	15.3	11.9	12.4	11.3	9.3	12.6
5.1	6.2	8.1	9.6	10.3	10.0	10.7	10.2	7.9	8.2	7.5	6.2	100.0

A.3.3. Tuntang River at Gunung Wulan Damsite

Monthly streamflow of the Tuntang River at the Gunung Wulan damsite has been estimated by proportioning the runoff from the uncontrolled catchment upstream of Glapan Weir according to drainage area. Values of average monthly runoff from the uncontrolled Tuntang drainage area upstream from the Glapan Weir (514 km^2) were taken as the discharge value for the Tuntang River at Glapan (Table A-10) minus the discharge value at Jelok Weir (Table A-11). A drainage area reduction factor of 387 km^2 (the uncontrolled drainage area at the Gunung Wulan damsite) divided by 514 km^2 was applied to the Glapan uncontrolled drainage area values to give runoff from the uncontrolled drainage area upstream from the Gunung Wulan damsite. These values were added to the monthly discharges at Jelok Weir to arrive at the monthly discharges of the Tuntang River at Gunung Wulan damsite. These data are presented in Table A-13 for the period 1952 to 1973.

The mean annual discharge of the Tuntang River at the Gunung Wulan damsite is estimated to be 24.4 m^3/s, or an average of 1,150 mm of runoff over the drainage area upstream from Gunung Wulan damsite annually.

Monthly values are summarized below

Long-Term Monthly Streamflow at Gunung Wulan Damsite

(m^3/s and %)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
9.5	18.6	29.7	36.4	37.2	38.4	38.2	29.5	16.8	16.4	12.8	9.4	24.4
3.2	6.4	10.1	12.4	12.7	13.2	13.0	10.1	5.7	5.6	4.4	3.2	100.0

A.3.4. Jragung River at Jragung Damsite

Monthly streamflows of the Jragung River at the Jragung damsite were simulated by Engineering Consultants, Inc. in their Upgraded Feasibility Study [6] and in the Jragung Final Design Report [12]. The streamflows were later updated in 1979 (Appendix H).

The streamflow simulation is based on a model which relates evapotranspiration and total rainfall over the basin. Using five years of actual streamflow records from a streamgaging station on the Jragung River at Borangan Bridge, 2.5 kilometers downstream from the damsite, average monthly discharge values at the damsite for the 52 year period of recorded rainfall were derived. The results are presented in Table A-14. The measured values of streamflow at the Borangan Bridge are given in Table A-15.

The values listed in Table A-14 for May 1973 and subsequent months are monthly volumes of streamflow measured at the Borangan Bridge but reduced by the ratio of the catchment area upstream from the damsite (94 km^2) to the area at the bridge (101 km^2)

The long-term mean annual discharge of the Jragung River at the Jragung damsite is 3.8 m^3/s. This value is equivalent to an average of 1,280 mm of runoff from the Jragung catchment annually.

TABLE A-2

MONTHLY RAINFALL TUNTANG CATCHMENT UPSTREAM FROM GLAPAN DAMSITE

(Units of mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar.	Apr	May	Jun	Jul	Aug	Sep	Total
1916-1917	230	262	383	443	408	311	402	193	166	24	66	186	3094
1917-1918	277	291	355	336	499	287	235	110	20	12	21	11	2454
1918-1919	70	234	407	425	320	277	312	321	77	27	32	83	2585
1919-1920	21	435	503	315	316	377	305	89	64	18	284	196	2923
1920-1921	405	213	242	391	314	442	196	72	100	103	35	123	2636
1921-1922	205	196	414	379	327	349	337	274	223	89	22	29	2844
1922-1923	168	191	355	285	380	276	222	159	184	321	0	0	2541
1923-1924	30	209	266	327	360	367	389	197	51	72	33	258	2559
1924-1925	395	356	295	360	300	396	216	73	1	11	1	1	2405
1925-1926	37	196	284	415	268	511	199	324	4	4	21	43	2306
1926-1927	129	197	532	529	302	356	345	310	141	39	28	38	2946
1927-1928	141	334	403	378	349	519	224	119	169	6	149	19	2810
1928-1929	104	308	513	319	241	496	149	39	62	0	1	33	2265
1929-1930	100	134	422	364	425	449	315	373	16	82	7	11	2698
1930-1931	188	185	400	600	292	376	308	204	44	24	23	12	2656
1931-1932	248	227	238	265	320	313	350	162	135	6	5	73	2342
1932-1933	170	202	245	370	319	390	232	326	136	21	122	158	2691
1933-1934	240	274	316	598	411	380	319	86	52	35	7	13	2731
1934-1935	168	375	195	396	394	334	230	163	47	0	4	1	2307
1935-1936	161	297	212	385	416	395	398	222	98	53	15	58	2710
1936-1937	147	353	192	417	260	293	348	235	217	2	9	131	2604
1937-1938	91	148	414	457	421	286	128	283	190	135	78	48	2679
1938-1939	128	349	425	296	366	354	262	119	275	287	100	47	3008
1939-1940	162	171	241	330	257	331	300	299	134	5	2	7	2239
1940-1941	41	163	318	466	365	539	325	359	192	39	20	51	2878
1941-1942	122	282	390	477	355	266	215	215	64	48	33	90	2557
1942-1943	208	276	184	258	315	579	312	307	275	121	148	12	2995
1950-1951	313	379	251	393	267	177	155	116	198	142	95	74	2560
1951-1952	80	104	413	433	388	474	179	189	85	21	128	70	2564
1952-1953	200	402	286	293	292	338	411	322	78	75	0	32	2729
1953-1954	25	287	343	393	353	324	286	273	101	103	167	140	2795
1954-1955	217	441	273	380	234	295	330	251	134	270	104	110	3048
1955-1956	212	360	274	548	291	217	162	153	278	61	187	101	2844
1956-1957	138	218	355	341	178	560	321	125	77	217	31	36	2597
1957-1958	73	166	450	341	534	423	367	309	79	247	247	120	3356
1958-1959	164	145	537	315	364	299	357	258	116	243	23	22	2843
1959-1960	203	205	442	295	470	261	301	285	70	76	19	26	2653
1960-1961	165	359	284	422	208	284	174	274	51	33	3	6	2263
1961-1962	61	194	258	320	294	442	378	60	66	95	157	14	2339
1962-1963	182	246	327	393	277	425	240	60	9	0	0	1	2160
1963-1964	17	185	296	229	341	342	345	250	136	36	75	129	2381
1964-1965	299	275	257	377	304	296	236	60	45	38	1	4	2192
1965-1966	40	155	314	362	385	480	197	120	107	2	7	22	2191
1966-1967	238	219	351	378	392	249	301	59	7	4	7	4	2209
1967-1968	63	238	291	453	349	384	290	373	237	223	202	96	3199
1968-1969	185	364	363	423	433	379	405	67	83	66	26	29	2833
1969-1970	119	244	418	262	252	518	264	265	93	151	1	97	2684
1970-1971	126	261	329	308	340	325	290	286	177	55	9	29	2531
1971-1972	259	270	357	370	227	338	163	234	8	0	10	1	2237
1972-1973	26	312	320	348	340	359	456	428	181	106	71	239	3186
Mean	156	258	339	378	336	369	284	209	111	77	57	64	2638

TABLE A-3

MONTHLY RAINFALL TUNTANG CATCHMENT UPSTREAM FROM GUNUNG WULAN DAMSITE

(Units of mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1916-1917	251	263	406	473	422	323	417	208	187	27	50	157	3184
1917-1918	282	285	352	329	491	299	250	116	23	10	20	9	2466
1918-1919	57	230	403	436	307	288	318	319	87	28	30	86	2589
1919-1920	18	459	519	306	333	400	306	98	70	18	302	195	3024
1920-1921	399	215	253	394	320	487	210	76	102	107	36	124	2723
1921-1922	216	185	431	375	351	340	358	286	234	94	14	31	2915
1922-1923	153	190	358	288	392	292	227	166	207	340	0	0	2613
1923-1924	29	199	271	330	365	381	408	202	50	69	31	288	2623
1924-1925	411	361	295	368	311	405	213	74	1	11	1	1	2452
1925-1926	37	189	280	428	287	554	208	340	4	5	22	44	2398
1926-1927	126	195	555	524	321	368	358	306	151	37	26	37	3004
1927-1928	140	334	405	399	356	575	232	128	186	6	158	16	2935
1928-1929	101	304	533	323	252	543	158	38	66	0	1	33	2352
1929-1930	90	109	424	378	447	469	316	405	16	86	5	9	2754
1930-1931	183	187	400	606	305	382	311	200	46	23	24	13	2680
1931-1932	225	233	251	260	319	315	365	165	132	5	5	76	2351
1932-1933	172	204	246	381	314	401	236	357	151	14	126	146	2748
1933-1934	243	280	332	605	412	410	322	85	58	29	6	13	2795
1934-1935	163	392	173	405	421	332	236	176	39	0	5	1	2343
1935-1936	151	302	202	393	437	416	419	237	99	46	10	55	2767
1936-1937	45	382	180	436	277	286	370	238	243	2	11	132	2702
1937-1938	95	150	416	485	419	298	117	293	191	134	85	50	2733
1938-1939	111	355	432	275	383	358	271	129	285	303	103	45	3050
1939-1940	167	163	238	-	-	-	DATA UNAVAILABLE				-	-	-
1940-1941	-	-	-	504	391	579	353	376	198	41	24	53	-
1941-1942	22	165	284	478	374	264	230	211	59	50	38	81	2256
1942-1943	217	272	187	264	310	612	312	346	298	117	152	12	3099
1950-1951	298	309	251	394	284	183	161	124	190	154	101	74	2523
1951-1952	80	104	393	430	419	481	179	202	95	20	126	67	2596
1952-1953	198	422	301	298	292	350	423	340	89	71	0	35	2819
1953-1954	22	285	354	403	356	325	309	270	98	100	172	132	2826
1954-1955	208	408	272	392	228	317	334	260	135	292	106	118	3070
1955-1956	213	354	278	575	304	217	172	156	295	61	197	103	2925
1956-1957	124	209	357	362	164	587	332	129	80	234	31	40	2649
1957-1958	68	160	474	346	540	434	392	308	82	264	243	120	3431
1958-1959	172	147	560	321	385	318	366	270	128	245	24	20	2955
1959-1960	215	194	452	309	491	264	324	312	73	86	19	21	2760
1960-1961	162	373	282	426	205	296	295	268	51	39	4	7	2408
1961-1962	65	201	259	327	308	459	391	65	69	95	163	15	2417
1962-1963	190	254	328	385	291	450	235	69	10	0	0	1	2213
1963-1964	12	193	293	246	372	351	356	259	131	34	76	126	2449
1964-1965	310	284	250	380	306	292	250	57	43	38	1	5	2216
1965-1966	43	163	327	365	283	492	200	122	117	1	8	15	2136
1966-1967	212	217	336	376	395	242	304	63	8	5	7	4	2169
1967-1968	62	233	298	446	365	406	308	392	254	231	223	96	3314
1968-1969	177	350	360	445	440	393	442	70	86	68	26	25	2882
1969-1970	116	257	446	264	257	530	272	263	95	166	1	97	2764
1970-1971	122	272	338	326	343	341	298	280	179	63	7	29	2598
1971-1972	268	275	369	362	232	348	165	249	8	0	9	1	2286
1972-1973	24	289	312	360	350	373	474	453	194	107	69	250	3255
Mean	154	256	341	387	345	384	296	215	116	81	59	63	2697

TABLE A-4

MONTHLY RAINFALL TUNTANG CATCHMENT UPSTREAM FROM JELOK WEIR

(Units of mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1916-1917	274	271	438	440	410	283	438	217	230	24	64	142	3231
1917-1918	300	351	312	323	541	319	248	132	24	15	22	6	2593
1918-1919	31	211	322	453	369	306	374	391	93	17	43	68	2678
1919-1920	13	343	549	338	314	437	344	105	90	30	312	183	3058
1920-1921	351	187	280	295	325	470	220	94	114	94	40	119	2589
1921-1922	244	218	460	404	394	346	420	320	206	107	12	16	3147
1922-1923	107	181	334	303	406	258	228	173	308	338	0	1	2637
1923-1924	32	187	273	302	347	351	456	216	78	63	44	64	2413
1924-1925	301	375	270	378	312	404	235	90	4	2	4	2	2377
1925-1926	14	164	288	407	292	562	234	337	5	9	18	30	2360
1926-1927	126	189	527	492	298	404	478	273	178	21	14	33	3033
1927-1928	117	296	415	414	351	612	250	99	216	13	184	19	2986
1928-1929	111	265	555	344	249	576	201	39	92	0	0	25	2457
1929-1930	77	85	436	404	448	479	383	543	18	107	5	5	2990
1930-1931	139	174	333	548	346	368	305	217	67	26	27	15	2565
1931-1932	255	241	289	264	373	418	405	188	159	5	2	54	2653
1932-1933	106	187	294	424	319	430	282	332	156	30	101	139	2800
1933-1934	179	313	339	603	350	386	345	80	87	42	8	17	2749
1934-1935	163	376	194	361	393	365	259	190	49	0	9	0	2359
1935-1936	94	262	216	356	492	421	448	312	110	54	13	70	2848
1936-1937	104	272	204	431	241	282	461	240	284	1	0	141	2661
1937-1938	52	125	463	443	387	373	149	347	210	150	67	51	2817
1938-1939	111	311	434	304	345	352	294	144	335	320	106	48	3104
1939-1940	218	122	237	290	266	310	311	357	151	3	4	11	2280
1940-1941	25	135	356	478	407	406	366	382	131	34	29	53	2802
1941-1942	79	288	397	439	362	281	256	202	65	53	20	70	2512
1942-1943	229	284	199	229	255	550	295	435	276	123	142	15	3032
1950-1951	285	450	243	390	300	208	164	152	233	176	121	64	2786
1951-1952	83	80	541	419	473	443	160	188	95	9	108	55	2654
1952-1953	212	492	324	246	300	450	406	314	69	60	0	25	2898
1953-1954	14	195	347	447	330	322	342	248	110	91	175	112	2733
1954-1955	126	518	295	342	234	318	341	265	96	313	132	155	3135
1955-1956	201	256	277	575	313	223	205	149	305	59	188	95	2846
1956-1957	119	190	340	418	148	526	303	166	93	224	31	55	2613
1957-1958	74	160	492	387	530	367	388	214	80	294	209	125	3320
1958-1959	147	178	579	316	380	364	301	315	195	254	17	25	3071
1959-1960	186	150	429	340	491	286	399	317	79	136	12	32	2857
1960-1961	125	407	221	425	208	270	159	279	46	45	0	1	2186
1961-1962	75	198	265	377	325	421	427	83	81	86	169	10	2517
1962-1963	202	224	338	351	344	409	259	87	10	0	0	0	2224
1963-1964	7	132	267	251	373	308	337	238	116	51	80	143	2303
1964-1965	323	312	274	384	287	299	191	81	44	54	1	7	2257
1965-1966	50	153	310	355	417	494	159	142	118	0	1	30	2229
1966-1967	324	227	385	366	362	201	329	47	6	0	1	5	2253
1967-1968	70	188	309	410	396	434	315	439	297	264	260	96	3478
1968-1969	159	327	344	421	412	376	536	90	81	33	6	26	2811
1969-1970	100	303	474	321	299	465	307	296	78	197	2	103	2945
1970-1971	106	291	333	324	321	364	328	390	195	86	2	39	2779
1971-1972	282	338	422	292	238	353	195	288	1	0	12	0	2421
1972-1973	20	192	324	369	428	335	351	482	182	104	62	261	3110
Mean	143	247	351	380	350	380	312	235	127	84	58	57	2724

TABLE A-5

MONTHLY RAINFALL JRAGUNG CATCHMENT UPSTREAM FROM JRAGUNG DAMSITE

(Units of mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1916-1917	269	262	326	537	457	195	330	187	174	48	117	276	3178
1917-1918	331	293	300	377	499	194	110	76	49	40	21	44	2334
1918-1919	69	148	302	356	315	328	339	305	68	15	83	15	2343
1919-1920	15	326	568	314	306	355	277	61	96	18	299	211	2846
1920-1921	330	206	272	324	344	399	183	34	96	100	19	153	2460
1921-1922	186	311	444	278	327	406	213	300	245	67	29	32	2838
1922-1923	202	192	410	397	291	323	124	213	154	341	0	0	2647
1923-1924	42	231	277	229	360	314	356	156	97	138	51	68	2319
1924-1925	342	498	135	393	312	379	121	99	0	11	0	8	2298
1925-1926	47	186	270	388	193	500	182	403	14	6	33	36	2258
1926-1927	126	224	494	507	239	294	400	443	172	33	8	118	3058
1927-1928	115	231	373	320	489	463	233	71	91	3	165	35	2589
1928-1929	191	335	461	184	239	403	134	35	80	0	7	49	2118
1929-1930	117	191	362	378	480	336	289	241	36	102	10	17	2559
1930-1931	156	215	276	698	237	433	257	172	65	34	53	9	2605
1931-1932	373	202	227	339	419	491	293	128	212	0	0	100	2784
1932-1933	178	234	284	398	435	695	115	263	163	373	149	157	3444
1933-1934	178	278	358	649	324	320	281	81	61	51	14	13	2608
1934-1935	163	398	153	440	207	414	346	88	73	0	1	0	2283
1935-1936	283	187	232	388	346	446	447	231	81	58	22	68	2789
1936-1937	106	221	168	503	195	423	387	260	164	8	6	124	2565
1937-1938	71	137	365	493	517	288	119	358	197	134	32	83	2794
1938-1939	167	413	411	347	406	419	296	51	416	289	81	65	3361
1939-1940	105	224	179	311	392	339	309	387	88	7	7	4	2352
1940-1941	42	171	483	405	424	426	412	359	124	74	16	42	2978
1951-1952	47	105	470	618	377	466	188	138	53	33	119	83	2697
1952-1953	170	231	264	260	197	328	255	267	23	83	16	4	2098
1953-1954	46	290	220	274	413	262	159	247	66	72	132	235	2416
1954-1955	199	559	264	272	531	242	299	301	112	259	163	147	3348
1955-1956	255	359	348	829	397	296	98	237	170	71	188	30	3278
1956-1957	108	158	397	335	282	363	149	120	124	181	114	13	2344
1957-1958	141	249	585	325	549	359	324	229	150	334	319	89	3653
1958-1959	178	186	380	443	247	204	304	302	89	170	7	132	2642
1959-1960	125	131	403	394	451	155	200	217	58	62	13	51	2260
1960-1961	84	472	232	904	195	395	102	285	14	35	0	0	2718
1961-1962	24	194	290	643	525	563	451	95	96	156	151	12	3200
1962-1963	244	158	323	738	269	419	217	48	6	0	0	0	2422
1963-1964	52	124	355	303	331	202	349	200	125	71	93	222	2427
1964-1965	274	441	276	950	354	333	205	111	43	43	0	3	3033
1965-1966	21	169	337	397	521	501	129	121	116	0	1	22	2335
1966-1967	342	187	331	418	498	327	346	32	0	0	12	3	2476
1967-1968	76	245	328	380	516	219	248	350	350	257	183	103	3255
1968-1969	134	292	542	192	218	220	495	35	46	32	4	9	2219
1969-1970	100	238	178	294	274	505	254	319	91	131	8	45	2437
1970-1971	154	297	454	560	584	375	231	171	170	72	3	30	3106
1971-1972	252	279	205	643	230	614	169	181	4	0	2	0	2579
1972-1973	13	178	278	490	367	331	417	375	114	121	44	177	2905
1973-1974	138	269	276	211	264	407	175	191	60	62	99	200	2352
1974-1975	314	302	227	377	215	338	374	334	72	23	68	292	2936
1975-1976	294	279	265	310	249	374	162	42	13	8	28	12	2035
1976-1977	249	249	74	188	250	311	180	243	160	6	0	8	1918
1977-1978	27	168	302	367	392	194	164	180	126	154	66	202	2342
1978-1979	155	85	375	331	241	216	405	171	52				
Mean	159	249	322	422	353	360	257	199	104	84	59	74	2642

TABLE A-6

RAINGAGE STATIONS USED FOR THIESSEN POLYGONS

I. Glapan Catchment

Station Number[1]	Station Name	Percent of Area
81 a	Kopeng	3.47
81	Getasan	5.27
80	Sepakung	4.06
86	Salatiga	5.27
88 a	Cepoko	2.75
89	Tingkir	2.21
89 a	Karangduren	1.03
82 KD	Sumowono	0.90
75	Tarukan	3.67
78	Tempuran	4.70
76	Ambarawa	3.50
79	Banyubiru	4.13
74	Bawen	2.29
83	Tuntang	4.34
73	Jatirunggo	2.31
85 a	Silumut	3.50
82	Karanglo	3.38
82 a	Grenjeng	9.97
91	Dadapayam	5.57
55 SKA	Repaking	14.55
100	Paras	1.89
57 SKA	Ngaren	1.11
56 SKA	Telawa	2.71
142	Temur	1.18
141	Glapan	6.24

II. Gunung Wulan Catchment

Station Number	Station Name	Percent of Area
81 a	Kopeng	4.13
81	Getasan	6.27
80	Sepakung	4.83
86	Salatiga	6.27
88 a	Cepoko	3.27
89	Tingkir	2.63
89 a	Karangduren	1.23
82 KD	Sumowono	1.07
75	Tarukan	4.37
78	Tempuran	5.59
76	Ambarawa	4.16
79	Banyubiru	4.91
74	Bawen	2.72

1. All stations are within the Semarang district, except KD Kedu district and SKA in Surakarta district.

TABLE A-6 (Cont.)

RAINGAGE STATIONS USED FOR THIESSEN POLYGONS

Station Number	Station Name	Percent of Area
83	Tuntang	5.16
73	Jatirunggo	2.75
85 a	Silumut	4.16
82	Karanglo	4.02
82 a	Grenjeng	11.86
91	Dadapayam	6.63
55 SKA	Repaking	13.55
100	Paras	0.42

III. Rawa Pening Catchment

Station Number	Station Name	Percent of Area
81 a	Kopeng	7.14
81	Getasan	11.56
86	Salatiga	11.41
85 a	Silumut	0.24
83	Tuntang	5.87
74	Bawen	3.09
76	Ambarawa	10.14
75	Tarukan	10.62
82 KD	Sumowono	2.62
78	Tempuran	13.60
80	Sepakung	11.76
79	Banyubiru	11.95

IV. Jragung Catchment 1916-1972

Station Number	Station Name	Percent of Area
68 b, 70 [2]	Klepu	54.26
72	Kajar	23.27
74	Bawen	3.26
75	Tarukan	1.24
82	Bringin	1.43
99	Barang	15.14
100	Paras	1.40

2. Station Klepu 68 b used for period 1916-1941.
Station Klepu 70 used for period 1951-1972.

TABLE A-6 (Cont.)

RAINGAGE STATIONS USED FOR THIESSEN POLYGONS

V. Jragung Catchment 1972-1978

Station Number	Station Name	Percent of Area
	Jimbaran	18.46
	Karangjati	11.85
	Klepu	16.79
73	Jatirunggo	17.42
	Sambiroto	35.48

VI. Service Area 1952-1973

Station Number	Station Name	Percent of Area
94	Genuk	10.2
96	Mranggen	6.6
100	Paras	10.5
115	Demak	19.7
124	Guntur	24.5
130 a	Tlogopring	14.3
141	Glapan	14.2

TABLE A-7

MAXIMUM DAILY STATION RAINFALL FOR PERIOD OF RECORD, TUNTANG CATCHMENT

Station Number	Station Name	Period of Record	Maximum Daily Rainfall, mm	Date of Event
78	Tempuran	1916 - 1978	260	Aug 1920
79	Banyubiru	1880 - 1978	180	Oct 1961
81	Getasan	1916-44/1972-75	400	Mar 1930
82 a	Grenjeng	1918 - 1978	255	Mar 1941
85	Getas	1880 - 1939	182	Jun 1904
85 a	Silimut	1918 - 1978	160	Feb 1952
86	Salatiga	1879 - 1978	250	Aug 1978
89	Tingkir	1916 - 1975	270	Apr 1908
91	Dadapayam	1916 - 1978	230	Apr 1949
100	Paras	1916 - 1975	273	Aug 1950
141	Glapan	1916 - 1978	212	Feb 1899
82 KD	Sumowono	1916 - 1978	220	Mar 1926
97 KD	Nglabak	1916 - 1975	400	Aug 1962
56 SKA	Telawa	1916-39/1952-75	218	Jul 1959

TABLE A-8

MAXIMUM DAILY STATION RAINFALL FOR THE PERIOD OF RECORD, JRAGUNG CATCHMENT (TO 1974)

Station Number	Station Name	Maximum Daily Rainfall, mm	Date
68 b	Klepu/Kendal	273	Feb 1967
70	Klepu/Ungaran	178	May 1927
70 a	Pagersari	247	Jan 1959
72	Pagersari	306	Jan 1963
73	Jatirunggo	194	Dec 1916
74	Bawen	205	Jun 1923
75	Tarukan	267	Jul 1960
82	Karanglo	260	Jan 1917
99	Banyumeneng	209	Feb 1933
100	Paras	273	Aug 1950

TABLE A-9

PROBABLE MAXIMUM 24-HOUR STATION RAINFALL

Station Number	Station Name	Number of Years	Period of Record	$\bar{X}$ mm	S mm	C_v
78	Tempuran	60	1916-1978	112	39.7	0.303
79	Banyubiru	84	1880-1978	89	27.4	0.309
81	Getasan	31	1916-1944/ 1972-1975	131	57.8	0.442
82 a	Grenjeng	58	1918-1978	122	33.4	0.274
85	Getas	53	1880-1939	106	26.0	0.245
85 a	Silumut	55	1918-1978	100	21.3	0.213
86	Salatiga	85	1879-1978	107	31.6	0.294
89	Tingkir	52	1916-1975	99	22.2	0.224
91	Dadapayam	57	1916-1978	122	35.6	0.291
100	Paras	55	1916-1975	128	42.3	0.331
141	Glapan	58	1916-1978	110	31.5	0.286
82 KD	Sumowono	53	1916-1978	128	37.5	0.292
97 KD	Nglabak	52	1916-1975	114	52.5	0.461
56 SKA	Telawa	46	1916-1939/ 1952-1975	112	31.0	0.278
			Mean:	112.8		0.303

Notes:

$\bar{X}$ is mean annual maximum daily rainfall at station
S is standard deviation of mean annual maximum
C_v is coefficient of variation

TABLE A-10

MONTHLY RAINFALL PROJECT SERVICE AREA

(Units of mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1951-'52	-	-	-	482	276	300	134	121	18	23	95	93	-
1952-'53	151	255	245	251	227	232	273	145	26	56	13	7	1,881
1953-'54	32	236	254	473	322	180	167	239	113	91	137	143	2,387
1954-'55	174	422	283	205	376	241	205	151	72	138	136	74	2,477
1955-'56	158	288	265	421	273	177	93	97	117	63	126	106	2,184
1956-'57	209	181	322	266	234	274	206	51	33	129	51	17	1,973
1957-'58	83	167	306	182	519	332	210	127	74	104	236	96	2,436
1958-'59	126	155	434	322	178	181	267	121	53	137	14	70	2,058
1959-'60	65	197	279	452	364	212	156	120	40	27	0	54	1,966
1960-'61	86	367	224	651	259	181	207	314	20	3	0	1	2,313
1961-'62	34	139	243	624	458	303	283	26	38	76	111	14	2,349
1962-'63	140	163	259	764	429	164	250	10	4	0	0	1	2,184
1963-'64	43	93	336	228	170	263	266	130	73	17	36	183	1,838
1964-'65	275	193	325	604	295	202	120	99	63	10	0	0	2,186
1965-'66	12	204	272	274	361	203	139	111	109	4	4	29	1,722
1966-'67	264	127	230	460	367	213	220	30	3	0	12	3	1,929
1967-'68	109	205	331	595	370	228	160	240	122	189	96	117	2,762
1968-'69	187	355	376	202	325	259	178	40	44	16	8	51	2,041
1969-'70	105	173	220	295	297	281	218	191	37	81	2	68	1,968
1970-'71	110	215	299	391	464	292	239	226	128	7	2	44	2,417
1971-'72	191	288	316	621	200	412	128	124	5	0	17	10	2,312
1972-'73	3	331	296	367	316	414	219	324	123	74	56	202	2,725
1973	226	274	425	-	-	-	-	-	-	-	-	-	-
Mean	127	229	297	415	322	252	197	138	60	57	52	63	2,208

Long-term monthly values are presented below.

Long-Term Monthly Streamflow at Jragung Damsite
(m^3/s and %)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1.3	3.2	5.2	9.1	8.0	7.7	5.3	3.5	1.4	0.8	0.4	0.4	3.8
2.8	6.8	11.5	20.2	16.1	17.2	11.3	7.8	2.9	1.8	0.8	0.8	100.0

A.4. WATER BUDGET

A.4.1. Water Budget for the Tuntang River Catchments

Monthly and annual water yields of the Tuntang River at Glapan, Jelok Weir and Gunung Wulan for the period 1952 through 1973 are shown in Tables A-11, A-12, and A-13, respectively. Tables A-11 and A-12 are reproduced from NEDECO's Glapan Dam Feasibility Study [11] and Table A-13 is derived therefrom.

The mean annual streamflows of the Tuntang River at Glapan, Jelok Weir and Gunung Wulan are 892, 400 and 770 x $10^6 m^3$ respectively.

Annual runoff values have been checked by using a water budget technique similar to that developed by Engineering Consultants, Inc. for the Jragung catchment [12]. Runoff, Q, is assumed to be equal to the difference between the catchment rainfall, P, and the evapotranspiration, E, or $Q = P - E$. This assumption is valid if yearly changes in the amount of groundwater and water stored in the soil are negligible and there is no subsurface exchange of groundwater with adjacent catchments.

Based on additional information obtained in this study, the relation between annual watershed evapotranspiration and annual rainfall presented by Engineering Consultants, Inc. [12] has been changed. The evapotranspiration has been increased approximately five percent for years when the rainfall is normal or greater. The new curve is shown on Figure A-2. Annual values of rainfall and evapotranspiration for the Glapan and Rawa Pening catchments for 21 years of record have been plotted on the figure.

Catchments with lakes have different amounts of evapotranspiration than catchments without lakes. The difference is given by the equation

$$\frac{E_{cl}}{E} = 1 + \left(\frac{E_l}{E} - 1\right)\frac{A_l}{A}$$

in which E_{cl} and E are the annual evapotranspiration for the catchment with and without a lake respectively; E_l is the annual lake evaporation; and A_l and A are the surface areas of the lake and catchment respectively. For the Rawa Pening catchment, the evapotranspiration should be 2 percent greater than indicated by the curve in Figure A-2 whereas the records indicate the annual evapotranspiration is 10 percent less than the curve. If one assumes the streamflow and rainfall records are correct, the implication is that there is a groundwater inflow from adjacent volcanic catchments.

The lake is not a factor in the water budget for the catchment upstream from the Glapan damsite. For this area, the average evapotranspiration for the 21 years is 6 percent greater than that indicated by the curve in Figure A-2.

A.4.2. Water Budget for the Jragung River Catchment

The annual evapotranspiration from the Jragung watershed upstream from the Jragung damsite was determined from 6 years of rainfall and streamflow measurements. The values are shown in Figure A-2. On the average, the 6 values of annual evapotranspiration for the Jragung catchment are 5 percent below the curve.

The long-term annual streamflow for the Jragung catchment used in the design of Jragung Dam was determined using the long-term annual rainfall and the original evapotranspiration versus basin rainfall curve [12].

The long-term monthly streamflows for the Jragung catchment were determined by employing a simplistic rainfall-runoff model and the long-term monthly rainfall values. The model was developed from the streamflow measurements made at the Borangan Bridge and the annual evapotranspiration versus annual basin rainfall curve.

Subsequent analysis has shown that the monthly rainfall-runoff model is almost totally stochastic whereas initially it was intended to be deterministic. It is primarily the instantaneous rainfall intensity and instantaneous soil infiltration processes which govern the amount of runoff in the Jragung catchment. Monthly values of precipitation are not an adequate representation of rainfall intensity.

A.5. FLOODS

A.5.1. Peak Discharges

Using their upgraded streamflow records of the Tuntang River at Glapan Weir for the water years 1951/52 through 1972/73, NEDECO [5] estimated the mean annual peak discharge to be 360 m^3/s. The coefficient of variation in the 22 years of annual peak discharge data is 0.310. Peak discharges with return periods of 25, 50, and 100 years were reported as 610, 680, and 760 m^3/s, respectively.

The flood peak versus frequency relation developed by NEDECO has been compared with the results of a regional flood analysis. Data used in the regional analysis have been assembled from the Jragung streamgaging records, Citanduy Basin Flood Control Plan [13] the Serang River Project Definite Scheme Report [4] and the Cimanuk Project study [14].

According to the mean flood frequency curve developed in the regional flood analysis, the mean annual peak discharge of the Tuntang River at Glapan is 540 m^3/s. The coefficient of variation is 0.307. For peak discharges with return periods of 25, 50 and 100 years, the flood peak magnitudes are 940, 1,090 and 1,190 m^3/s, respectively.

By way of comparison, the mean annual flood peak in the Serang River at Kedungombo damsite derived by SMEC using various frequency distributions on 26 years of streamflow records, is 600 m^3/s. The drainage area at the Kedungombo damsite is 614 km^2 which compares with the uncontrolled drainage area of 514 km^2 for Glapan.

Using the regional flood analyses curves, the estimate of the mean annual flood peak for the Tuntang River at Gunung Wulan damsite is 450 m^3/s; the coefficient of variation is 0.321. The 25-year, 50-year and 100-year return period flood peaks are 800, 930, and 1,020 m^3/s respectively.

For the Rawa Pening catchment, the mean annual inflow peak derived using the regional flood analysis is 360 m^3/s with a coefficient of variation of 0.341. The 25-year, 50-year, and 100-year return period inflow peaks are 640, 750 and 830 m^3/s, respectively.

Flood hydrographs of the Tuntang River at Jelok Weir were obtained by routing the inflow flood hydrographs for the Rawa Pening catchment through the Rawa Pening lake. The peaks of the outflow hydrographs are very much smaller, with only a slight rise in discharge above the 370 m^3/s maximum discharge of Jelok Weir when Rawa Pening is at full storage level. The peak discharge of the 100-year return period flood with peak of 830 m^3/s going into the lake is only 403 m^3/s at the Jelok Weir. The outflow peak occurs five hours after the inflow peak.

The most recent estimate of the mean annual flood peak for the Jragung river at the Borangan Bridge is 304 m^3/s. The catchment area is 101 km^2. The annual peaks are as follows.

Annual Peak Flood

Year	Date	Peak Discharge m^3/s	Volume of Flood 10^6 m^3
1*	9 Mar 1974	294	4.41
2	5 Jan 1975	280	3.13
3	18 Mar 1976	345	3.35
4	23 Apr 1977	158	1.12
5	31 Dec 1977	387	3.55
6	6 Apr 1977	358	3.13

* Record begins on 4 May 1973.

The mean annual maximum peak discharge in the Jragung River at the Jragung damsite is 280 m^3/s. This value was obtained from the regional flood frequency curve. For extreme flood events with return periods of 10, 25, 50, and 100 years, the peak discharges are 470, 560, 660, 730 m^3/s, respectively. These values are slightly greater than those given by NEDECO in the first Jragung Dam feasibility study [9].

A.5.2. Flood Volumes

Frequencies of flood volumes of the Tuntang River at Glapan Weir for the period of 1951/52 through 1972/73 were calculated by NEDECO in 1975 [5]. The mean annual maximum flood volume was 16 x 10^6 m^3. Flood volumes with return periods of 25, 50, and 100 years were estimated at 31, 34, and 37 x 10^6 m^3, respectively.

Using the regional flood frequency analysis, the volume of the mean annual peak flood for rain during a single day on the Tuntang River catchment upstream from Glapan is 21 x 10^6 m^3. For peak return periods of 25, 50, and 100 years, the flood volumes are 37, 43, and 47 x 10^6 m^3, respectively.

From the regional flood frequency, the estimates of flood volumes for peaks resulting from rain during a single day for the Gunung Wulan and Rawa Pening catchments are:

Flood Event	Volume at Gunung Wulan 10^6 m^3	Volume at Jelok Weir 10^6 m^3	Volume at Jragung Damsite 10^6 m^3
Mean annual maximum flood	14	8.7	2.8
25-year flood	25	15	5.6
50-year flood	29	18	6.6
100-year flood	32	20	7.3

The volumes of the floods measured in the Jragung River at the Borangan Bridge have been determined for each of the annual peak hydrographs. These volumes are listed with the peaks in the table given previously in the table of annual peak floods.

For the flood peak Q_p with a return period of T years, the flood volume at the Jragung damsite is

$$V = Q_p \times 10^4$$

in which V = volume of the flood resulting from the rain during a single day, m^3

Q_p = peak discharge, m^3/s.

These volumes are listed in the previous table.

Based on flood volume alone, the 6 largest annual flood volumes for rainfall during a single day are as follows:

Annual Flood Volume

Year	Date	Peak Discharge m^3/s	Volume of Flood 10^6 m^3
1*	29 May 1973	185	5.33
2	11 Jan 1975	139	4.28
3	25 May 1975	287	6.55
4	20 Mar 1977	117	2.48
5	1 Feb 1978	356	4.58
6	15 Jan 1979	191	4.31

* Record begins on 4 May 1973

Using these data, the average annual flood volume for the Jragung River at the Borangan Bridge is 4.59×10^6 m^3. The period of record is too short to estimate the frequency distribution of these flood volumes accurately.

The flood volumes for the Jragung River at the damsite and at the

Borangan Bridge given in this report are much smaller than those estimated in 1973 by NEDECO [9] who had to work without the benefit of any streamflow measurements.

A.5.3. Probable Maximum Floods

A.5.3.a. General

Probable maximum floods for the Tuntang and Jragung catchments have been developed by maximizing the runoff from the 24-hour probable maximum rainfall over the particular drainage area of interest. The probable maximum flood peaks were estimated using regional curves. Time to peak was estimated after a study of recorded flood hydrographs and a review of basin characteristics. The shapes of the probable maximum flood hydrographs were then drawn to obtain the appropriate volumes of runoff.

A.5.3.b. Tuntang River Catchments

Probable maximum flood hydrographs on the Tuntang River have been derived for the catchment upstream from Gunung Wulan damsite and for the Rawa Pening catchment. The hydrographs are presented in Figure A-3.

At the Gunung Wulan damsite, the probable maximum peak discharge is 6,700 m^3/s. For the Rawa Pening catchment, the peak inflow of the probable maximum flood is 5,600 m^3/s. After routing through Rawa Pening lake, the outflow peak of the probable maximum flood at Jelok Weir is 775 m^3/s.

In estimating the probable maximum flood at the Gunung Wulan damsite, the probable maximum outflow hydrograph from the Rawa Pening catchment was added to the hydrograph of the probable maximum flood over the 387 km^2 uncontrolled drainage area upstream from the Gunung Wulan damsite. No attenuation of the Rawa Pening outflow peak in the river channel was considered. Travel time of the outflow flood hydrograph was estimated based on the river channel characteristics. From Jelok Weir to the Gunung Wulan damsite, the travel time is approximately 1.5 hours.

In each case, the appropriate 100-year flood event was assumed to occur 24 hours ahead of the probable maximum flood to establish wet antecedent moisture conditions in the catchment. The 100-year flood peak employed here was taken from the regional flood analysis envelope curve, rather than the mean curve. The envelope curve is used for the design of structures which must not fail. The mean curve is used for other situations.

A.5.3.c. <u>Jragung River at Jragung Damsite</u>

The probable maximum flood for the Jragung River at the Jragung damsite was estimated by Engineering Consultants, Inc. in their Jragung Dam Project Upgraded Feasibility Study in 1976 [6]. The probable maximum flood hydrograph was obtained by temporally distributing the probable maximum rainfall and employing the unit hydrograph developed for the catchment. The resulting probable maximum flood hydrograph, shown in Figure A-3, has a peak of 3,000 m^3/s. The volume is 45×10^6 m^3.

A.6. SEDIMENT YIELD

The purpose of the sediment yield studies is to estimate the total amount of sediment being carried past the proposed storage sites on the Tuntang and Jragung Rivers and in Rawa Pening. These estimates are needed to predict long-term reservoir sedimentation so that the proper size of reservoir is provided to meet the project needs.

A.6.1. Definitions

The definitions of erosion and sedimentation terms used in this report are those recommended by the ASCE Task committee for the preparation of the manual on sedimentation, sedimentation committee of the hydraulics division [15].

Erosion is the loosening or dissolving and removal of earthy or rock materials from any part of the earth's surface. Erosion is often differentiated according to the eroding agent (wind, water, rain-splash) and the type or source (sheet, gully, rill, slide, etc.) Denudation is the geologic term for erosion.

Sediment is the undissolved particles of mineral composition derived from the weathering of rocks forming the crust of the earth. Accordingly sediment is the undissolved portion of erosion.

Sheet erosion is the wearing away of a thin layer of the land surface and includes rill erosion unless otherwise specified.

Rill erosion is the removal of soil by small concentrations of flowing water with the formation of channels that are small enough to be smoothed completely by normal mechanical cultivation methods.

Gully erosion is the removal of soil by concentrations of flowing water sufficient to cause the formation of channels that could not be smoothed completely by normal mechanical cultivation methods.

Soil loss is the quantity of soil actually removed by erosion from small test areas.

Sediment yield is the total sediment outflow from a watershed or drainage basin, measurable at a reference cross section of the drainage-way in a specified period of time. When the weight of sediment yield is measured, the common way of reporting yield is in metric tons per square kilometer of catchment per year ($t/km^2/y$).

Soil erosion is the rate at which soil is eroded from a given area. Units employed are commonly millimeters (of erosion) per year (mm/y).

Within most watersheds, soil erosion occurs on some part of the watershed and soil deposition on other parts. In general the sediment yield of a watershed is less than the soil erosion within the same watershed. The difference is the amount of soil eroded but not carried out of the catchment.

Sediment delivery ratio is a measure of the diminution of eroded sediments by deposition as they move from the point of erosion to any designated downstream location. The main reason for the decrease is that in most fluvial systems the landscape slope decreases in the downstream direction, at least until the catchment gets very large.

The experience in the United States [15, 16] indicates that the sediment yield is inversely proportional to the drainage area according to the expression.

$$Y \sim A^m$$

Here Y is the sediment yield in $t/km^2/y$, A is the catchment area in km^2 and m is a coefficient ranging from 0.12 to 0.23.

A.6.2. Previous Studies

A.6.2.a. Jragung River

The first estimate of sediment yield in the Jragung River at the Borangan Bridge was made early in this century. Concentrations of sediment and total dissolved solids were measured in 1907. The results were reported by Rutten in 1917 [17] and in 1932 [18], who concluded that the measurements indicated a denudation rate of from 1.6 to 2.5 mm/y. The values include sediment and total dissolved solids. This is approximately equivalent to a sediment yield of 2,400 to 3,800 $t/km^2/y$.

In describing the 1907 measuring program, Rutten pointed out that most of the sediment leaves the watershed during the floods. He reported that approximately 0.5 mm of denudation occurred in one day in January and another 0.3 mm occurred in one day in December.

The next reference to erosion in the Jragung catchment was made by NEDECO in 1973 [9]. In this feasibility study it was assumed that the average denudation rate was approximately 3 mm/y. This value is approximately 1.5 times that reported by Rutten from measurements made in 1907.

NEDECO used this estimate of sediment yield to estimate the rate of sedimentation in the proposed Jragung Reservoir at $6 \times 10^6\ m^3$ in 30 years. This low value did not warrant any apprehension concerning the feasibility of the Jragung project.

In 1974, Tudor Engineering Company [19] reviewed NEDECO's feasibility report. Tudor wrote that sedimentation did not appear to be a problem for the proposed reservoir but that the estimate should be reviewed.

In 1976, the Jratunseluna Project undertook a sediment measuring program at the gaging station on the Jragung River at the Borangan Bridge. The Delft Bottle sampler was used to measure the bed-material load (sediment with a median diameter greater than 50 microns). The water trap was employed to determine the wash load, that part of the suspended sediment load with median diameters smaller than 50 microns.

The measuring program began on 5 February 1976 and continued on until 3 March 1976. A total of 100 Delft bottle samples and 133 water trap samples were collected. A summary of these measurement is given in Appendix H.

These 1976 measurements indicated that the sediment load in the river was larger than had been estimated previously. Also, the suspended sediment was the major portion of the sediment load transported by the river. Most of the suspended sediment is silt and clay. The largest suspended sediment concentration measured was 32,600 mg/l. This concentration occurred during a flood with a peak discharge of only 56 m^3/s.

A summary of the measured suspended sediment data collected during 4 floods in February and March, 1976 is given in Table A-16. The volume of water discharged during the 4 floods was 5.1×10^6 m^3, only 4 percent of the annual volume of runoff. The amount of suspended sediment carried out during the 4 floods was 101,000 metric tons.

For these 4 floods, there was no correlation between discharge and suspended sediment concentration nor between concentration and measured rainfall. The indication was that most of the sediment was produced by raindrop erosion. Yet, the storm of 22 March 1976 with the smallest maximum station rainfall (28 mm) produced the largest measured peak suspended sediment concentration (32,600 mg/l). The storm of 18 March 1976 with the largest station rainfall (106 mm) produced the smallest peak concentration (15,000 mg/l).

Engineering Consultants, Inc. summed up the knowledge gained in 1976 with the following statements:

> "The measurements indicate that the sediment transport rate in the Jragung River at the proposed damsite may be as large as 1,500,000 t/y. This is 3 to 4 times as large as the estimate made from 1907 measurements. Assuming a density of 1.2 t/m^3 for the deposited sediment and 90 percent trap efficiency, the initial decrease in reservoir capacity is approximately 1.1×10^6 to 1.5×10^6 m^3/y; 5 to 7 times greater than NEDECO's estimate. However, this new estimate must be considered very approximate. The lack of correlation between water discharge, measured rainfall and suspended sediment concentration means that projections based on a small number of measurements could be in error by a large amount.
>
> Considering the size of the proposed investment in the Jragung Dam and uncertainity in the above estimate of the sediment transport rate in the river, it would be prudent to conduct sediment measurements throughout the entire wet season in 1976 - 1977. The data collection program should be modified and simplified from that program used in February and March 1976".

The Jratunseluna Project did undertake another measuring program during the 1976 - 1977 wet season but this program was soon abandoned. First, the Delft bottle and its sled proved too cumbersome for the fast velocities in the Jragung River at the Borangan Bridge. The apparatus would drift far downstream. Then it became inpractical to measure the velocity at the points where the samples were taken.

On 1 November 1977, a new program for measuring sediment in the Jragung River at the Borangan Bridge was undertaken. Based on the knowledge that more than 90 percent of the total sediment load in the river is suspended load and furthermore the suspended load is almost entirely silt and clay, only suspended sediment samples were collected.

The new program was continued until 30 April 1978, discontinued during the dry season and then repeated from 1 October 1978 to 31 May 1979.

The measuring program is described in detail in the summary report in Appendix H. Essentially, the suspended sediment load graph versus time was derived on an instantaneous basis for all floods and on a daily basis for low flow. The total load for the season was obtained by numerically integrating the suspended sediment load versus time relation.

The results of this latest measuring program are presented in section A.6.4.

A.6.2.b. Rawa Pening

The 1:25,000 scale topographic map prepared in the years 1905 to 1908 shows Rawa Pening as a marshy area or swamp. The surface area of the swamp was 7.4 km^2. Two open water areas were shown each less than 25 hectares in surface area. The land surrounding the swamp was marked as sawah.

Rawa Pening was converted from a swamp into a freshwater lake by the completion of the construction of the weir at Jelok in 1916. [25].

The lake was sounded in part and its shoreline mapped again in 1926 [20]. This map showed channels in the bottom of the lake around the entire periphery. The center portion of the lake was higer than the channels. A delta had formed where the Galeh, Torong and Pangang rivers entered on the west side. The delta extended approximately 500 m into the lake.

An elevation versus capacity curve was prepared for the lake in the early 1930's. This curve carries the identification "Rawa Pening Inhouds - En Oppervlakt Kromme, Volgas Opname 1932 - 1936." At an elevation of 463 m, the indicated capacity was 38 x 10^6 m^3 and the area 24 km^2.

In 1972, NEDECO [21] completed a prefeasibility study directed at increasing the storage at Rawa Pening. During this study, the 1926 and 1936 contour maps of the lake were compared with a number of cross-section measured during NEDECO's investigation. The conclusion was that no noticeable siltation of the lake was occuring.

Another 1:10,000 scale map was prepared from surveys made in 1975 by the Topographical Department of the Jratunseluna Project [22]. This map shows depressions in the lake bed which indicate spring water flowing into the lake.

The elevation versus capacity curve prepared from the 1975 survey has approximately 5×10^6 m^3 more capacity than the curve prepared from data in 1932 - 1936. The difference could be in datum.

Aerial photographs of the lake were taken in April 1978. At a scale of 1:15,000, these photographs show the Galeh - Torong - Pangang delta still extending 500 m into the lake. However, as the full supply level for the lake had been raised between 1926 and 1978, it is difficult to tell how much growth had occurred in the delta.

The aerial photographs show fine sediment in suspension following the lake shore to the outlet which is the source for the Tuntang River. No delta deposits nor suspended sediment was visible at other locations in the lake.

Satya Wacana Christian University at Salatiga has been conducting research in aquatic biology and aquatic management of the Rawa Pening lake. Their work included measuring water and sediment coming into the lake. [7]. The estimates were based on a few samples taken on 1 to 5 Aug 1976 for the dry season at 30 December 1976 to 2 Jan 1977 for the wet season. From our experience in measuring water and sediment, these estimates are not reliable.

All evidence found in previous studies listed above indicates that very little sediment is accumulating in Rawa Pening Lake.

The 1955 soils study of East Java [23] did not cover the tributary catchments of Rawa Pening. However the east sector of the Merbabu cone was mapped as either lateritic or humic mountain soils. As this area is adjacent to the Rawa Pening catchment, the soils are of interest.

The lateritic soil group is comprised of red, brown and yellow soil characterized by an open, crumbly structure, slight plasticity and stickiness, slight shrinkage and cracking, good permeability and moderate water retaining capacity.

The clay mineral in the red soils is kaolinite. From 60 to 80 percent of the soil is made up of particles less than 50 microns in diameter.

The humic mountain soils are a thick layer of acid "mor", a dark brown to black very humic topsoil generally 10 to 30 centimeters thick which overlies a brown or yellowish-brown subsoil. The soil depth to parent material is usually less than 1.5 meters. The parent material is weathered volcanic tuff.

The humic soils have a water-holding capacity far greater than the lateritic and margalite soils. The humic soils are continuously moist under natural vegetation. Moreover they are highly permeable.

The natural humic soil is very friable and smeary when wet. There is no shrinking and swelling. On drying, however, the topsoil is transformed into a loose mass of fine black dust or of fine hard granules. These desiccated, "sandy" soils are then highly susceptible to erosion by water and wind. The subsoils are slightly hardened after drying and their water-holding capacities are greatly decreased.

It's cone penetrating 3,142 meters into the tropical sky, Merbabu is heavily cut by erosion and consists of a system of steep ridges, divided by deep ravines. Now, if Merbabu has been deeply eroded in the past and Rawa Pening is not filling with sediment, what is the explanation ? That question is addressed in the section A.6.4, Estimates.

A.6.2.c. Tuntang River

Sediment and total dissolved solid measurements were also made on the Tuntang River in 1907. The results were reported by Rutten in 1917 [17]. The measurements indicated a denudation rate of 2.5 mm/y (from NEDECO [5]). This value is equivalent to a sediment yield of 3,800 $t/km^2/y$.

In 1955, the General Agricultural Research Station at Bogor published the soil study of East Central Java [23]. Most of the Tuntang catchment downstream from Rawa Pening was mapped. Parts of the soils report are pertinent to this reconnaissance of the Tuntang River system.

The headwaters of the tributaries to Tuntang River downstream from Rawa Pening originate in the Kending Hills. The Mio-Pliocene deposits in these hills are a strongly folded monotonous series of marly clay with intercalated layers of calacareous tuff-sandstones and quartz-sandstones. The Miocene deposits are marine tuff-sandstones and volcanic breccias alternating with tuffaceous marls. The Plio-Pleistocene deposits are white unstratified globigerina marls and green and grey clay marls, interbedded with layers of platy or massive limestone.

On the whole, the Kendeng Hills consist of soft clays and marls with undulating gently rolling topography, while harder rocks, such as sandstones, breccias, and limestones, form isolated and steep ridges.

The Kendeng Hills are mapped as margalite soils. These comprise black and grey, loamy to heavy clay soils which are extremely plastic and sticky when wet. As a rule, the soils contain only a small percentage of sand. The amount of clay (less than 50 microns) usually exceeds 50 percent. The clay mineral is mainly montmorillonite.

The margalite soils are impermeable and water movement and aeration are poor. In addition, these soils are highly susceptible to erosion-sheet and gully erosion as well as creep.

In the report, there are comments which indicate that erosion has been severe in the past. In some places there are 10-cm thick layers of limestone and sandstone in the soil profile and at the surface. In other areas, the original black soil has been eroded and a yellow clay lies at the surface.

The soils on the intensely folded Miocene beds where the terrain is steep have been almost entirely carried away by erosion. Now there is at the best a 10-cm thick dark grey, coarse granular top layer on a gutty subsoil which at a shallow depth rests upon the tuff.

The soils of the Demak plain are built up from those eroded from the Kendeng Hills exclusively.

Practically all upland areas in the Kendeng Hills covered by the margalite soils were classified as severely eroded 30 years ago. The level to gently undulating margalite soils were considered moderately eroded.

In preparing the feasibility report for Glapan Dam in 1975, NEDECO [5], used a value of 2.5 mm/y for soil erosion quoting Rutten as the source of sediment yield data.

In their reservoir sedimentation study it was assumed that no sediment would come from Rawa Pening, 2.5 mm/y of soil erosion would occur on the remainder of the catchment, the trap efficiency of the reservoir would be 90 to 100 percent and the dry unit weight of deposits would be 1.5 t/m^3. The loss of storage would then be 1.3 x 10^6 m^3/y.

NEDECO [24] published the results of water trap measurements of suspended sediment made in 1973 in the Tuntang River at the Glapan Weir. A summary is given in Table A-17. The samples were taken at mid-depth at a number of vertical sections. Approximately 10 percent by volume of the sediment in each sample was greater than 50 microns.

From 1 January 1976 to 3 January 1977, the Jratunseluna Project collected suspended sediment samples in the Glapan Timur canal at its offtake from the Tuntang River immediately upstream from the Glapan Weir. The values of all measured concentrations greater than 7,500 mg/l are given in Table A-18.

The largest measured concentration of suspended sediment was 17,600 mg/l. This sample was collected at 2130 hours on 21 November 1976. This and the many other large concentrations measured in the canal indicate that the sediment yield may be much larger than the 3,800 t/km^2/y assumed by NEDECO in 1975.

A.6.3. Ongoing Studies

A.6.3.a. Jragung River

The program to measure suspended sediment concentrations in the Jragung River at the Borangan Bridge is being continued through the 1979-80 wet season.

A.6.3.b. Rawa Pening

Soundings are being taken in Rawa Pening currently to check again if any evidence of sedimentation can be detected in the lake.

A.6.3.c. Tuntang River

The automatic water level recorder was installed on the Tuntang River at Kedungjati in 1975 by the Serang Unit of the Jratunseluna Project. Continuous readings are available to date. However, there is no stage-discharge curve available for this site. An attempt at establishing a stage-discharge curve by making velocity and depth measurements from the railroad bridge immediately upstream was halted in 1975 when permission to use the bridge was denied by railroad officials.

In May 1979, Project personnel initiated a new operations plan for the Tuntang study. A cableway was constructed approximately 300 m downstream from railroad bridge.

On 9 May 1979, Jragung Unit personnel began sediment sampling approximately 300 m upstream from railroad bridge. Samples were taken with US DH48 suspended load sampler by wading. The discharge was measured and the corresponding stage recorder height was also noted.

The concentration of suspended sediment samples ranged from 40 to 2,500 mg/l during the month of June. The measured discharge were from 12 to 56 m^3/s. Other dry-season data will be available soon.

Sediment sampling with the P61 sampler is being done at the Kedungjati cableway during the 1979-80 wet season. A stage-discharge curve will be established at the cableway section and related to the continuous stage records available at the bridge. This program is similar to the Jragung River sediment measuring program in many respects.

Jratunseluna personnel in charge of the installation at Glapan Weir (which includes a staff at the weir, and an automatic water level recorder on the Tuntang River at Glapan Timur Intake), also take suspended load samples in the Glapan Timur Canal. Samples are taken daily at 0700 hours approximately 20 m downstream from the Glapan Timur intake on the north side of the canal. The sample is scooped by hand from the surface using a 1-liter can with handle, then poured into a bottle. Sampling in this manner at this location has been carried on since 24 January, 1977. During floods in the Tuntang River, the Glapan Timur intake gates are closed to prevent inflow of sediment-laden water.

A.6.4. Estimates

A.6.4.a. Jragung River

Suspended Sediment - The monthly values of suspended sediment yield for the Jragung catchment obtained by measurements at the Borangan Bridge are given in Table A-19. The summaries of the measurements and the daily values are listed in Appendix H. The measured values of concentration and corresponding discharge are plotted in Figure A-4.

The data in Figure A-4 are proof that there is no suspended sediment rating curve for the Jragung River. The concentrations depend mostly on intensity of rainfall, and the conditions of the watershed where it is raining; not on the water discharge in the river. Ground cover, soil type, soil moisture and topography are the prime factors which determine to what degree a given rain intensity will erode the soil. Neither is there any correlation between the weight of suspended sediment and the volume of water discharged monthly. This can be ascertained by studying the values listed in Table A-19.

On a season basis, nearly twice as much sediment was discharged in 1977-78 as in 1978-79 even though the runoff was greater in the latter period. On the average, concentrations were much larger in the 1977-78 wet season than in the 1978-79 season. That is, the cloud of points in Figure A-4 is displaced farther to the right in the first year than in the second.

Comparison of monthly basin rainfall and streamflow during the months when suspended sediment samples were taken are shown in Table A-20.

Both years were equally drier than normal; the rainfalls for the seasons were 81 and 85 percent of the long-term normal. Streamflows were also less than normal only more so. In 1977-78 streamflow was only 59 percent of the long-term average and in 1978-79, 65 percent.

There is an another difference in the two years record. In 1977-78, it was extremely dry at the start of the wet season whereas in the next year there was more rain at the beginning of the season.

There is enough evidence in the record to indicate that sediment yield is greater for a given storm rainfall at the beginning of the wet season than at the end. At the beginning, vegetation is sparse and the soil is dry. At the end, the vegetation is more luxurious and the soil is wet most of the time.

As the two years of record were extremely dry (the rainfall in 1977-78 was the second lowest in the entire 52 years of record), it is necessary to estimate the suspended sediment for a normal year.

The method employed in the final design report [12] to obtain the suspended sediment load was to multiply the monthly average concentration for the 1977-78 wet season given in Table A-19 by the long-term monthly streamflow.

The estimate of the average long-term suspended sediment load for the months November through April was 1,800,000 metric tons. At that time it was estimated that the suspended sediment discharged in the remainder of the year was less than 1 percent of that discharged in the other months and could be ignored.

Using the same method with two years of record results in a suspended sediment load for the entire year of 1,400,000 metric tons. The calculations are shown in Table A-21.

Bed-Load - The bed-load in the Jragung River is almost entirely gravel. The river is not totally alluvial in form as the bed degrades down to bedrock is some reaches.

Calculations of bed load using 5 different bed-load formulas, the instantaneous flow duration curve and the assumption that there is a plentiful supply of bed material indicate the load is in the range of 50,000 to 300,000 t/y. A value of 200,000 t/y is used for the estimate of sediment yield.

Sediment Yield - The total yield of sediment from the Jragung catchment upstream from the Borangan Bridge is the sum of the suspended and bed loads.

Employing only the first year estimate of suspended load, the long-term average sediment yield is 20,000 t/km^2/y. This is the value used to design the Jragung Dam [12].

Employing both years of record of suspended sediment, the long-term average sediment yield is 16,000 t/km^2/y. This is the value used in this reconnaissance.

The distribution of the long-term sediment yield by month is shown in Figure A-5, along with the distribution of long-term monthly rainfall and streamflow.

It must be emphasized that two years of record is not considered a suitable length of record to estimate long-term sediment yield. In the first place, sediment yield can vary greatly from year to year even when the rainfall and land use remain relatively constant. This point is illustrated by the data collected in two years at the Borangan Bridge. In these cases, ten to thirty years of record are required to obtain an accurate estimate of average sediment yield. Secondly, changes in land use in the future can affect the sediment yield by a very large factor.

The value of 16,000 $t/km^2/y$ for long-term average sediment yield is the "best estimate" available at this time. The method of interpolating the meaning of the 2 years of record is not proven. Other interpretations are possible. As more data are collected in the future, the "best estimate" will improve.

A.6.4.b. Rawa Pening Catchment

Other than the inconclusive measurements done in conjunction with the biological research effort in Rawa Pening [7], there is only indirect evidence of the magnitude of sediment yield in the Rawa Pening catchment.

First, the evidence is fairly conclusive that the lake bottom is not accumulating any sediment. Secondly, the only noticeable encroachment along the shore is the small delta on the west side.

The sediment derived from the steep slopes of Ungaran, Telomoyo and Merbabu and from the hill of sedimentary breccias between Ungaran and Telomoyo is being stored on the alluvial plains surrounding the lake.

The largest alluvial plain is on the eastern side, it extends a distance of 5.5 km from the base of the hills to the lake and slopes gently at approximately 7 m/km towards the lake.

The Galeh, Torong and one un-named river enter the eastern alluvial plain at its western extremity. The un-named river is converted into an irrigation canal running along the base of the volcano. The Galeh and Torong spill their water and sediment onto the alluvial plain and then convey the drainage out to the lake. The Torong River is approximately a quarter the size of the Galeh River.

Where it enters the alluvial plain, the Galeh River is approximately 10 m wide and 4 m deep. Yet, the river banks are higher than the surrounding sawah. Near the lake, the width is still 10 m but the depth is only 0.5 m at the most. The channel is maintained by small bunds approximately 40 cm high. As this river drains the area with the most erosive rocks, it probably carries more sediment than the others.

The Klegung River drains a large valley in the flanks of Telomoyo and an older volcano, Gilipetung. The valley is the sector-graben described by von Bemmelen [26] and called the Klegung rent. Here the slopes are steep and the rainfall large. The river has dumped its coarse load of sand and gravel in an alluvial fan where it enters the eastern alluvial plain. The water is channelized into irrigation ditches; there is nothing left of the river.

The other rivers flowing north directly into the lake from the volcanic slopes are gravel and boulder bed streams with very steep slopes. Their contributions of sediment to the alluvial plain appear to be smaller than the other rivers. Infiltration may be very large in this region so erosive surface water is less than in the hill areas to the west.

The rivers flowing into the lake from the east drain the slopes of Merbabu. They have developed a small flat alluvial plain at the edge of the lake. Water in these rivers is utilized for irrigation and there are no deltas along the lake shore.

For this reconnaissance. the sediment yield of 5,000 $t/km^2/y$ is used for the non-alluvial portion of the Rawa Pening catchment. Although the catchment is primarily recent volcanic material, very steep, cultivated and has a high rainfall, the large infiltration and groundwater flow have resulted in less surface flow than in most other catchments. Muncul springs alone account for 20 percent of the flow at the Jelok Weir. Other springs in the bottom of the lake could account for 20 percent more.

A.6.4.c. Tuntang River Catchment

For that portion of the Tuntang River catchment downstream from the Jelok Weir and upstream from the Gunung Wulan damsite, the sediment yield of 15,000 $t/km^2/y$ is used in this reconnaissance. This large value is employed because; the few measurement of sediment concentrations at the Glapan Weir indicate large sediment loads; the soils in the Kendeng Hills are very erosive; the area is heavily populated; the catchment is adjacent to the Jragung catchment where the sediment yield is 16,000 $t/km^2/y$; and it is prudent to use a large value for sediment yield in the reconnaissance study when few or no measurements are available.

For the catchment downstream from the Gunung Wulan damsite and upstream from the Glapan Weir, a value of 9,000 $t/km^2/y$ is used for the sediment yield. This catchment is mostly teak forest. The land has been abused but not as badly as the cultivated hills upstream.

TABLE A-11

MONTHLY DISCHARGE OF TUNTANG RIVER AT GLAPAN

(Units of m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual m^3/s	Annual mm
1952	-	-	-	60.5	44.8	59.7	19.4	7.9	4.3	7.8	10.5	11.8	-	-
1952-'53	13.5	51.4	43.8	54.4	51.1	49.0	79.8	70.4	18.6	13.9	9.5	10.2	38.8	1,532
1953-'54	8.9	19.4	28.9	45.2	53.0	46.6	40.0	30.8	20.4	15.1	20.9	13.9	28.6	1,126
1954-'55	16.5	47.9	41.6	46.2	39.4	40.3	39.4	29.9	18.1	37.7	22.5	14.9	32.9	1,304
1955-'56	13.3	38.2	30.2	75.5	58.5	29.7	11.9	11.0	29.0	10.8	19.2	12.7	28.3	1,121
1956-'57	10.8	18.3	42.6	38.2	26.6	74.8	39.9	17.0	8.6	25.8	9.6	7.8	26.7	1,060
1957-'58	6.6	9.5	45.2	40.6	96.5	80.6	74.3	55.9	23.6	36.2	39.8	17.9	43.9	1,727
1958-'59	20.1	18.0	78.0	71.9	58.0	41.4	62.8	61.1	33.2	44.5	16.9	10.1	43.0	1,706
1959-'60	11.7	18.1	61.4	40.3	60.7	43.4	42.7	35.0	15.0	17.9	10.4	8.4	30.4	1,206
1960-'61	9.1	28.1	26.7	54.4	33.1	35.6	29.7	42.2	12.0	9.3	6.6	3.1	24.2	958
1961-'62	2.9	7.3	10.2	31.0	37.3	51.1	64.4	23.9	11.9	12.8	13.6	7.4	22.8	899
1962-'63	8.0	23.7	37.5	58.2	34.8	61.4	33.7	14.1	8.1	8.1	7.0	6.5	25.1	994
1963-'64	5.2	6.6	22.4	19.3	31.3	32.6	33.0	31.6	14.6	9.9	8.1	7.8	18.5	736
1964-'65	19.9	33.0	19.0	45.2	46.5	45.4	32.3	9.6	8.2	6.5	4.6	3.2	22.8	897
1965-'66	3.3	5.1	14.9	28.2	33.3	66.2	29.5	14.6	14.1	7.5	5.7	5.4	19.0	750
1966-'67	11.0	13.3	43.1	38.7	50.3	32.9	47.5	16.9	7.4	5.4	4.3	3.9	22.9	901
1967-'68	3.4	5.3	20.8	44.9	35.7	42.6	42.1	59.1	43.0	34.2	28.3	11.9	30.9	1,229
1968-'69	19.3	36.6	37.1	39.7	68.0	62.1	86.3	21.8	18.7	8.9	9.9	7.0	34.6	1,360
1969-'70	6.3	14.3	29.9	22.5	20.4	50.1	31.9	29.6	16.9	15.5	12.2	13.2	21.9	871
1970-'71	8.1	16.4	27.2	29.5	40.0	38.6	44.3	32.8	25.5	13.8	10.6	7.1	24.5	965
1971-'72	12.2	26.7	53.4	55.9	26.8	38.2	30.6	33.0	12.4	12.6	9.5	5.9	26.4	1,053
1972-'73	2.7	18.6	32.9	37.5	30.7	41.9	57.9	76.3	26.6	22.5	11.1	19.1	31.5	1,249
Mean	10.1	21.7	35.6	44.5	44.4	48.4	44.3	32.9	17.7	17.1	13.2	9.5	28.3	1,121

TABLE A-12

MONTHLY DISCHARGE OF TUNTANG RIVER AT JELOK WEIR

(Units of m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952-'53	9.3	17.0	15.4	15.1	15.9	20.2	23.6	22.6	12.3	10.7	9.5	9.6	15.1
1953-'54	8.1	7.7	8.7	13.6	14.7	14.7	12.7	12.2	10.0	9.9	15.2	10.7	11.5
1954-'55	8.4	16.6	17.2	14.8	13.5	16.6	16.9	15.6	11.4	20.4	16.5	13.3	15.1
1955-'56	9.5	12.4	11.5	25.1	20.4	14.4	8.5	6.7	13.1	9.9	14.0	10.8	13.0
1956-'57	8.8	8.6	13.6	16.7	12.6	24.4	14.2	10.6	6.9	17.3	10.8	10.2	12.9
1957-'58	7.2	6.1	14.7	16.9	30.1	21.5	25.8	19.6	12.5	17.2	16.6	12.7	16.8
1958-'59	13.7	9.8	18.0	19.8	23.9	18.7	17.0	22.2	18.5	19.1	12.1	9.4	16.9
1959-'60	7.7	8.7	14.3	15.4	22.6	15.2	16.5	16.4	12.3	13.3	10.8	10.0	13.6
1960-'61	7.9	9.3	12.8	17.1	13.0	2.7	11.8	18.2	9.9	9.3	7.6	5.5	10.4
1961-'62	4.8	5.5	6.9	11.0	12.7	13.8	18.6	13.5	10.8	11.0	10.1	8.8	10.6
1962-'63	6.9	9.7	7.9	13.7	13.7	17.6	12.1	10.0	8.1	8.2	7.3	7.2	10.2
1963-'64	6.7	5.3	6.7	8.5	8.9	10.9	9.2	10.1	8.8	9.5	8.5	7.9	8.4
1964-'65	9.2	13.7	10.3	15.1	16.7	11.6	11.5	9.9	7.4	7.2	4.8	4.1	10.1
1965-'66	4.3	6.0	6.8	10.2	14.3	18.8	14.6	10.2	9.6	9.4	7.4	5.9	9.8
1966-'67	6.5	7.8	9.9	12.5	13.5	13.5	23.8	14.4	10.4	9.1	9.2	7.9	11.5
1967-'68	4.0	4.9	8.4	11.5	11.5	13.0	15.6	20.3	17.4	18.0	21.0	12.1	13.1
1968-'69	11.6	11.8	17.2	17.7	19.7	17.9	26.8	14.5	14.4	11.3	11.5	8.6	15.3
1969-'70	6.0	9.0	15.4	12.4	11.7	11.6	15.8	17.5	12.9	13.1	12.2	10.6	12.4
1970-'71	6.4	7.9	11.8	11.6	12.2	11.7	12.0	14.4	14.2	12.5	11.8	9.2	11.3
1971-'72	7.9	12.5	21.8	14.3	13.6	13.8	16.1	18.0	12.7	10.6	10.0	8.2	13.3
1972-'73	4.9	4.8	6.2	10.9	11.3	12.0	15.0	23.8	16.8	13.2	9.9	12.4	11.8
Average	7.6	9.3	12.2	14.5	15.5	15.0	16.1	15.3	11.9	12.4	11.3	9.3	12.5

TABLE A-13

AVERAGE MONTHLY DISCHARGE OF TUNTANG RIVER AT GUNUNG WULAN DAMSITE

(Units of m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Annual
1951-'52	–	–	–	–	–	–	–	–	–	–	–	–	–
1952-'53	12.5	42.9	36.8	44.7	42.4	41.9	65.9	58.6	17.0	13.1	9.5	10.1	33.0
1953-'54	8.7	16.5	23.9	37.4	43.5	38.7	33.3	26.2	17.8	13.8	19.5	13.1	24.4
1954-'55	14.5	40.2	35.6	38.4	33.0	34.4	33.8	26.4	16.4	33.4	21.0	14.5	28.5
1955-'56	12.4	31.8	25.6	63.1	49.1	25.9	11.1	9.9	25.1	10.6	17.9	12.2	24.6
1956-'57	10.3	15.9	35.4	32.9	23.1	62.4	33.6	15.4	8.2	23.7	9.9	8.4	23.3
1957-'58	6.8	8.7	37.7	34.7	80.1	66.0	62.3	46.9	20.9	31.5	34.1	16.6	37.2
1958-'59	18.5	16.0	63.2	59.0	49.6	35.8	51.5	51.5	29.6	38.2	15.7	9.9	36.5
1959-'60	10.7	15.8	49.8	34.2	51.3	36.4	36.2	30.4	14.3	16.8	10.5	8.8	26.3
1960-'61	8.8	23.5	23.3	45.2	28.1	27.5	25.3	36.3	11.5	9.3	6.9	3.7	20.6
1961-'62	3.4	6.9	9.4	26.1	29.5	41.9	53.1	21.4	11.6	12.4	12.7	7.8	19.7
1962-'63	7.7	20.2	30.2	47.2	29.6	50.6	28.4	13.1	8.0	8.1	7.1	6.7	21.4
1963-'64	5.6	6.3	18.5	15.6	25.8	27.2	27.1	26.3	13.2	12.5	8.2	7.8	16.2
1964-'65	17.3	28.2	16.9	37.8	39.1	37.1	27.2	9.7	8.0	6.7	4.7	4.8	19.8
1965-'66	3.6	5.3	12.9	23.8	28.6	54.5	25.8	13.5	13.0	8.0	6.1	5.5	16.7
1966-'67	9.9	11.9	34.9	32.2	41.2	28.1	41.6	16.3	8.1	6.3	5.5	4.9	20.1
1967-'68	3.6	5.2	17.7	36.7	29.7	35.3	35.6	49.5	36.7	30.2	26.5	12.0	26.6
1968-'69	17.4	30.5	32.2	34.3	56.1	51.2	71.6	20.0	17.6	9.5	10.3	7.4	29.8
1969-'70	6.2	13.0	26.3	20.0	13.3	40.6	27.9	26.6	15.9	14.9	12.2	12.6	19.5
1970-'71	7.7	14.3	23.4	25.1	33.1	32.0	36.3	28.3	22.7	13.5	10.9	7.6	21.2
1971-'72	11.1	23.2	45.6	45.6	23.5	32.2	27.1	29.3	12.5	12.1	9.6	6.5	23.2
1972-'73	3.2	15.2	24.3	30.9	25.9	34.5	47.3	63.3	24.2	20.2	10.8	17.4	26.4
Mean	9.5	18.6	29.7	36.4	37.2	38.4	38.2	29.5	16.8	16.4	12.8	9.4	24.4

TABLE A-14

MONTHLY RUNOFF OF JRAGUNG RIVER AT JRAGUNG DAMSITE

(Units of $10^6 m^3$)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1916-1917	7.2	8.1	31.4	31.3	26.4	9.7	18.0	8.3	6.3	0.4	1.5	6.8	137.4
1917-1918	10.0	9.5	11.9	18.8	29.8	9.7	4.8	2.5	0.9	0.2	0.0	0.0	98.1
1918-1919	0.2	3.4	12.0	17.4	16.3	17.8	18.6	15.0	1.5	0.0	0.4	0.0	102.6
1919-1920	0.0	11.2	31.4	14.8	15.7	19.6	14.6	1.9	2.6	0.0	8.5	4.3	124.6
1920-1921	9.9	5.7	10.5	15.4	18.1	22.8	9.1	0.8	2.6	1.8	0.0	2.4	99.1
1921-1922	4.0	10.4	21.1	12.7	17.1	23.3	10.7	14.7	9.7	0.8	0.0	0.0	124.5
1922-1923	4.5	5.2	18.7	20.2	14.8	17.5	5.6	9.7	5.3	12.7	0.0	0.0	114.2
1923-1924	0.0	6.7	10.7	10.0	19.2	16.9	19.7	6.6	2.6	3.4	0.0	0.0	95.8
1924-1925	10.5	22.9	4.0	19.9	16.1	21.3	5.4	3.6	0.0	0.0	0.0	0.0	103.7
1925-1926	0.0	5.0	10.4	19.6	9.1	30.7	9.0	21.4	0.0	0.0	0.0	0.0	105.2
1926-1927	1.8	6.4	25.1	28.8	11.7	15.7	22.8	24.4	6.2	0.0	0.0	1.1	144.0
1927-1928	1.4	6.7	16.2	15.2	29.0	27.7	11.9	2.3	2.3	0.0	3.2	0.0	115.9
1928-1929	4.2	11.7	22.4	7.7	11.7	23.1	6.2	0.8	1.9	0.0	0.0	0.0	89.7
1929-1930	1.5	5.1	15.5	18.9	28.2	18.4	15.4	11.2	0.5	1.9	0.0	0.0	116.6
1930-1931	2.9	6.1	10.7	45.1	11.6	25.3	13.4	7.5	1.4	0.0	0.0	0.0	124.0
1931-1932	12.3	5.5	8.2	16.3	23.4	30.0	15.6	5.1	8.0	0.0	0.0	0.6	125.0
1932-1933	3.7	6.9	11.1	20.3	24.6	47.4	5.1	12.5	5.7	14.6	2.6	2.5	157.0
1933-1934	3.7	8.9	15.2	40.9	16.9	17.3	14.9	2.7	1.3	0.4	0.0	0.0	122.2
1934-1935	3.2	15.4	4.8	23.3	9.9	23.9	19.0	3.1	1.7	0.0	0.0	0.0	104.3
1935-1936	7.8	5.0	8.5	19.6	18.3	26.3	26.4	10.7	2.0	0.6	0.0	0.0	125.2
1936-1937	1.1	6.3	5.5	28.4	9.2	24.5	21.9	12.3	5.8	0.0	0.0	1.3	116.3
1937-1938	0.2	2.9	15.7	27.6	31.3	15.3	5.3	18.3	7.3	3.2	0.0	0.2	127.3
1938-1939	3.3	16.4	18.8	16.8	22.5	24.2	15.8	1.5	19.9	10.0	0.4	0.0	149.6
1939-1940	1.1	6.4	6.1	14.6	21.5	18.6	16.6	20.3	2.2	0.0	0.0	0.0	107.4
1940-1941	0.0	4.4	24.2	20.8	23.8	24.8	23.7	18.4	3.8	1.0	0.0	0.0	144.9
1951-1952	0.0	1.7	23.2	38.3	20.4	27.9	9.3	5.7	1.0	0.0	1.5	0.2	129.2
1952-1953	3.4	6.7	10.1	11.7	9.3	17.8	13.3	12.7	0.1	1.2	0.0	0.0	86.3
1953-1954	0.0	9.4	7.9	12.5	23.0	13.7	7.6	11.6	1.5	1.0	2.0	5.2	95.4
1954-1955	4.4	28.1	10.1	12.4	32.5	12.5	16.0	14.7	3.3	8.6	3.2	2.2	148.0
1955-1956	6.6	13.0	14.6	70.9	21.8	15.8	4.1	11.0	6.1	0.9	4.1	0.0	168.9
1956-1957	1.2	3.8	17.8	16.1	14.3	20.2	7.1	4.7	3.8	5.2	1.4	0.0	95.6
1957-1958	2.3	7.5	32.9	15.5	34.1	19.9	17.6	10.6	5.1	12.3	9.4	0.3	167.5
1958-1959	3.7	5.0	16.6	23.6	12.2	10.2	16.3	14.8	2.3	4.8	0.0	1.6	111.1
1959-1960	1.7	2.7	18.2	20.0	25.9	7.4	10.0	9.9	1.2	0.7	0.0	0.0	97.7
1960-1961	0.5	20.8	8.5	77.3	9.2	22.5	4.4	13.8	0.0	0.0	0.0	0.0	157.0
1961-1962	0.0	5.2	11.4	40.4	32.0	36.1	26.7	3.4	2.6	4.1	2.7	0.0	164.6
1962-1963	6.1	5.8	13.2	63.7	13.5	24.2	11.0	1.4	0.0	0.0	0.0	0.0	136.9
1963-1964	0.0	2.4	15.0	14.2	17.3	10.1	19.2	9.0	3.9	0.9	0.7	4.7	97.4
1964-1965	7.4	18.4	10.7	73.9	18.8	18.2	10.3	4.2	0.7	0.2	0.0	0.0	162.8
1965-1966	0.0	4.3	14.0	20.2	31.7	30.8	5.9	4.7	3.4	0.0	0.0	0.0	115.0
1966-1967	10.5	5.0	12.5	21.7	29.7	17.8	19.0	0.7	0.0	0.0	0.0	0.0	116.9
1967-1968	0.3	7.3	13.5	19.0	31.3	11.1	12.8	17.8	15.5	8.5	3.9	0.7	141.7
1968-1969	2.1	9.5	29.2	8.1	10.5	11.2	30.3	0.8	0.8	0.0	0.0	0.0	102.5
1969-1970	0.9	7.0	6.0	13.6	13.8	31.2	13.2	15.8	2.3	3.1	0.0	0.0	106.9
1970-1971	2.8	9.7	22.3	33.3	37.1	21.0	11.8	7.5	6.1	1.0	0.0	0.0	152.6
1971-1972	6.4	8.9	7.2	40.4	11.2	40.5	8.2	8.0	0.0	0.0	0.0	0.0	130.8
1972-1973	0.0	4.6	10.8	27.4	19.7	18.0	24.1	22.4	5.9	4.0	0.3	5.6	142.8
1973-1974	3.4	10.6	17.0	12.7	16.7	30.1	12.7	7.4	2.3	1.2	1.3	3.5	118.9
1974-1975	10.0	11.2	7.7	19.0	9.2	15.4	21.7	15.8	0.3	0.0	0.1	3.5	113.9
1975-1976	7.1	11.1	11.4	23.6	14.0	27.0	12.3	4.1	2.0	1.8	0.5	1.0	115.9
1976-1977	3.6	9.2	2.7	4.8	11.0	18.2	8.6	9.9	8.9	0.7	0.4	0.2	78.2
1977-1978	0.2	1.2	8.8	14.5	19.8	9.2	5.4	6.1	3.3	5.1	2.2	5.2	81.0
1978-1979	4.0	2.8	10.0	16.1	9.5	7.1	17.4	-	-	-	-	-	-
Mean	3.4	8.2	13.9	24.3	19.4	20.7	13.7	9.3	3.5	2.2	1.0	1.0	120.6

TABLE A-15

MONTHLY STREAMFLOW

JRAGUNG RIVER AT THE BORANGAN BRIDGE

(10^6 m^3)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1972-1973								23.9	6.3	4.3	0.3	6.0	-
1973-1974	3.7	11.4	18.3	13.6	17.9	32.3	13.6	8.1	2.5	1.1	1.4	3.8	127.7
1974-1975	10.8	12.0	8.3	20.4	9.9	16.6	23.3	17.0	0.3	0.0	0.1	3.8	122.5
1975-1976	7.6	11.9	12.2	25.3	15.6	29.0	13.2	4.4	2.1	1.9	0.5	1.1	124.8
1976-1977	3.9	9.9	2.9	5.1	11.8	19.6	9.2	10.6	9.6	0.8	0.4	0.2	84.0
1977-1978	0.2	1.3	9.4	15.6	21.3	9.9	5.8	6.6	3.5	5.5	2.4	5.6	87.1
1978-1979	4.3	3.0	10.8	17.3	10.2	7.7	18.7	5.8					
Short-term Mean	5.1	8.2	10.3	16.2	14.4	19.2	14.0	10.9	4.0	2.3	0.8	3.4	108.8

TABLE A-16

SUSPENDED SEDIMENT DISCHARGED DURING STORMS

	Hydrograph of 18-2-76	23-2-76	18-3-76	22-3-76
Peak discharge, m^3/s	57	105	358	56
Peak measured suspended sediment concentration, mg/l	24,200	15,000	24,000	32,600
Volume of water dis charged, m^3	460,000	980,000	3,3000,000	350.000
Amount of suspended sediment transport, metric tons	7,600	11,500	76.000	6,500
Suspended sediment transport rate, tons/10^6 m^3	16,000	12,000	23,000	19.000
Maximum station rainfall, mm	50	106	71	28

TABLE A-17

MEASURED SUSPENDED SEDIMENT

TUNTANG RIVER AT GLAPAN WEIR

Date	Vertical Number	Discharge m^3/s	Volume of Sediment $10^{-6} m^3$	Dry Weight of Sediment $10^{-3} kg$	Concentration mg/l	Dry Unit Weight kg/m^3
13 Feb 1973	4I	50	10.5	1.02	816	97
	5I	50	8.3	1.70	1,360	205
	6I	50	6.2	0.99	792	160
	7I	50	8.2	1.60	1,280	195
17 Feb 1973	3I	49	39.5	9.10	7,280	230
	4I	49	34.5	8.61	6,890	250
	5I	49	30.5	7.93	6,340	260
	6I	49	26.7	6.36	5,090	239
	7I	35	22.9	5.84	4,670	255
	8I	35	23.5	5.40	4,320	230
	9I	35	20.0	3.89	3,110	195
1 Mar 1973	3I	51	8.0	1.23	984	154
	4I	51	8.8	1.34	1,070	152
	5I	48	7.8	1.37	1,100	176
	8I	34	8.7	1.33	1,060	153
	9I	33	7.0	1.03	824	147
8 Mar 1973	2II	104	34.3	9.22	7,380	269
	3I	112	28.5	7.83	6,260	275
	3II	116	28.6	7.27	5,820	254
	4I	130	43.6	3.76	3,010	86
	4II	145	41.7	6.73	5,380	161
	5I	155	34.5	6.38	5,100	185
	5II	156	23.3	6.35	5,080	273
	6I	144	19.5	4.62	3,700	237
	6II	138	32.0	5.84	4,670	182
	7I	129	26.3	4.21	3,370	160
	7II	120	29.2	4.98	3,980	171
	8I	116	27.7	4.00	3,200	144
	8II	103	29.2	4.27	3,420	146
	9I	98	25.9	3.39	2,710	131
20 Mar 1973	3I	188	55.1	8.81	7,050	160
	4I	185	41.8	9.09	7,270	217
	5I	184	28.5	6.24	4,990	219
	6I	175	35.1	8.94	7,150	255
	7I	175	42.8	9.80	7,840	229

Note: The volume of water and sediment in each sample was 1.25 liters.

TABLE A-18

MEASURED SUSPENDED SEDIMENT

GLAPAN TIMUR CANAL

1976

Date	Hour	Suspended Sediment Concentration mg/l
Record begins 1 Jan 1976		
Mar 9	1730	7,560
	1847	7,740
Mar 12	2030	11,000
Mar 19	1900	8,020
	1930	8,440
	2000	7,860
	2100	7,550
Apr 20	0900	8,400
	0930	8,770
	1000	8,040
Nov 17	2100	7,640
Nov 21	2100	16,800
	2130	17,600
	2200	17,100
	2230	16,900
	2300	14,900
	2330	13,100
	2400	12,900
Nov 22	0030	12,100
	0100	12,300
	0130	13,100
Nov 24	1800	12,000
	1830	9,860
	1900	10,800
	1930	11,800
	2000	10,200
	2030	12,200
	2100	10,100
Nov 25	2100	15,400
	2130	16,700
	2200	14,200
	2230	13,000
	2300	12,000
	2330	10,000
	2400	8,950
Nov 26	0030	8,320
	1800	15,200
	1830	9,550
	1900	13,000
	1930	11,900
	2000	11,300
	2030	10,600
	2100	11,000
	2200	9,220
	2230	8,300
	2330	7,600
Dec 1	1630	13,800
	1700	13,600
	1730	14,700
	1800	13,900
	1830	10,900
	1900	11,800
	1930	11,000
	2000	10,100
	2030	9,100
	2100	9,980
Dec 11	2100	16,200
Record ends 30 Jan 1977.		

TABLE A-19

SUSPENDED SEDIMENT YIELD

JRAGUNG CATCHMENT UPSTREAM FROM BORANGAN BRIDGE

Water Year	Month	Suspended Sediment kg	Water Discharged m^3	Monthly Average Concentration mg/1
1977 - 78	Nov	16,620,000	1,256,000	13,200
	Dec	386,073,000	9,377,000	41,200
	Jan	175,078,000	15,619,000	11,200
	Feb	513,583,000	21,302,000	24,200
	Mar	33,007,000	9,915,000	3,330
	Apr	56,560,000	5,750,000	9,840
	Total	1,180,921,000	63,219,000	
1978 - 79	Oct	48,733,000	4,311,000	11,300
	Nov	10,766,000	2,964,000	3,630
	Dec	76,719,000	10,802,000	7,100
	Jan	105,780,000	17,328,000	6,100
	Feb	107,850,000	10,228,000	10,500
	Mar	51,746,000	7,656,000	6,760
	Apr	213,768,000	18,732,000	11,410
	May	48,882,000	5,844,000	8.360
	Total	664,244,000	80,385,000	

TABLE A-20

BASIN RAINFALL AND STREAMFLOW

JRAGUNG RIVER AT BORANGAN BRIDGE

Water Year	Month	Rainfall mm	Percent of Long-term Rainfall	Streamflow 10^6 m^3	Percent of Long-term Streamflow
1977-78	Nov	168	67	1.3	15
	Dec	302	94	9.4	63
	Jan	367	87	15.6	60
	Feb	392	111	21.3	102
	Mar	194	54	9.9	45
	Apr	164	64	5.8	39
	Season	1,587	81	63.3	59
1978-79	Oct	155	97	4.3	116
	Nov	85	34	3.0	34
	Dec	375	116	10.8	72
	Jan	331	78	17.3	66
	Feb	241	68	10.2	49
	Mar	216	60	7.7	34
	Apr	405	158	18.7	127
	May	171	86	5.8	66
	Season	1,979	85	77.8	65

TABLE A-21

LONG-TERM SUSPENDED SEDIMENT LOAD

JRAGUNG RIVER AT BORANGAN BRIDGE

Month	Average Concentration mg/l	Long-term Streamflow 10^6 m^3	Long-term Suspended Sediment metric ton
Oct	11,300	3.71	41,900
Nov	8,420	8.78	73,900
Dec	24,200	14.91	360,800
Jan	8,650	26.14	226,100
Feb	17,400	20.79	361,700
Mar	5,050	22.24	112,300
Apr	10,600	14.71	155,900
May	8,360	10.00	83,600
Remainder	500	8.34	4,200
		129.62	1,420,400

A.7. SEDIMENT ACCOMMODATION

In addition to emphasizing the importance of good soil management practices in the upland watersheds, any water development plan for the Jragung and Tuntang basins must have provisions to accommodate the sediment eroded from the uplands and carried by the river flows. The main problems caused by sediment are: loss of water storage capacity in the reservoirs and lakes as a result of sediment being deposited; and the loss of carrying capacity in the rivers, canals and floodways due to sedimentation.

A.7.1. Sediment Storage

The criterion used in this reconnaissance is to provide accommodation for 50 years of sediment storage in any proposed reservoir. That is, the reservoir is sized to provide the amount of water storage needed for the project and for 50 years of sediment deposits.

The sediment yield values presented in the previous section were used to compute the amount of sediment coming into the reservoir. For normally operated reservoirs, Churchill's trap efficiency curve [27] was employed to determine the amount of sediment passing through the reservoir. The distribution of sediment in the reservoir was determined with the empirical method developed by the US Bureau of Reclamation [15].

The dry unit weight of sediment deposited in the reservoir is estimated as 1,000 kg/m^3. This is the value obtained in investigations of the Cimanuk delta in the Java Sea. The dry unit weight of the soil deposited in the Demak plain has been measured in many studies. Values reported by NEDECO in 1978 [28] ranged from 860 kg/m^3 to 1,460 kg/m^3. The average is approximately 1,200 kg/m^3. The samples of soil were taken in 33 borings at depths of 1, 3 and 5 m. In other studies in the same area, the values range from 800 to 1,300 kg/m^3.

Recent deposits of organic clay in the Citanduy River floodplain in Java have dry unit weights less than 1,000 kg/m^3.

A.7.2. Sediment Passing

In situations where the water yield from the catchment is much greater than the annual storage volume required for the project, it is possible to pass some of the incoming sediment through the reservoir along with the excess water.

Sediment passing is accomplished by building a low-level outlet through the dam or abutment at river bed level. A high-level outlet is also provided in the reservoir to supply water to the turbines and irrigation outlet works.

With the low-level outlet closed, the reservoir is operated in the conventional manner. Water for poser and irrigation is obtained through the high-level outlets. Floods are either stored in the reservoir or passed over the spillway. The incoming sediment is stored in the reservoir at all levels including the conservation pool.

At the end of the irrigation season, when the reservoir is drawn down to the level of the high-level intake, the low-level gates are opened and the remaining water is drained from the reservoir. Thereafter, the gates are left open so that any flood will pass directly through the reservoir and dam almost unimpeded. The reservoir is operated in the same manner as a single-purpose flood control reservoir without much flood attenuation.

With the low-level gates open, the sediment load in the river is passed as well as the water. Little or no sedimentation in the reservoir occurs with the low-level gates open.

It must be emphasized that the sediment passing scheme used in this study is not an effort to flush or erode sediment deposited in the reservoir during periods when the low-level gates are closed. Full-scale tests have proven that sediment cannot be eroded from reservoir deposits in any quantity sufficient to increase the life of the reservoir significantly.

At some time during the wet season, the low-level gates must be closed so that the reservoir can be filled for the next dry season.

The amount of sediment passed through the reservoir and the low-level outlets during one season was estimated using the measured seasonal distribution of sediment yield for the Jragung River at the Borangan Bridge. The distribution is shown in Figure A-5.

For example, if the low-level conduit in the proposed Jragung Dam is kept open during the months of November, December and January, then about 66,500 m^3, 324,700 m^3 and 203, 500 m^3, of sediment will be passed through the dam in those respective months assuming average annual discharges.

The above numbers are based on the mean monthly long-term suspended sediment yield presented in Figure A-5. It is assumed that all bed load transported by the river will be retained in the reservoir and the trap efficiency of the reservoir under conditions of floods and sediment passing will be 10 percent. The effects of sediment passing on the storage capacity of the reservoir and the useful life of the project will be as follows.

1. On an average basis, a volume of 0.6×10^6 m^3 of sediment will pass through the reservoir every year, which would have deposited in the reservoir had the passing of floods during the months of November, December and January not been done.
2. Over a period of 50 years, which is assumed in the economic analysis as the useful life of the project, the volume of storage for sediment needed in the reservoir will be 40×10^6 m^3 against 70×10^6 m^3 needed for the operation of the reservoir without sediment passing.

Consequently, the storage capacity of the Jragung Reservoir for the sediment passing mode of operation would be 30 x 10^6 m^3 less than that needed for the condition if the sediment was not passed through the reservoir.

From the above illustrative example, it may be hypothesized that the height of the dam needed to impound water and also accommodate sediment will be less if the sediment is passed through the reservoir during a part of the rainy season compared to the corresponding height of the dam needed for the conventional operation of the reservoir. The exact amount of the sediment that can actually be passed will depend upon the length of the time the low-level outlets can be kept open without jeopardizing the projected usages of the reservoir. The simulated operation studies for the period of the available data will establish the actual period of sediment passing and the time during the rainy season when the low-level outlets should be closed so that the reservoir can be filled to its full capacity needed for the next dry season.

The dry unit weight of the sediment deposited in a reservoir with low-level outlets was assumed to be 1,100 kg/m^3.

A.7.3. Downstream Sedimentation

Sedimentation is occuring at rapid rates in the canals and floodways in the Demak plain. Some examples are cited below. In 1978, NEDECO [28] reported that

> "....... the capacity of the Jragung canal is reduced to some 3 m^3/s because of heavy siltation. (The first part of the canal was rehabilitated a few years ago for 8 m^3/s) ...."

Sediment has piled up on the crest of the Jragung Weir to a level 2 meters above the crest on the right side. It has been necessary to maintain the capacity of this weir by excavating this sediment by hand.

The floodplain of the Tuntang River between its levees is filled with sediment. Our studies of the cross-sectional surveys made by the Jratunseluna Project in June 1972 indicate that the deposits on this floodplain range linearly from 4 m at the Semarang-to-Surabaya road at Gubug to almost nil at the Java Sea.

The indication is that the bed of the main channel of the Tuntang River has not aggraded even as the floodplain between the levees filled. In 1972, the bankfull depth was approximately 6 m at the road and 2 m at the sea.

Unless the sediment load in the lower reaches of the Tuntang and Jragung Rivers is decreased, the design criteria for flood control channels should reflect these facts:

1. The floodplains between the levees fill rapidly with sediment.

2. Any excavations of the main channel, either in width or in depth will probably sediment quickly back to its existing shape.

Some cutoffs of meander loops in the lower reaches of the rivers are appropriate.

For the channels, the sedimentation problem is the same. Canals receive large concentrations of clay and silt which, when deposited on the bed and banks, cannot be eroded again by flowing water. Thus, the canals in the Demak plain cannot be considered nor designed as "regime" canals.

If the sediment load in the Tuntang and Jragung Rivers is not reduced greatly, five factors should be considered in the design of irrigation canals.

1. Reducing the amount of sediment entering the head gate of the canal.

2. Providing sedimentation ba ins in the canal at its headworks.

3. Keeping canal velocities as large as practical as long as possible to prevent sedimentation.

4. Providing the proper shape (width-to-depth ratio) so that sedimentation rates are low.

5. Providing maintenance funds to remove the sediment from the canal periodically.

A.7.4. Rawa Pening

For Rawa Pening, the sediment is being stored primarily on the alluvial plains adjacent to the lake. If the lake and its principal tributaries are leveed, the sediment will then be carried into the lake. If additional storage is provided by building levees around the villages and leaving the alluvial plains unprotected, the sediment will not threaten to fill the existing lake. Sedimentation will continue to occur on the plain as it has in the last 60 years.

A.7.5. Gunung Wulan

Two alternatives are available at the proposed Gunung Wulan project. First, the reservoir can be sized to accommodate the annual deposition of sediment. Secondly, because there is excess water available, a sediment passing scheme can be considered.

A.7.6. Glapan Barrage

If Gunung Wulan dam is built first and traps most of the upstream sediment yield, the Glapan site could be developed as a conventional storage site with 50-year project life for water storage.

Without Gunung Wulan to trap sediment, the Glapan reservoir would fill quickly with sediment. However, sediment passing could be accomplished as the flow in the Tuntang River is much greater than the storage available at Glapan if the full supply level is kept below the railroad and major towns.

A.7.7. Jragung

The proposed reservoir on the Jragung River could be operated in the sediment passing mode or as a conventional reservoir. The choice depends on the amount of water diverted from the Tuntang River and the demand for storage in the proposed Jragung reservoir.

BIBLIOGRAPHY

No. Title

1. Thaden, R.E., Harli Sumadirdja and Richards, P.W., "Geological Map of the Magelang and Semarang Quadrangles, Java," Geological Survey of Indonesia, Directorate General of Mines, Ministry of Mines, Jakarta, 1975.

2 Belgian Technical Assistance Program, "Report on Activities of Project ATA 105," Soil physics report, Soil Research Institute, Bogor, West Java, 1977

3. Geological Survey of Indonesia, "Geological Map of Java and Madura, Sheet Central Java," Second edition, Directorate General of Mines, Ministry of Mines, 1977.

4. Snowy Mountains Engineering Corporation, "Definite Scheme Report, Volume 4, Water Investigations. The Improvement and Development of the Serang River and Irrigation Project, Central Java," report prepared for Republic of Indonesia, Ministry of Public Works, Directorate General of Water Resources Development, Jakarta, September, 1978.

5. NEDECO, "Jratunseluna Basin Development Plan, Central Java, Glapan Dam, Irrigation, Flood Control and Hydro-Power Project Feasibility Study, Vol. 2, Appendices I - IX, Part B, Tables, Annexes and Figures", report prepared for Republic of Indonesia, Ministry of Public Works and Electric Power, Directorate General of Water Resources Development, Jakarta, July 1975.

6. Engineering Consultants, Inc.," Jragung Dam Multi-Purposed Irrigation, Flood Control, Hydro-Electric and Municipal and Industrial Water Supply Project, Upgraded Feasibility Study, Appendix II, Hydrology," report prepared for Republic of Indonesia, Ministry of Public Works and Electric Power, Directorate General of Water Resources Development, Directorate of Irrigation, Jakarta, September 1976.

7. Iswandi Haryanto, "The Seasonal Variation of the Water and Sediment Distribution to the Rawa Pening Lake," Journal of Satya Wacana Research, Vol. Serie 3, Salatiga, Central Java, 1978

8. The Institute of Meteorology and Geophysics, "Rain Observations in Indonesia," Department of Communications, Yearbooks 1879 to 1975, Jakarta.

BIBLIOGRAPHY
(Cont.)

No.	Title
9.	NEDECO, "Jragung Dam Flood Control and Irrigation Project Feasibility Study," report prepared for Directorate General of Water Resources Development, Ministry of Public Works and Electric Power, Republic of Indonesia, August 1973.
10.	Hershfield, D.M., "Method for Estimating Probable Maximum Rainfall," Journal of American Waterworks Assoc., vol. 57, pp. 965 - 972, August 1965.
11.	NEDECO, "Ngrambat Dam Irrigation, Flood Control and Hydro-Power Project Feasibility Study, Vol. 3 Supporting Data, Jratunseluna Basin Development Plan Central Java," report prepared for the Directorate General of Water Resources Development, Ministry of Public Works and Electric Power, Republic of Indonesia, Jakarta, June 1975.
12.	Engineering Consultants, Inc., "Jragung Dam Project, Final Design Report, Part I,"Text, report prepared for the Directorate General of Water Resources and Development, Ministry of Public Works, Republic of Indonesia, April 1979.
13.	Engineering Consultants, Inc., "Citanduy Basin Feasibility Report," report prepared for Directorate of Rivers, Directorate General of Water Resources and Development, Ministry of Public Works, Republic of Indonesia, November 1974.
14.	Snowy Mountains Engineering Corporation, "Cimanuk Project, Jatigede Dam and Power Facility, Report on Hydrology," prepared for the Ministry of Public Works and Electric Power, Directorate General of Water Resources Development, Republic of Indonesia, 1977.
15.	American Society of Civil Engineers, "Sedimentation Engineering", manuals and Reports on Engineering Practice No. 54, Vito A. Vanoni, editor, New York 1975.
16.	Schumm, S.A. "The Fluvial System", John Wiley & Sons, New York, 1977.

No. Title

17. Rutten, L.M.R., "Over Denudatie Snelheid op Java", Versl: Wis en Natuurk. Afd. Kon. Academie van Wetenschappen, Amsterdam, XXVI, page 921-930, 1917.

18. Rutten, L.M.R, "De Geologie van Ned. Indie," W.P. van Stockum & Zoon, Den Haag, 218 pp, 1932

19. Tudor Engineering Company, "Technical Evaluation of Feasibility Studies for Jragung Dam and Ngrambat Dam", report prepared for U.S. Agency for International Development, Department of State, May 1974.

20. Jratunseluna Project, "Tranchekaart Volgens Opn 1926 Rawa Pening", 1:10,000 scale map prepared for Proyek Rehabilitasi Irigasi Semarang - Kudus, 29 December 1970.

21. NEDECO, "Djratunseluna Basin Development Project, Prefeasibility Study, Rawa Pening", report prepared for the Directorate General of Water Resources Development, Ministry of Public Works and Power, Republic of Indonesia, February 1972.

22. Jratunseluna Project, "Rawa Pening Scale 1:10,000", map prepared by the Topographical Department, 1976.

23. Dames, T.W.G. "The Soils of East Central Java, with a Soil map 1:250,000" Nr 141 Contributions of the General Agricultural Research Station, Bogor, Jan 1955.

24. NEDECO, "Jratunseluna Basin Development Plan, River Morphology", Supporting Report VII, prepared for the Directorate General of Water Resource Development, Ministry of Public Works and Electric Power, Republic of Indonesia, July 1973.

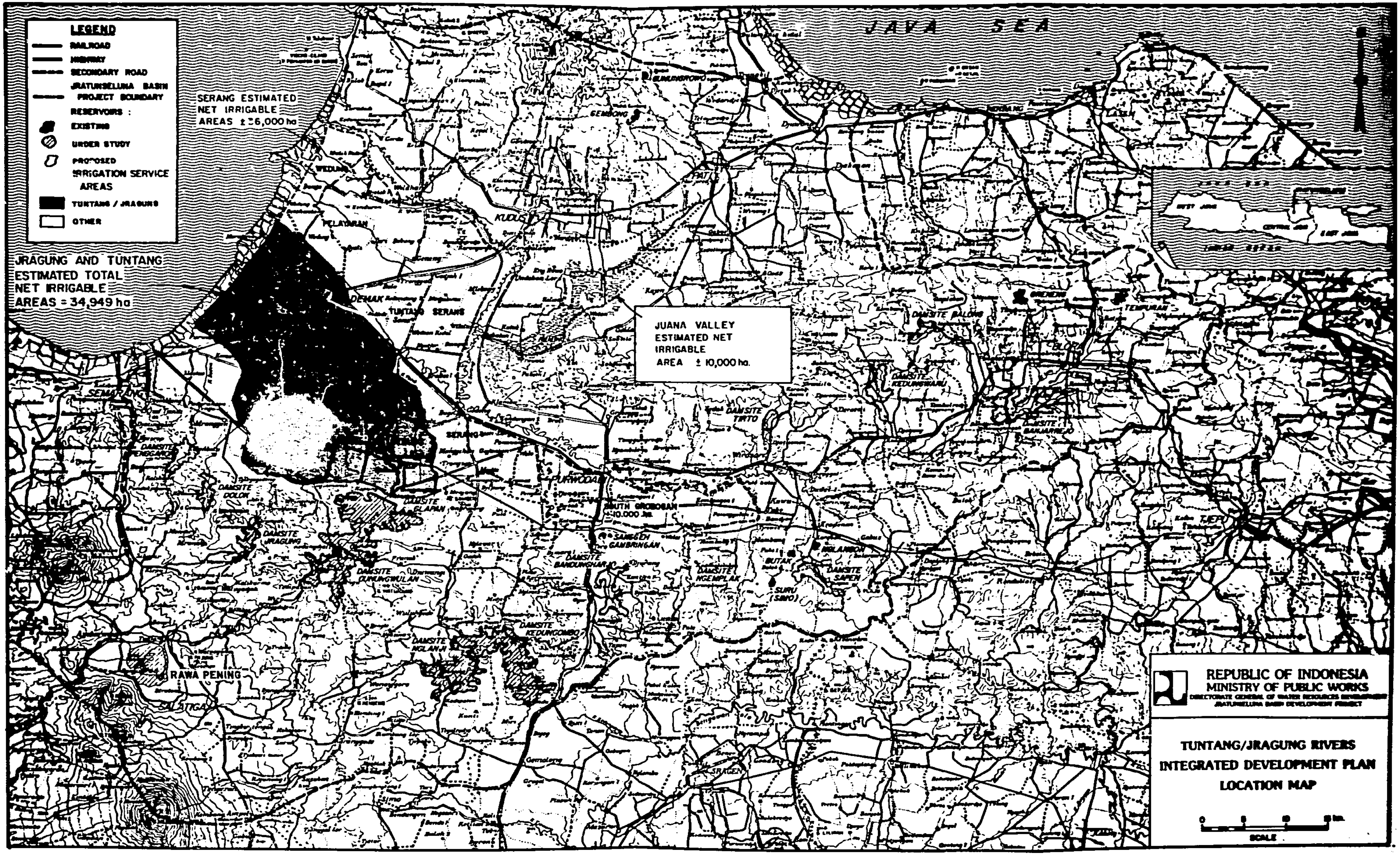
25. Goeltenboth, F., "The Rawa Pening Lake-Background Information, Facts and Problems," Proc. of the First Seminar in Aquatic Biology and Aquatic Management of the Rawa Pening Lake, Satya Wacana Christian University, Salatiga, Central Java, Nov 20-21, 1978.

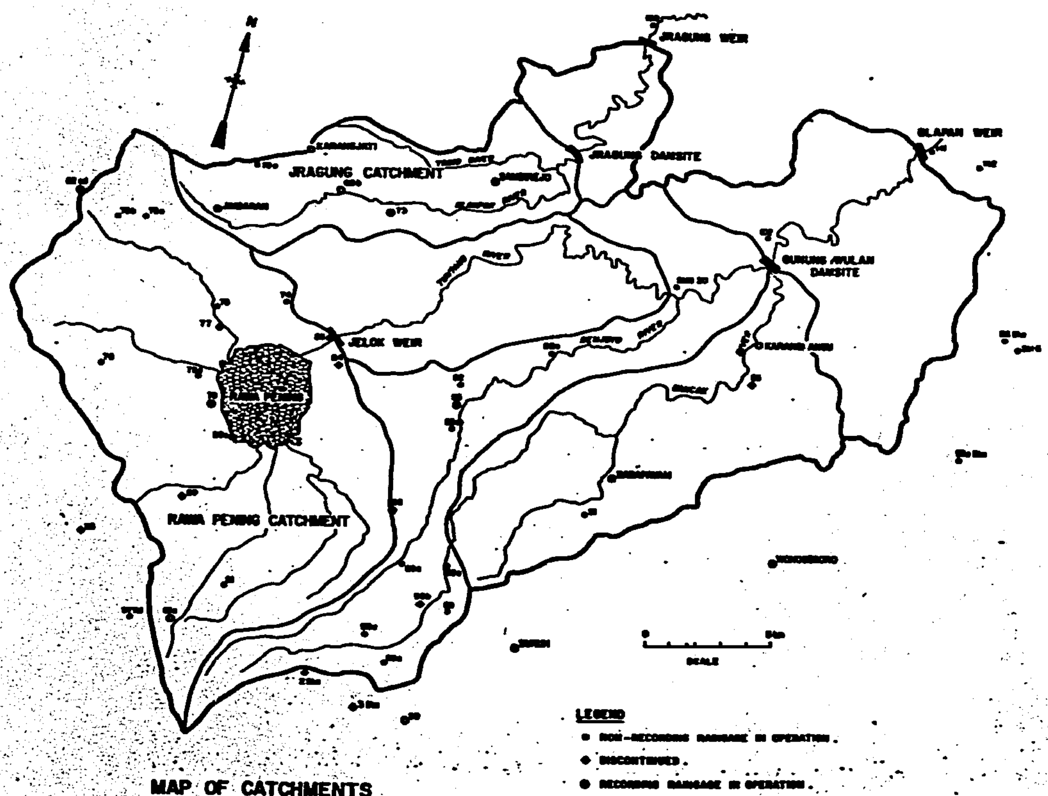
26. von Bemmelen, R.W., "The Geology of Indonesia," vol. 1 A, General Geology of Indonesia and Adjacent Archipelagoes, 2nd edition, Martinus Nijhoff, the Hague, 1970.

No. | Title

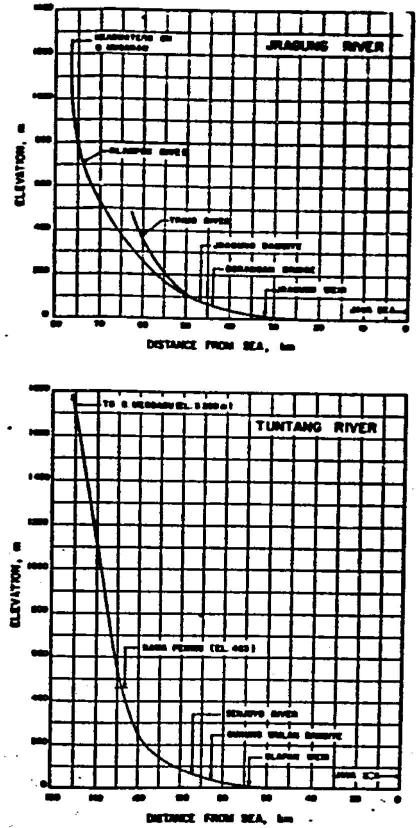
27. Churchill, M.A., discussion of "Analysis and Use of Reservoir Sedimentation Data," by L.C. Gottschalk, Proceeding of the Federal Interagency Sedimentation Conference, Denver, Colorado, pp 139-140, 1947.

28. NEDECO, "Sedeku - Prosida Semarang - Demak - Kudus Irrigation Rehabilitation Project," Quarterly Report No. 3, prepared for the Directorate General of Water Resources Development, Ministry of Public Works, Republic of Indonesia, October 1948.


LEGEND
RAILROAD
HIGHWAY
SECONDARY ROAD
JRATUNSELUNA BASIN PROJECT BOUNDARY
RESERVOIRS :
EXISTING
UNDER STUDY
PROPOSED
IRRIGATION SERVICE AREAS
TUNTANG / JRAGUNG
OTHER
JAVA SEA
SERANG ESTIMATED NET IRRIGABLE AREAS ± 26,000 ha
JRAGUNG AND TUNTANG ESTIMATED TOTAL NET IRRIGABLE AREAS = 34,949 ha
JUANA VALLEY ESTIMATED NET IRRIGABLE AREA ± 10,000 ha.
DEMAK
KUDUS
SERANG
PURWODADI
SEMARANG
SALATIGA
RAWA PENING
SRAGEN
DAMSITE DOLOK
DAMSITE JRAGUNG
DAMSITE GLAPAN
DAMSITE DUNUNGWULAN
DAMSITE NGLANJI
DAMSITE KEDUNGOMBO
DAMSITE BANDUNGHARJO
DAMSITE NGEMPLAK
DAMSITE SAPEN
DAMSITE TIRTO
DAMSITE KEDUNGWARU
DAMSITE BANJARREJO
DAMSITE BALONG
SOUTH GROBOGAN ±10,000 ha.
REPUBLIC OF INDONESIA
MINISTRY OF PUBLIC WORKS
TUNTANG/JRAGUNG RIVERS
INTEGRATED DEVELOPMENT PLAN
LOCATION MAP
SCALE



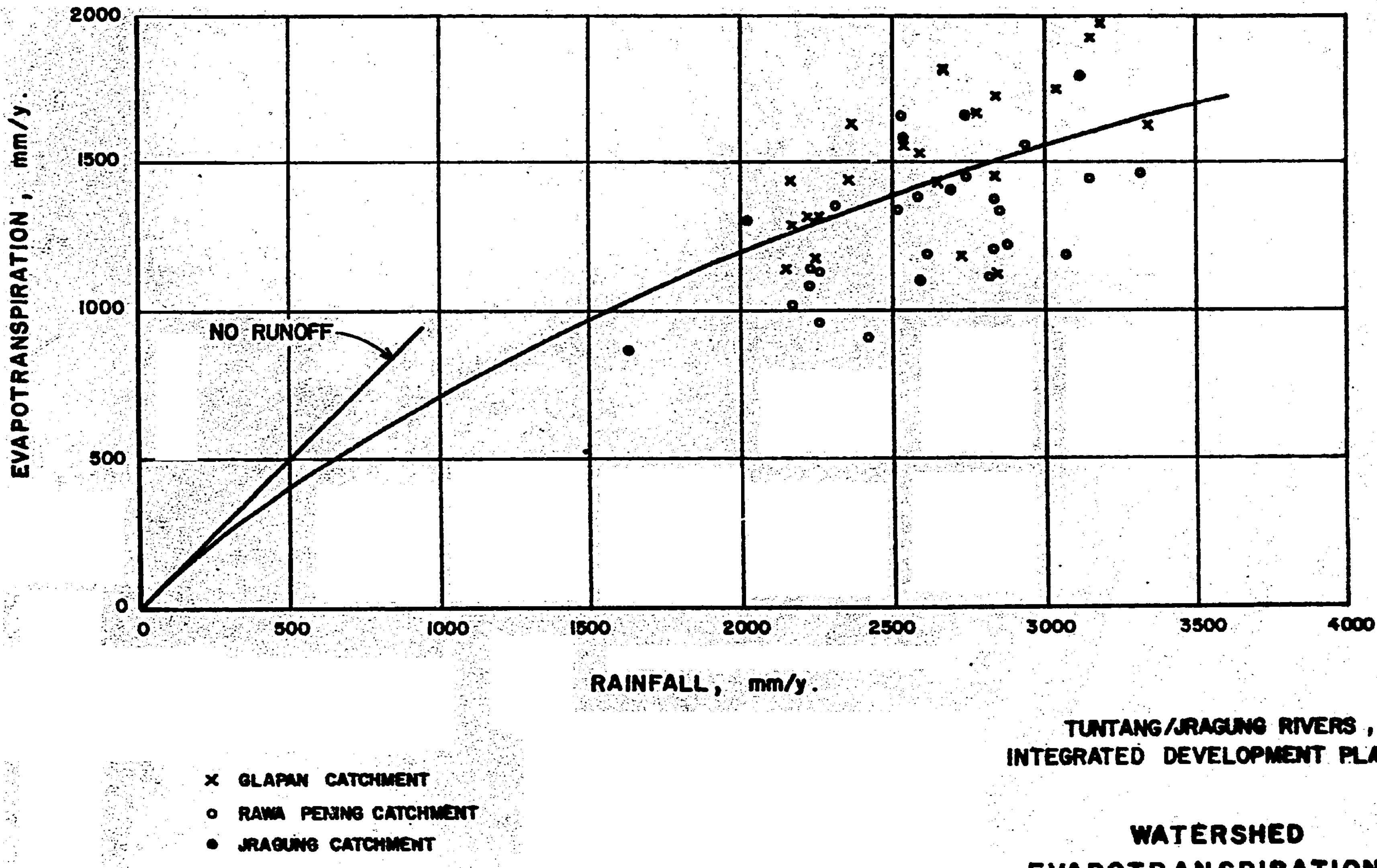
MAP OF CATCHMENTS



RIVER PROFILES

TUNTANG/JRAGUNG RIVERS
INTEGRATED DEVELOPMENT PLAN

MAP AND PROFILES



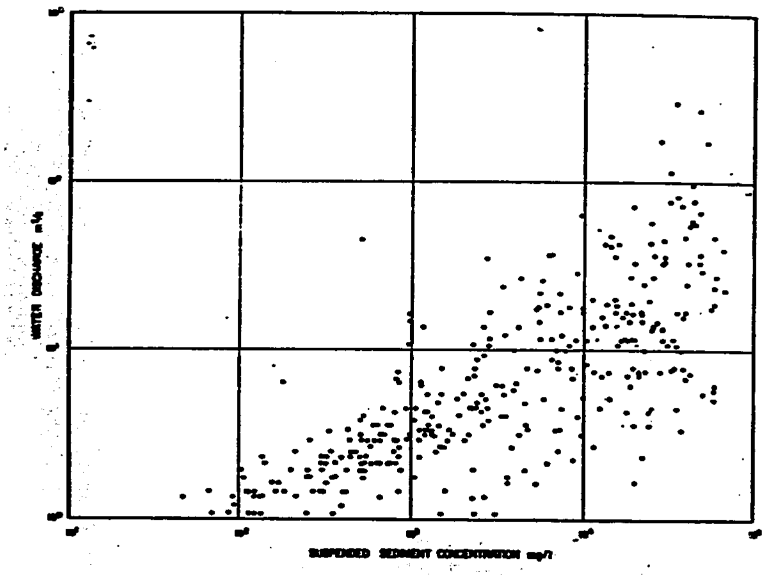
TUNTANG/JRAGUNG RIVERS, INTEGRATED DEVELOPMENT PLAN

WATERSHED EVAPOTRANSPIRATION

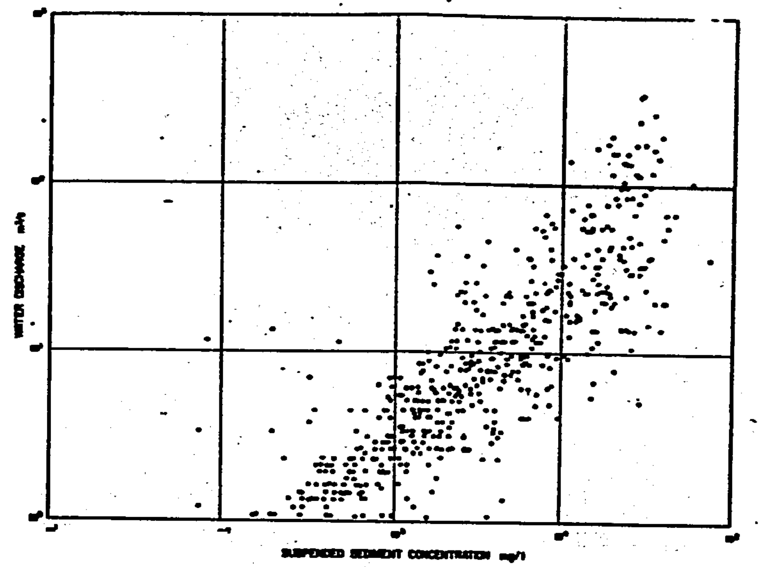
FIGURE A-2

PRC ENGINEERING CONSULTANTS, INC.

PRC ENGINEERING CONSULTANTS, INC



1977-1978 WET SEASON



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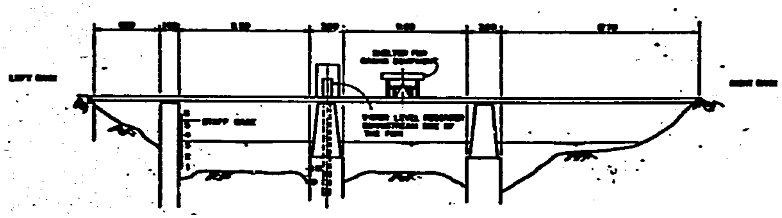
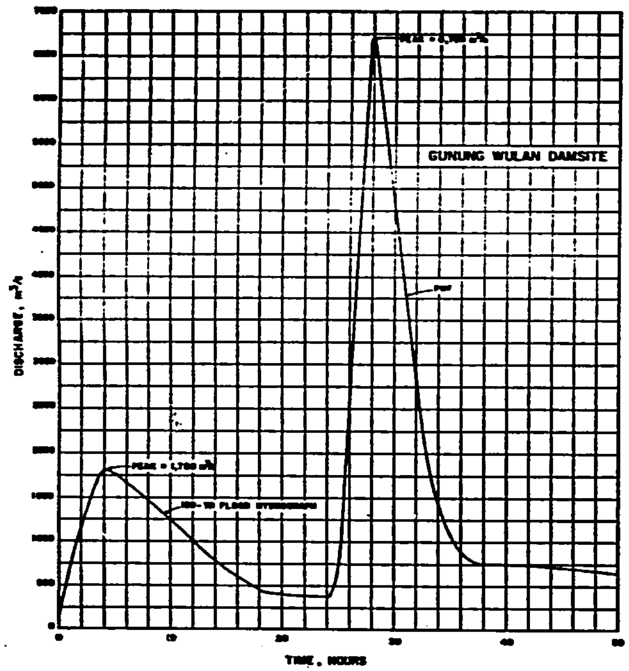
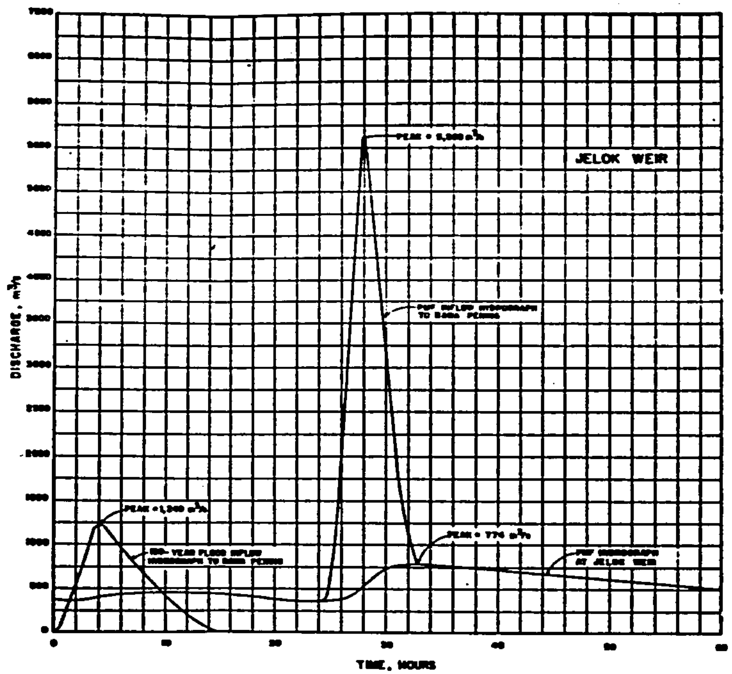


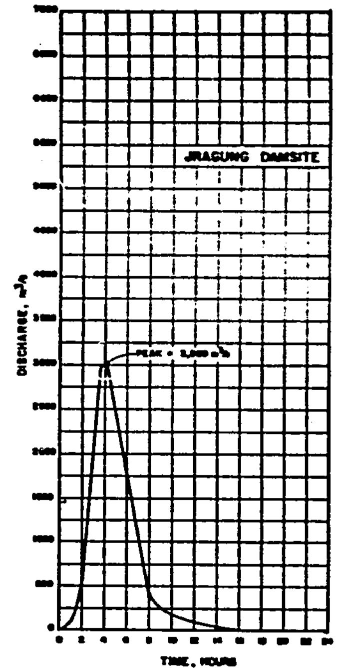
CROSS SECTION AT BRIDGE

TUNTANG / JRAGUNG RIVERS
INTEGRATED DEVELOPMENT PLAN

SUSPENDED SEDIMENT CONCENTRATIONS
JRAGUNG RIVER

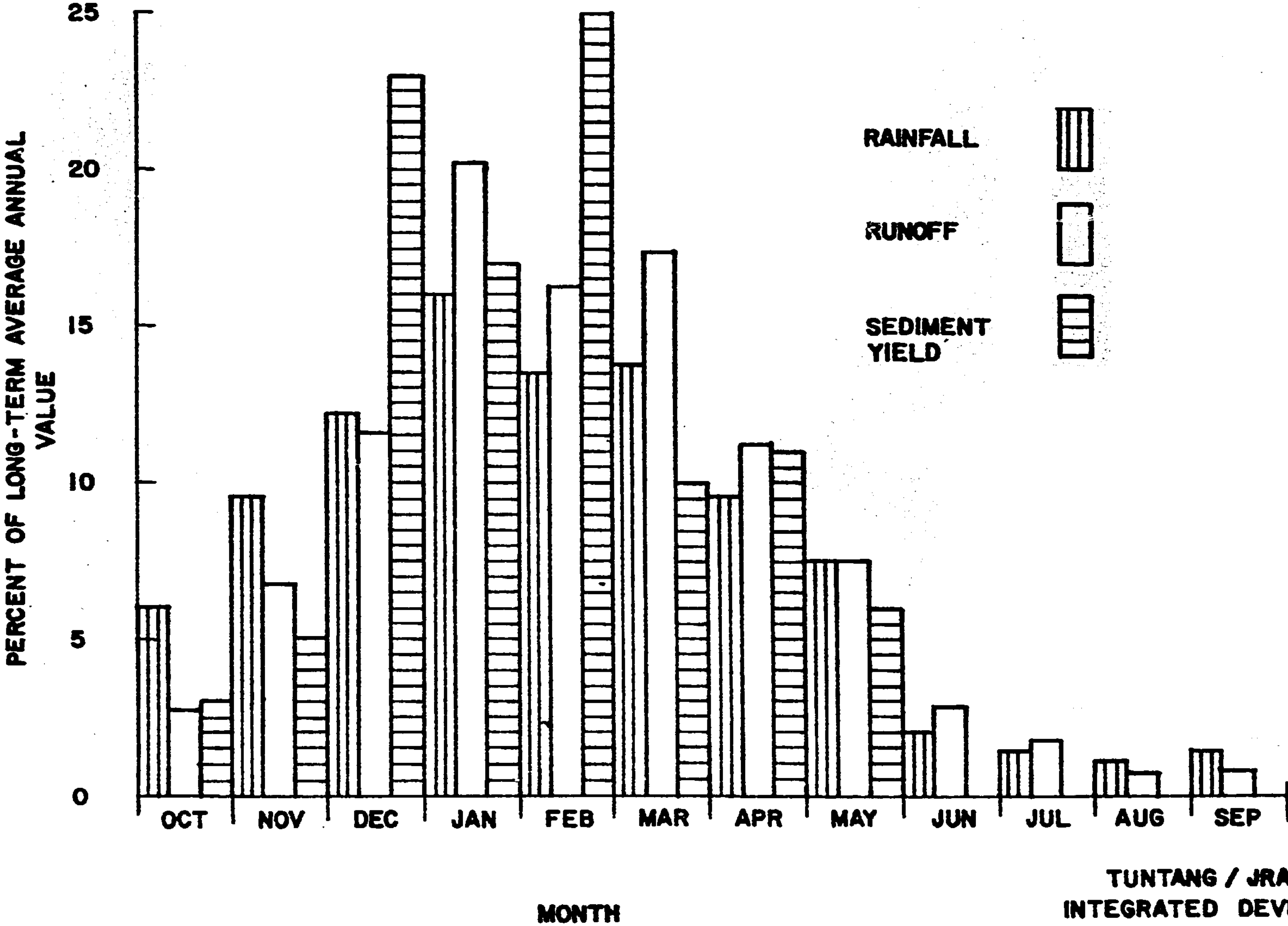






TUNTANG / JRAGUNG RIVERS
INTEGRATED DEVELOPMENT PLAN

INFLOW DESIGN HYDROGRAPHS



PRC ENGINEERING CONSULTANTS, INC

TUNTANG / JRAGUNG RIVERS
INTEGRATED DEVELOPMENT PLAN

MONTHLY DISTRIBUTIONS

FIGURE A-5

PART II
TUNTANG AND RELATED RIVERS BASINS DEVELOPMENT PLAN

APPENDIX A
HYDROLOGY

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APPENDIX A - PART II

HYDROLOGY

LIST OF FIGURES

APPENDIX A - PART II

HYDROLOGY

TABLE A-1

SUMMARY OF HYDROLOGIC DATA
PENGGARON AND DOLOK RIVERS BASINS

	Unit	Penggaron River	Dolok River
Area:			
Catchment area at weir	km^2	77.7	41.5
Catchment area at damsite	km^2	75.6	34.0
Rainfall over Catchment:			
Mean annual rainfall	mm	2,721	2,415
Maximum annual rainfall	mm	3,455	3,098
Minimum annual rainfall	mm	2,212	1,635
Maximum daily station rainfall (Sta. No. 79, No. 686)	mm	501	273
Rainfall over Service Area:			
Mean annual rainfall	mm	2,175	2,241
Maximum annual rainfall	mm	2,864	2,780
Minimum annual rainfall	mm	1,583	1,626
Maximum daily station rainfall (Sta. No. 79)	mm	501	501
Runoff: (At weir)			
Mean annual runoff	mm	1,325	1,116
Average annual discharge	m^3/s	3.3	1.50
Annual yield	10^6 m^3	103.0	46.31
Floods:			
Mean annual flood peak	m^3/s	240	130
Diversion design flood peak	m^3/s	400	230
Diversion design flood volume	10^6 m^3	3.2	0.9
Probable maximum flood peak	m^3/s	2,700	1,800
Probable maximum flood volume	10^6 m^3	21.6	7.3

TUNTANG AND RELATED RIVERS
BASINS DEVELOPMENT PLAN

APPENDIX A - PART II

HYDROLOGY

A.1. PENGGARON AND DOLOK RIVERS BASIN

A.1.1. Description of Watersheds

(i) General

The Penggaron and Dolok watersheds are adjacent basins having their headwaters on the slopes of the Ungaran Volcano (Figure A-1). Streams drain down from the volcano's north-eastern slope flowing out on a radial pattern, incising their beds into the volcanic debris.

The following main tributaries combine into the Penggaron River as shown in Figure A-2.

- Kali Gendera
- Kali Kresek
- Kali Klangit
- Kali Surugodo
- Kali Penggung
- Kali Porong
- Kali Juru Gajah

The following tributaries combine into the Dolok River as shown in Figure A-3:

- Kali Sat
- Kali Luing
- Kali Grengseng

- Kali Lana
- Kali Gandu
- Kali Bokor
- Kali Juwet
- Kali Juruk
- Kali Kalam
- Kali Mara
- Kali Dilar

Nothing is known about the movement of groundwater in the area. Similar to what has been followed in the hydrologic studies of other basins is the Jratunseluna Project Area, it is assumed that there is no transfer of groundwater to or from adjacent catchments.

The catchment areas of the basins are:

Penggaron River upstream of Pucanggading weir:	77.7 km^2
Penggaron River upstream of proposed damsite:	75.6 km^2
Dolok River upstream of Barang weir:	41.5 km^2
Dolok River upstream of proposed damsite:	34.0 km^2

(ii) Land Use

Land use in the Penggaron and Dolok Rivers catchments is indicated in Figure A-4 (Reproduced from 1:50,000 scale) land use maps from site surveys conducted in September 1969). The land use for the watershed upstream of the Penggaron proposed damsite are as follows:

Land Use	Percent of Area
Rice fields	16
Dry fields	48
Villages	12
Teak forest	19
Rubber plantation	5
	100

The land use for the watershed upstream of the Dolok proposed damsite are as follows.

Land Use	Percent of Area
Rice fields	6
Dry fields	24
Villages	6
Teak forest	56
Rubber plantation	7
	100

The land use for the watershed upstream of the Jragung damsite, as determined by Engineering Consultants Inc. in the Jragung Dam Upgraded Feasibility Study [6] are indicated for comparison:

Land Use	Percent of Area
Rice fields	44
Dry fields	17
Villages	10
Teak forests	20
Rubber plantations	9
	100

(iii) River Profiles:

The slope of the Penggaron Riverbed at the proposed damsite is approximately 17 m/km. At the Dolok River proposed damsite the riverbed slope is approximately 17 m/km as well.

(iv) Damsites

The proposed damsite on Penggaron River is located about 2.00 km upstream of Pucanggading weir. The length of the river stream down to the damsite is about 17.5 km.

The proposed Dolok damsite is located at 2.00 km upstream of Barang weir. The Dolok river had incised its channel in a a narrow gorge between two volcanoes.

A.1.2. Rainfall

(i) Annual Catchment Rainfall

The mean annual rainfall on the catchment for the years 1952 through 1973 are as follows:

Catchment	Annual Rainfall
Penggaron Upstream of Pucanggading Weir	2,721 mm
Dolok Upstream of Barang Weir	2,415 mm

The same values apply to the Penggaron and Dolok catchments upstream of the proposed damsites respectively. These values are calculated using the Thiessen polygon applied to monthly rainfall data, as detailed in paragraph (ii) hereoff. The yearly rainfall totals for the different gages were checked by double mass analysis.

For the Penggaron catchment, the wettest water year was 1967-1968 with 3,455 mm of rain, while the driest was 1962-1963 with 2,212 mm.

The wettest water year for the Dolok catchment was 1957-1958 with 3,098 mm and the driest year was 1962-1963 with 1,635 mm.

(ii) Monthly Catchment Rainfall

Monthly data from selected raingage stations have been Thiessen-averaged to arrive at monthly catchment rainfall for each of the two catchments.

Some records of rainfall gages were missing and could not be made available by all possible sources, including:

- LMG (Institute of Meteorology and Geophysics, Jakarta)
- DPU Wilayah Semarang
- DPU Propinsi Jateng
- Jratunseluna Project Office
- Serang Branch, Jratunseluna Project

In most of the cases, records are available for the closest 4 rain gages forming, more or less, the corners of a square around the point in question. These records were used to synthesize the missing data by weighing by its inverse square distance from the point [12].

The values of the monthly catchment rainfall on the Penggaron catchment upstream of the Pucanggading Weir and on the Dolok catchment upstream of Barang Weir are presented in Tables A-3 and A-4 respectively. The Thiessen weights used to derive these monthly catchment rainfall values are presented in Table A-2'.

The mean monthly values of the Penggaron catchment upstream of Pucanggading at Dolok upstream of Barang are as follows:

MONTHLY RAINFALL

(mm/%)

PUCANGGADING WEIR CATCHMENT

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
143	253	342	440	398	364	260	197	101	91	61	71	2,721
5.3	9.3	12.6	16.2	14.6	13.4	9.6	7.2	3.7	3.3	2.2	2.6	100.0

BARANG WEIR CATCHMENT

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
139	258	296	406	325	292	233	183	72	84	68	59	2,415
5.8	10.7	12.3	16.7	13.5	12.1	9.6	7.6	3.0	3.5	2.8	2.4	100.0

(iii) Daily and Maximum Rainfall:

An attempt was made to compute the different catchment and service area rainfall, and hence the simulated streamflow, on ten-daily or half monthly basis. Unfortunately the Institute of Meteorology and Geophysics, Jakarta, started keeping records of ten-day means of daily precipitation as from January 1973. Not one complete year of records was available for the period of integrated operations (October 1952 through September 1973). Computing such means from daily records for the numerous gages used in this study would require much longer period than the time available.

The maximum recorded daily station rainfall for raingage stations in and near the Penggaron and Dolok catchments for the period of record and up to the end of 1973, are shown in Table A-5, as transcribed from the records of the Institute of Meteorology and Geophysics (LMG) in Jakarta.

The highest daily recorded station rainfall in the Penggaron and Dolok vicinity was 501 mm, raingage 96, January 1934.

The lowest daily recorded station rainfall in the vicinity was 203 mm, raingage 93, November 1964.

The average maximum recorded daily station rainfall in the vicinity from the commencement of record upto the end of 1973 is 307 mm.

(iv) Probable Maximum Rainfall

The probable maximum daily rainfall over the Tuntang and Jragung estimated by Engineering Consultants, Inc. by using

Hershfield method. The annual maximum daily rainfall values for 14 selected stations in the Tuntang catchment and 8 selected gages adjacent to the catchment above Jragung damsite were used for the analysis. The results are transcribed as indicated in Table A-6. By way of expolation, the probable maximum station daily rainfall over the vicinity of Penggaron and Dolok catchments is 640 mm.

The probable maximum station 24-hour rainfall is 704 mm and the probable maximum 24-hour catchment rainfall 641 mm for Penggaron catchment and 667 mm for Dolok catchment.

This regional approach for estimating the probable maximum precipitation is adequate for the purpose of the model operation, but further analysis of the daily records of raingages located in the vicinity of Penggaron and Dolok basins will be necessary for the design of the dams. The daily records are available at the Institute of Meteorology and Geophysics (LMG), Jakarta.

(v) <u>Annual Service Area Rainfall</u>

The mean annual rainfall on the Penggaron service area is 2,175 mm and on the Dolok service area is 2,241 mm. These values were obtained by employing the records of six raingages from a Thiessen network over the two service areas (Table A-2'). The period of record was 1952 to 1973, which coincides with the period used for model operation studies.

The annual rainfall for the six raingages varied from 1031 to 3349 during the period of record. The annual averaged rainfall over the Penggaron service area varies from 1,538 mm to 2,864 mm and over the Dolok service area ranges from 1,626 mm upto 2,780.

(vi) Monthly Service Area Rainfall

The Thiessen averaged values of monthly rainfall over the Penggaron and Dolok service areas are presented in Tables A-7, A-8. The mean monthly values are as follows:

PENGGARON SERVICE AREA

(mm/%)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
123	213	259	410	305	242	215	145	63	73	61	66	2,175
5.7	9.8	11.9	18.9	14.0	11.1	9.9	6.7	2.9	3.4	2.8	2.9	100.0

DOLOK SERVICE AREA

(mm/%)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
127	236	270	372	289	267	241	167	67	77	63	65	2,241
5.7	10.5	12.0	16.6	12.9	11.9	10.8	7.5	3.0	3.4	2.8	2.9	100.0

A.1.3. Streamflow

(i) Penggaron River:

Daily records for the discharges of Penggaron River at Pucanggading weir were made available by DPU Wilayah Semarang. The discharge was calculated from stage records at 7:00 a.m. by using rating curves for:

Pucanggading Weir
Intake of right canal
Intake of left canal

The records were checked for possible correlation of runoff with rainfall over the catchment. Unfortunately no records of the flood discharges spilled into the Eastern Banjir Canal, upstream of Pucanggading Weir, were available. The status of nonreliability of the discharge data, as indicated by NEDECO [1, 3, 11] was still unchanged. In 1971 NEDECO [1] used the monthly runoff coefficient of the Tuntang River to compute the monthly streamflow of the Penggaron and Dolok Rivers. Since 1971, runoff data were available for Jragung [ECI, 6] and Serang [NEDECO, 5].

A comparison between the Penggaron basin and each of the Jragung, Tuntang and Serang Rivers Basins was performed from the following standpoints:

a. Climate Factors:

- Type of precipitation
- Rain intensity and duration
- Distribution of rainfall on the basin
- Other climatological conditions.

b. <u>Physiographic Factors</u>:

- Land Use
- Type of Soil
- Slope
- Elevation
- Area of basin
- Drainage net, length of tributaries, stream density, drainage density

Closer analogy was found between Penggaron and Jragung Rivers Basins. The assumption that yearly changes in the amount of groundwater and water stored in the soil are negligible and that no subsurface exchange of groundwater with adjacent catchments were also maintained. The simplistic rainfall-runoff model used by Engineering Consultants, Inc. in the Upgraded Feasibility Study [6] as updated in the Appendix A - Part I of this study [14] was used to simulate the monthly runoff of the Penggaron River at Pucanggading Weir throughout the months starting January 1952 upto December 1973, which coincides with the period of the Integrated Jratunseluna Basin model operation. Results are shown in Table A-9. Table A-10 shows the monthly relationship between rainfall and effective rainfall, which ranges from logarithmic to power relation.

To facilitate the use of the simulated streamflow data, tables are presented in units of cubic meters per second as well as million cubic meters per month. (Tables A-11, A-12).

Results are summarized as follows:

MEAN MONTHLY STREAMFLOW,

PENGGARON RIVER AT PUCANGGADING WEIR

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
R.O. mm	31	92	155	259	241	222	158	98	31	21	9	8	1,325
Q m^3/s	0.9	2.8	4.5	7.5	7.7	6.5	4.8	2.8	0.9	0.6	0.3	0.3	3.3
Y 10^6 m^3	2.4	7.2	12.0	20.1	18.7	17.3	12.3	7.6	2.4	1.6	0.7	0.7	103.0
%	2.3	7.0	11.7	19.5	18.2	16.8	11.9	7.4	2.3	1.5	0.7	0.7	100.0

Corresponding values of streamflow at the proposed damsite could be obtained by pro-ratio of the dam catchment 75.6 km^2, to the Pucanggading weir catchment, 77.7 km^2

Noteworthy pointing out, despite the fact that the simulated streamflow data, being the best quality which could be obtained from the available data, are satisfactory for the purpose being used as inputs for the operation model of the integrated Jratunseluna Basin, yet measures should be made to provide reliable discharge measurements through the day hours at Pucanggading weir, intakes of right and left canals, and at the intake of Eastern Banjir Canal.

Automatic recording raingages are also necessary to establish the necessary hydrographs for the basin.

(ii) Dolok River:

Similar analysis of the daily discharge records of Dolok River at Barang weir have indicated its nonreliability for use as basis for simulating runoff from rainfall data. Similar analogy indicated that close similarity exists between Dolok River Basin and Jragung River Basin from both climatological and physiographic standpoints. The application of the Jragung runoff-rainfall model was found to be the most appropriate method to derive the runoff of Dolok River during the period of model operation. Results are shown in Tables A-13, A-14 and A-15. The summary is as follows:

MEAN MONTHLY STREAMFLOW:
DOLOK RIVER AT BARANG WEIR

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
R.O. mm	30	87	126	238	186	169	129	94	21	20	12	4	1,116
Q m^3/s	0.5	1.4	1.9	3.7	3.2	2.6	2.1	1.5	0.4	0.3	0.2	0	1.5
Y $10^6 m^3$	1.3	3.6	5.2	9.9	7.7	7.0	5.4	3.9	0.9	0.8	0.5	0.1	46.3
%	2.8	7.8	11.2	21.4	16.6	15.1	11.7	8.4	2.0	1.7	1.1	0.2	100.0

Corresponding streamflow values at the proposed damsite can be obtained by pro-ratio of the dam catchment, 34.0 km^2 to the Barang weir catchment, 41.5 km^2.

Further reliable discharge measurements at Barang Weir, Right and Left canals, and at the intake of the Dolok-Penggaron Diversion are also required to be made available prior to the design of any structure on the Dolok river.

A.1.4. Floods

(i) Peak Discharges

NEDECO [1, 2] estimated the peak discharges for Penggaron and Dolok Rivers as follows:

Return Period	Penggaron	Dolok
20 Years	320	210
100 Years	410	240
1000 Years	570	270

The mean annual peak discharge of the Penggaron River at damsite is 240 m^3/s according to the mean flood frequency curve developed in the regional flood analysis. As indicated in Part I of this Appendix, data used in the regional analysis have been assembled from the Jragung streamgaging records, Citanduy Basin Flood Control Plan, the Serang River Project Definite Scheme Report [9] and the Cimanuk Project Study. The coefficient of variation is 0.42. The peak discharges with return periods 10, 25, 50, and 100 years are 400, 410, 560 and 620 m^3/s respectively.

The mean annual peak discharge of the Dolok River at damsite is 130 m^3/s, according to the mean flood frequency regional curve. The coefficient of variation is 0.46. The peak discharges with return periods 25, 50 and 100 years are 270, 320 and 360 m^3/s respectively.

(ii) Flood Volumes

Using the regional flood frequency analysis, the volume of the mean annual peak flood for rain during a single day on Penggaron River catchment upstream the proposed damsite is 1.9×10^6 m^3.

For peak return periods of 10, 25, 50 and 100 years, the flood volumes are 3.2, 3.8, 4.5 and 5.0 x 10^6 m^3 respectively.

Using the same analysis, the mean annual peak flood volume for rain during a single day on Dolok River catchment upstream the proposed damsite is 0.5 x 10^6 m^3. For peak return periods of 10, 25, 50 and 100 years, the flood volumes are 0.9, 1.1, 1.3 and 1.5 x 10^6 m^3 respectively.

(iii) Probable Maximum Flood

The probable maximum flood peak for the Penggaron River is estimated at 2,700 m^3/s, using the regional curve. The probable maximum flood volume is 21.6 x 10^6 m^3.

The probable maximum flood peak for Dolok River is estimated at 1,800 m^3/s. The probable maximum flood volume is 7.3 x 10^6 m^3.

TABLE A-2

THIESSEN WEIGHT FOR RAINGAGES OVER PENGGARON AND DOLOK RIVERS BASINS CATCHMENTS

PENGGARON RIVER:

Pucanggading Weir Catchment Area:

Raingage	Thiessen Weight
64	58%
68 B	4%
98	22%
99	16%

DOLOK RIVER:

Barang Weir Catchment Area:

Raingage	Thiessen Weight
68 B	33%
99	67%

TABLE A-2'

THIESSEN WEIGHTS FOR RAINGAGES OVER THE PENGGARON AND DOLOK SERVICE AREAS

The following service areas were studied:

Service Area	Gross Area (ha)	Net Irrigable Area (ha)	Rain Gage	Thiessen % Area
Penggaron	8,780	4,590	93	24.72
			94	34.85
			96	11.05
			97	29.38
Dolok	5,400	1,956	93	5.56
			96	59.63
			98	10.00
			99	24.81

TABLE A-3

MONTHLY RAINFALL

PENGGARON CATCHMENT UPSTREAM PUCANGGADING WEIR

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	472	456	424	162	201	2	33	153	145	-
1952-'53	226	404	298	342	165	315	243	203	38	100	1	5	2,340
1953-'54	27	239	330	321	295	303	221	244	150	82	104	154	2,470
1954-'55	170	420	249	341	423	273	250	223	112	174	170	131	2,936
1955-'56	278	427	197	532	351	247	171	95	130	54	107	22	2,601
1956-'57	197	151	574	472	454	658	320	99	53	211	73	30	3,292
1957-'58	67	154	560	166	685	409	400	246	98	296	231	108	3,415
1958-'59	138	236	381	687	408	341	347	288	111	244	10	126	3,317
1959-'60	120	142	401	410	417	322	258	214	75	38	23	57	2,477
1960-'61	80	361	247	623	191	402	163	363	5	45	0	0	2,781
1961-'62	25	225	201	498	477	507	490	145	110	90	118	13	2,899
1962-'63	206	198	301	669	310	276	195	54	3	0	0	0	2,212
1963-'64	39	105	350	257	421	160	307	221	84	18	75	201	2,238
1964-'65	360	350	294	636	265	427	315	117	95	5	0	0	2,864
1965-'66	17	194	329	373	442	382	248	106	66	6	30	45	2,238
1966-'67	343	177	249	379	662	351	377	44	8	0	17	5	2,612
1967-'68	66	186	488	541	553	369	201	335	248	253	155	160	3,455
1968-'69	107	305	449	198	584	440	327	30	101	72	12	6	2,625
1969-'70	141	155	242	260	275	391	352	383	94	145	8	77	2,523
1970-'71	113	264	371	572	475	343	362	218	222	48	6	54	3,048
1971-'72	225	294	336	591	273	447	121	152	13	1	0	1	2,454
1972-'73	9	193	252	344	174	229	254	357	151	93	47	232	2,528
1973	214	388	383	-	-	-	-	-	-	-	-	-	-
Mean	143	253	342	440	398	364	260	197	101	91	61	71	2,721

TABLE A-4

MONTHLY RAINFALL

DOLOK CATCHMENT UPSTREAM BARANG WEIR

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
1952	-	-	-	543	419	363	167	135	14	21	193	111	-
1952-'53	184	243	261	160	141	310	154	155	27	78	7	0	1,720
1953-'54	45	254	225	325	305	245	107	268	65	67	96	143	2,145
1954-'55	281	502	198	283	406	260	327	268	72	239	140	106	3,082
1955-'56	195	365	263	622	274	211	105	74	136	53	136	2	2,436
1956-'57	154	70	361	294	272	307	242	68	80	134	120	34	2,136
1957-'58	120	178	429	154	653	302	364	198	79	282	268	71	3,098
1958-'59	144	184	263	372	230	189	268	209	51	219	5	118	2,252
1959-'60	108	159	313	359	414	144	183	182	82	30	5	75	2,054
1960-'61	88	379	204	666	140	362	158	356	14	23	0	0	2,390
1961-'62	17	180	219	494	379	602	424	104	56	93	171	16	2,755
1962-'63	178	141	228	507	271	131	159	13	7	0	0	0	1,635
1963-'64	30	137	345	203	199	176	317	281	45	48	90	126	1,997
1964-'65	340	298	307	836	362	332	209	94	121	23	0	0	2,922
1965-'66	12	200	256	287	468	322	125	110	121	0	3	43	1,947
1966-'67	255	201	262	477	367	257	285	39	7	1	5	4	2,160
1967-'68	91	230	375	624	400	235	149	285	154	205	134	67	2,949
1968-'69	147	511	534	113	315	223	304	21	52	58	14	7	2,199
1969-'70	97	276	196	256	233	442	264	441	71	99	34	90	2,499
1970-'71	119	274	394	419	443	335	312	238	176	58	12	49	2,829
1971-'72	210	301	169	543	210	389	179	178	5	0	0	0	2,184
1972-'73	10	172	295	397	244	293	314	319	151	127	59	228	2,609
1973	235	432	406	-	-	-	-	-	-	-	-	-	-
Mean	139	258	296	406	325	292	233	183	72	84	68	59	2,415

TABLE A-5

MAXIMUM RECORDED DAILY STATION RAINFALL FOR THE PERIOD OF RECORD UPTO END OF 1973 PENGGARON AND DOLOK CATCHMENTS AND VICINITY

Raingage	Year of Commencement of Record	Maximum Recorded Daily Rainfall (mm)	Month of Occurence
93	1905	203	Nov 1964
96	1905	501	Jan 1934
98	1893	255	Jan 1906
99	1905	209	Feb 1933
64	1909	402	Jan 1963
686	1932	273	Feb 1967

TABLE A-6

PROBABLE MAXIMUM DAILY STATION RAINFALL

TUNTANG AND JRAGUNG BASINS

Station No.	Mean Annual Maximum Dail Rainfall (mm)	Coefficient of Variation (Cv)	Probable Maximum Precipitation (mm)
78	112	0.303	621
79	89	0.309	501
81	131	0.442	996
829	122	0.274	623
85	106	0.254	510
85 a	100	0.213	461
86	107	0.294	579
89	99	0.224	432
91	122	0.291	654
100	128	0.331	764
141	110	0.286	582
82 KD	128	0.292	689
97 KD	114	0.461	902
96 SKA	112	0.278	580
68 b	138	0.420	1,007
70	112	0.301	618
72	130	0.342	799
73	120	0.279	620
74	96	0.233	432
75	127	0.341	779
99	109	0.261	538
100	120	0.291	642

TABLE A-7

MONTHLY RAINFALL

PENGGARON SERVICE AREA

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	564	304	196	171	160	9	26	88	108	-
1952-'53	180	175	259	306	149	207	141	105	28	26	0	7	1,538
1953-'54	43	205	233	392	284	227	172	239	114	118	124	188	2,338
1954-'55	186	451	187	165	415	290	230	115	108	161	153	131	2,592
1955-'56	181	287	287	460	271	176	138	106	101	58	126	107	2,298
1956-'57	191	203	200	312	228	238	206	78	17	162	91	11	1,937
1957-'58	100	191	229	102	464	353	253	180	83	117	257	57	2,386
1958-'59	145	201	381	445	234	154	380	97	16	112	30	57	2,252
1959-'60	70	170	297	452	269	144	210	114	51	39	19	31	1,866
1960-'61	53	386	194	707	270	242	236	297	8	11	0	0	2,404
1961-'62	30	135	190	576	411	275	307	63	66	151	129	6	2,339
1962-'63	114	218	176	717	388	197	279	18	3	0	0	0	2,110
1963-'64	19	96	280	184	188	297	190	202	70	18	57	224	1,825
1964-'65	315	204	181	670	281	210	160	93	45	14	0	0	2,173
1965-'66	4	181	170	275	386	179	129	143	162	0	7	64	1,710
1966-'67	270	223	330	378	385	183	185	22	7	1	16	5	2,005
1967-'68	154	140	307	561	358	235	210	307	124	291	113	64	2,864
1968-'69	121	233	365	195	239	231	199	21	96	28	3	30	1,761
1969-'70	94	117	162	249	164	239	252	161	62	137	8	116	2,369
1970-'71	87	122	233	310	575	324	287	215	105	62	0	49	2,359
1971-'72	146	225	344	657	189	415	197	124	10	0	55	1	2,363
1972-'73	6	255	241	348	250	315	200	339	102	76	63	201	2,396
1973	206	261	446	-	-	-	-	-	-	-	-	-	-
Mean	123	213	259	410	305	242	215	145	63	73	61	66	2,175

TABLE A-8

MONTHLY RAINFALL

DOLOK SERVICE AREA

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
1952	-	-	-	571	313	236	167	201	2	15	111	102	-
1952-'53	130	226	258	188	117	333	152	103	52	64	1	2	1,626
1953-'54	34	290	295	349	287	306	214	248	118	112	130	127	2,510
1954-'55	212	406	172	180	334	244	256	138	128	190	126	123	2,509
1955-'56	164	319	218	478	218	223	135	45	114	45	111	65	2,135
1956-'57	251	104	252	273	188	282	244	34	23	148	111	22	1,932
1957-'58	87	249	320	101	534	384	312	175	39	151	270	77	2,699
1958-'59	166	155	330	366	260	169	385	213	36	154	25	59	2,318
1959-'60	96	199	287	461	339	165	213	148	76	20	2	51	2,057
1960-'61	89	367	163	647	211	304	198	458	7	12	0	0	2,456
1961-'62	45	189	198	451	390	378	328	84	61	123	145	12	2,404
1962-'63	143	197	196	542	253	139	246	16	1	0	0	0	1,733
1963-'64	24	100	333	205	174	235	307	226	29	35	40	190	1,898
1964-'65	324	279	235	616	304	272	234	92	115	37	0	0	2,780
1965-'66	3	166	218	254	357	283	188	151	130	0	8	86	1,844
1966-'67	268	218	270	310	362	219	252	19	1	1	19	6	1,945
1967-'68	133	210	299	536	385	197	161	275	136	208	132	73	2,745
1968-'69	125	284	385	112	361	265	219	15	88	50	14	25	1,943
1969-'70	103	180	207	279	145	325	224	285	75	123	30	118	2,094
1970-'71	94	182	324	345	464	285	374	254	116	52	5	62	2,557
1971-'72	147	288	297	529	185	348	228	158	6	0	37	0	2,223
1972-'73	8	244	274	332	175	284	268	344	112	97	59	225	2,422
1973	157	339	415	-	-	-	-	-	-	-	-	-	-
Mean	127	236	270	372	289	267	241	167	67	77	63	65	2,241

TABLE A-9

MONTHLY RUNOFF PENGGARON RIVER AT PUCANGGADING WEIR

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	277	280	266	80	94	0	1	29	18	-
1952-'53	58	161	126	180	83	179	131	95	8	19	0	0	1,040
1953-'54	0	74	145	166	159	172	116	120	54	13	12	21	1,052
1954-'55	35	170	96	179	254	150	135	107	44	49	36	13	1,268
1955-'56	81	174	65	325	199	132	85	36	47	5	13	0	1,162
1956-'57	46	34	310	277	278	466	187	38	11	62	2	0	1,711
1957-'58	2	35	300	79	471	254	250	121	28	106	63	5	1,714
1958-'59	23	73	179	453	242	201	207	149	43	77	0	11	1,658
1959-'60	17	30	192	229	249	186	141	101	18	2	0	0	1,165
1960-'61	5	138	111	399	96	249	81	203	0	3	0	0	1,285
1961-'62	0	68	68	297	297	335	324	67	43	15	16	0	1,530
1962-'63	50	55	127	438	170	152	99	18	0	0	0	0	1,109
1963-'64	0	15	159	125	252	79	177	105	22	0	0	41	975
1964-'65	120	322	123	410	139	269	183	58	28	0	0	0	1,652
1965-'66	0	52	145	202	269	233	134	56	15	0	0	0	1,106
1966-'67	92	45	96	207	451	208	231	12	0	0	0	0	1,342
1967-'68	1	49	250	332	359	222	103	182	105	82	30	24	1,739
1968-'69	7	108	224	93	385	280	192	5	42	10	0	0	1,346
1969-'70	24	36	91	126	146	240	211	218	27	42	0	0	1,123
1970-'71	15	87	172	357	295	202	219	104	89	4	0	0	1,544
1971-'72	58	102	150	373	145	285	62	70	0	0	0	0	1,245
1972-'73	0	52	97	182	88	120	138	199	54	17	0	55	1,002
1973	53	152	180	-	-	-	-	-	-	-	-	-	-
Mean	31	92	155	259	241	222	158	98	31	21	9	8	1,325

TABLE A-10

MONTHLY RUNOFF - RAINFALL FORMULAE: JRAGUNG RIVER

October	=	P - Q	=	$2.58\ P^{0.77}$
November	=	P - Q	=	$2.86\ P^{0.74}$
December	=	P - Q	=	$4.25\ P^{0.65}$
January	=	P - Q	=	$237 \log 0.1P + 35$
February	=	P - Q	=	$214 \log 0.1P + 35$
March	=	P - Q	=	$181 \log 0.1P + 42$
April	=	P - Q	=	$175 \log 0.1P + 45$
May	=	P - Q	=	$205 \log 0.1P + 45$
June	=	P - Q	=	$216 \log 0.1P + 58$
July	=	P - Q	=	$283 \log 0.1P + 57$
August	=	P - Q	=	$2.84\ P^{0.75}$
Sept	=	P - Q	=	$3.90\ P^{0.70}$

P = Average monthly rainfall over catchment in mm

Q = Monthly runoff in mm

TABLE A-11

AVERAGE MONTHLY DISCHARGE
PENGGARON RIVER AT PUCANGGADING WEIR

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	8.0	9.0	7.7	2.4	2.7	0	0	0.8	0.5	-
1952-1953	1.7	4.8	3.9	5.2	2.7	5.2	3.9	2.8	0.2	0.6	0	0	2.6
1953-1954	0	2.2	4.2	4.8	5.1	5.0	3.4	3.5	1.6	0.4	0.3	0.6	2.6
1954-1955	1.0	5.1	2.8	5.2	8.2	4.4	4.0	3.1	1.3	1.4	1.0	0.4	3.2
1955-1956	2.4	5.2	1.9	9.4	6.4	3.8	2.5	1.0	1.4	0.1	0.4	0	2.9
1956-1957	1.3	1.0	9.0	8.0	8.9	13.5	5.6	1.1	0.3	1.8	0.1	0	4.2
1957-1958	0.1	1.0	8.7	2.3	15.1	7.4	7.4	3.5	0.8	3.1	1.8	0.1	4.3
1958-1959	0.7	2.2	5.2	13.1	7.8	5.8	6.2	4.3	1.3	2.2	0	0.3	4.1
1959-1960	0.5	0.9	5.6	6.6	8.0	5.4	4.2	2.9	0.5	0.1	0	0	2.9
1960-1961	0.1	4.1	3.2	11.6	3.1	7.2	2.4	5.9	0	0.1	0	0	3.1
1961-1962	0	2.0	2.0	8.6	9.5	9.7	9.6	1.9	1.3	0.4	0.5	0	3.8
1962-1963	1.5	1.6	3.7	12.7	5.5	4.4	2.9	0.5	0	0	0	0	2.7
1963-1964	0	0.4	4.6	3.6	8.1	2.3	5.3	3.0	0.7	0	0	1.2	2.4
1964-1965	3.5	9.7	3.6	11.9	4.5	7.8	5.4	1.7	0	0	0	0	4.0
1965-1966	0	1.6	4.2	5.9	8.6	6.8	4.0	1.6	0.4	0	0	0	2.8
1966-1967	2.7	1.3	2.8	6.0	1.6	6.0	6.9	0.3	0	0	0	0	2.3
1967-1968	0	1.5	7.3	9.6	11.5	6.4	3.1	5.3	3.1	2.4	0.9	0.7	4.3
1968-1969	0.2	3.2	6.5	2.7	12.4	8.1	5.7	0.1	1.3	0.3	0	0	3.4
1969-1970	0.7	1.1	2.6	3.7	4.7	7.0	6.3	6.3	0.8	1.2	0	0	2.9
1970-1971	0.4	2.6	5.0	10.4	9.5	5.9	6.5	3.0	2.7	0.1	0	0	3.8
1971-1972	1.7	3.1	4.4	10.0	4.7	8.3	1.8	2.0	0	0	0	0	3.0
1972-1973	0	1.6	2.8	5.3	2.8	3.5	4.1	5.8	1.6	0.5	0	1.6	2.5
1973	1.5	4.6	5.2	-	-	-	-	-	-	-	-	-	-
Average	0.9	3.0	4.5	7.5	7.2	6.4	4.7	2.8	0.9	0.7	0.3	0.3	3.2

TABLE A-12

MONTHLY YIELD : PENGGARON RIVER AT PUCANGGADING

(Units in $m^3 \times 10^6$)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Annual
1952	-	-	-	21.5	21.8	20.7	6.2	7.3	0.0	0.1	2.3	1.4	-
1952-'53	4.5	12.5	10.6	14.0	6.4	13.9	10.1	7.4	0.6	1.5	0.0	0.0	81.5
1953-'54	0.0	5.7	11.3	12.9	12.4	13.4	8.9	9.3	4.2	1.0	0.9	1.6	81.6
1954-'55	2.7	13.2	7.5	13.9	19.7	11.7	10.4	8.3	3.4	3.6	2.8	1.0	98.2
1955-'56	6.3	13.5	5.1	25.3	15.5	10.3	6.6	2.8	3.7	0.4	1.0	0.0	90.5
1956-'57	3.6	2.6	24.1	21.5	21.6	36.2	14.4	3.0	0.9	4.8	0.2	0.0	132.9
1957-'58	0.2	2.7	23.3	6.1	36.6	19.7	19.2	9.4	2.2	8.2	4.9	0.4	132.9
1958-'59	1.8	5.7	13.9	35.2	18.8	15.6	15.9	11.6	3.3	6.0	0.0	0.9	128.5
1959-'60	1.3	2.3	14.9	17.8	19.3	14.5	10.9	7.8	1.4	0.2	0.0	0.0	90.4
1960-'61	0.4	10.7	8.6	31.0	7.5	19.3	6.2	15.8	0.0	0.2	0.0	0.0	93.6
1961-'62	0.0	5.3	5.3	23.1	23.1	26.0	25.0	5.2	3.3	1.2	1.2	0.0	118.7
1962-'63	3.9	4.3	9.9	34.0	13.2	11.8	7.6	1.4	0.0	0.0	0.0	0.0	86.1
1963-'64	0.0	1.2	12.4	9.7	19.6	6.1	13.6	8.2	1.7	0.0	0.0	3.2	75.7
1964-'65	9.3	25.0	9.6	31.9	10.8	20.9	14.1	4.5	2.2	0.0	0.0	0.0	128.3
1965-'66	0.0	4.1	11.3	15.7	20.9	18.1	10.3	4.4	1.2	0.0	0.0	0.0	86.0
1966-'67	7.1	3.5	7.5	16.1	4.0	16.2	17.8	0.9	0.0	0.0	0.0	0.0	73.1
1967-'68	0.1	3.8	19.4	25.0	27.9	17.2	7.9	14.1	8.2	6.4	2.3	1.9	134.2
1968-'69	0.5	8.4	17.4	7.2	29.9	21.8	14.8	0.4	3.3	0.8	0.0	0.0	104.5
1969-'70	1.9	2.8	7.1	9.8	11.3	18.6	16.2	16.9	2.1	3.3	0.0	0.0	90.0
1970-'71	1.2	6.8	13.4	27.7	22.9	15.7	16.9	8.1	6.9	0.3	0.0	0.0	119.9
1971-'72	4.5	7.9	11.7	29.0	11.3	22.1	4.8	5.4	0.0	0.0	0.0	0.0	96.7
1972-'73	0.0	4.0	7.5	14.1	6.8	9.3	10.6	15.5	4.2	1.3	0.0	4.3	77.6
1973	4.1	11.6	14.0	-	-	-	-	-	-	-	-	-	-
Mean	2.4	7.2	12.1	20.1	17.3	17.2	12.2	7.6	2.4	1.8	0.7	0.7	101.7

TABLE A-13

MONTHLY RUNOFF DOLOK RIVER AT BARANG WEIR

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	333	251	218	82	63	0	0	46	6	999
1952-'53	41	76	103	77	74	177	76	71	0	0	0	0	695
1953-'54	0	82	81	168	166	131	57	135	15	10	9	17	871
1954-'55	83	217	81	141	241	141	192	135	17	75	24	4	1,351
1955-'56	45	140	104	398	145	108	56	26	49	4	23	0	1,098
1956-'57	29	4	166	148	144	175	130	21	20	41	17	0	895
1957-'58	17	46	210	74	428	171	221	92	20	98	80	0	1,457
1958-'59	26	48	104	201	118	95	148	98	11	65	0	8	922
1959-'60	13	27	135	192	247	71	92	84	22	1	0	0	884
1960-'61	7	147	69	435	74	217	78	198	0	0	0	0	884
1961-'62	0	47	78	294	270	417	269	40	13	15	37	0	1,430
1962-'63	39	30	83	305	143	66	79	0	0	0	0	0	745
1963-'64	0	28	155	95	100	88	184	144	8	4	7	11	824
1964-'65	110	104	131	582	207	196	108	35	45	0	[illegible]	0	1,518
1965-'66	0	56	100	143	290	186	63	57	45	0	0	0	942
1966-'67	71	56	103	281	211	139	160	160	10	0	0	0	1,031
1967-'68	8	70	175	400	236	124	74	147	56	60	22	0	1,372
1968-'69	27	222	282	65	173	116	174	0	11	0	0	0	1,070
1969-'70	10	93	65	124	119	281	145	354	17	18	0	0	1,226
1970-'71	17	92	187	236	270	196	181	116	65	6	0	0	1,366
1971-'72	52	106	50	333	106	238	90	82	0	0	0	0	1,057
1972-'73	0	43	124	220	126	164	182	171	54	41	0	54	1,179
1973	62	177	195	-	-	-	-	-	-	-	-	-	-
Mean	30	87	126	238	186	169	129	94	21	20	12	4	1,116

TABLE A-14

AVERAGE MONTHLY DISCHARGE DOLOK RIVER AT BARANG WEIR

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	5.2	4.3	3.4	1.3	1.0	0.0	0.0	0.7	0.0	-
1952-'53	0.7	1.2	1.6	1.2	1.3	2.7	1.2	1.1	0.0	0.0	0.0	0.3	1.3
1953-'54	0.0	1.3	1.3	2.6	2.8	2.0	0.9	2.1	0.2	0.2	0.1	0.0	1.1
1954-'55	1.3	3.5	1.3	2.2	4.1	2.2	3.1	2.1	0.3	1.2	0.4	0.0	1.8
1955-'56	0.7	2.3	1.6	6.2	2.5	1.7	0.9	0.4	0.8	0.1	0.4	0.0	1.5
1956-'57	0.4	0.1	2.6	2.3	2.5	6.0	2.1	0.3	0.3	0.6	0.3	0.0	1.5
1957-'58	0.3	0.7	3.3	1.1	7.3	7.0	3.5	1.4	0.3	1.5	1.2	0.1	2.3
1958-'59	0.4	0.8	1.6	3.1	2.0	8.0	2.4	1.5	0.2	1.0	0.0	0.0	1.8
1959-'60	0.2	0.4	2.1	3.0	4.2	9.0	1.5	1.3	0.4	0.0	0.0	0.0	1.8
1960-'61	0.1	2.4	1.1	6.7	1.3	3.4	1.3	3.1	0.0	0.0	0.0	0.0	1.6
1961-'62	0.0	0.8	1.2	4.6	3.8	6.5	4.3	0.6	0.2	0.2	0.6	0.0	1.9
1962-'63	0.6	0.5	1.3	4.7	2.5	1.0	1.3	0.0	0.0	0.0	0.0	0.2	1.1
1963-'64	0.0	0.4	2.4	1.5	1.7	1.4	2.9	2.2	0.1	0.1	0.1	0.0	1.1
1964-'65	1.7	1.7	2.0	9.0	3.6	3.0	1.7	0.5	0.7	0.0	0.0	0.0	2.0
1965-'66	0.0	0.9	1.6	2.2	5.0	2.9	1.0	0.9	0.7	0.0	0.0	0.0	1.3
1966-'67	1.1	0.9	1.6	4.4	3.6	2.2	2.6	0.2	0.0	0.0	0.0	0.0	1.4
1967-'68	0.1	1.1	2.7	6.2	4.0	1.9	1.2	2.3	0.9	0.9	0.3	0.0	1.8
1968-'69	0.4	3.6	4.4	1.0	3.0	1.8	2.8	0.0	0.2	0.0	0.0	0.0	1.4
1969-'70	0.2	1.5	1.0	1.9	2.0	4.4	2.3	4.1	0.3	0.3	0.0	0.0	1.5
1970-'71	0.3	1.5	2.9	3.7	4.6	3.0	2.9	1.8	1.0	0.1	0.0	0.0	1.8
1971-'72	0.8	1.7	0.8	5.2	1.8	3.7	1.4	1.3	0.0	0.0	0.0	0.0	1.4
1972-'73	0.0	0.7	1.9	3.4	2.2	2.5	2.9	2.7	0.9	0.6	0.0	0.9	1.6
1973	1.0	2.8	3.0	-	-	-	-	-	-	-	-	-	-
Mean	0.5	1.4	2.0	3.5	3.2	2.6	2.1	1.4	0.3	0.3	0.2	0.0	1.6

TABLE A-15

MONTHLY YIELD DOLOK RIVER AT BARANG WEIR

(Units in 10^6 m^3)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Annual
1952	-	-	-	13.8	10.4	9.0	3.4	2.6	0.0	0.0	1.9	0.0	-
1952-'53	1.7	3.2	4.3	3.2	3.1	7.3	3.2	2.9	0.0	0.0	0.0	0.7	29.6
1953-'54	0.0	3.4	3.4	7.0	6.9	5.4	2.4	5.6	0.6	0.4	0.4	0.2	35.7
1954-'55	3.4	9.0	3.4	5.9	10.0	5.9	8.0	5.6	0.7	3.1	1.0	0.0	56.0
1955-'56	1.9	5.8	4.3	16.5	6.0	4.5	2.3	1.1	2.0	0.2	1.0	0.0	44.7
1956-'57	1.2	0.2	6.9	6.1	6.0	7.3	5.4	0.9	0.8	1.7	0.7	0.0	37.2
1957-'58	0.7	1.9	8.7	3.1	17.8	7.1	9.2	3.8	0.8	4.1	3.3	0.3	60.8
1958-'59	1.1	2.0	4.3	8.3	4.9	3.9	6.1	4.1	0.5	2.7	0.0	0.0	37.9
1959-'60	0.5	1.1	5.6	8.0	10.3	2.9	3.8	3.5	0.9	0.0	0.0	0.0	36.6
1960-'61	0.3	6.1	2.9	18.1	3.1	9.0	3.2	8.2	0.0	0.0	0.0	0.0	50.9
1961-'62	0.0	2.0	3.2	12.2	9.1	17.3	11.2	1.7	0.5	0.6	1.5	0.0	59.3
1962-'63	1.6	1.2	3.4	12.7	5.9	2.7	3.3	0.0	0.0	0.0	0.0	0.5	32.3
1963-'64	0.0	1.2	6.4	3.9	4.2	3.7	7.6	6.0	0.3	0.2	0.3	0.0	44.6
1964-'65	4.6	4.3	5.4	24.2	8.6	8.1	4.5	1.5	1.9	0.0	0.0	0.0	63.1
1965-'66	0.0	2.3	4.2	5.9	12.0	7.7	2.6	2.4	1.9	0.0	0.0	0.0	39.0
1966-'67	2.9	2.3	4.3	11.7	8.8	5.8	6.6	0.4	0.0	0.0	0.0	0.0	42.8
1967-'68	0.3	2.9	7.3	16.6	9.8	5.1	3.1	6.1	2.3	2.5	0.9	0.0	56.9
1968-'69	1.1	9.2	11.7	2.7	7.2	4.8	7.2	0.0	0.5	0.0	0.0	0.0	44.4
1969-'70	0.4	3.9	2.7	5.1	4.9	11.7	6.0	11.0	0.7	0.7	0.0	0.0	47.0
1970-'71	0.7	3.8	7.8	9.8	11.2	8.1	7.5	4.8	2.7	0.2	0.0	0.0	56.6
1971-'72	2.2	4.4	2.1	13.8	4.4	9.9	3.7	3.4	0.0	0.0	0.0	0.0	43.9
1972-'73	0.0	1.8	5.1	9.1	5.2	6.8	7.6	7.1	2.2	1.7	0.0	2.2	48.8
1973	2.6	7.3	8.1	-	-	-	-	-	-	-	-	-	-
Mean	1.2	3.6	5.1	9.9	7.7	7.0	5.4	3.8	0.9	0.8	0.5	0.2	46.1

TABLE A-16

SUMMARY OF HYDROLOGIC DATA LUSI AND SERANG RIVERS

Area:

Lusi Catchment at Banjarejo damsite	:	506 km^2
Lusi Catchment at Purwodadi Weir	:	1,981 km^2
Lusi Catchment at Confluence	:	2,101 km^2
Kedungwaru Catchment at damsite	:	88 km^2
Glugu catchment at Bandungharjo damsite	:	41 km^2

Rainfall Over Catchment: (in mm)

	Upper Lusi	Lower Lusi	Purwodadi	Kedung-Waru	Bandungharjo
Mean annual rainfall	1,750	1,936	1,873	1,931	2,086
Maximum annual rainfall	2,206	2,480	2,368	3,369	2,769
Minimum annual rainfall	1,241	1,528	1,534	1,545	1,466
Maximum daily station rainfall	370	350	370	256	238

Rainfall On Service Area: (in mm)

	South Grobogan	Juana Valley	Wedung	Pelayaran
Mean annual	2,164	2,375	2,418	2,342
Maximum annual rainfall	2,606	3,313	3,283	3,025
Minimum annual rainfall	1,439	1,845	1,643	1,787

Runoff:

Lusi River

	Banjarrejo	Purwodadi	Confluence with Serang	Kedung-Waru	Bandung-harjo
Annual Runoff (mm)		883		89.5	971
Average annual discharge (m^3/s)	13.1	55.4	58.8	2.5	1.3
Annual Yield (10^6 m^3)	411.5	1,737.9	1,807.8	78.8	39.7

Serang River:

	Kedungombo	Sedadi	Wilalung
Annual Runoff (mm)		1,179	
Average annual discharge (m^3/s)	22.2	30.6	95.5
Annual Yield (10^6 m^3)	690.5	951.8	2,971.9

Floods:

	Banjarejo	Kedungwaru	Bandungharjo
Mean annual flood peak, m^3/s	540	270	150
Diversion design flood peak, m^3/s	920	505	305
Diversion design flood volume, $10^6 \times m^3$	36	4.5	1.4
Probable maximum flood peak m^3/s	7,100	2,850	1,900
Probable maximum flood volume 10^6 m^3	277	25.6	8.9

A.2. LUSI RIVER BASIN

A.2.1. Description of Watershed

(i) General:

The Lusi watershed is the longest watershed in the Jratunseluna Basin; catchment area of Lusi River at Confluence is about 2,100 km^2. The slope of the river bed is relatively mild, not exeeding 0.5 m/km (.0005) throughout the lower 140 km of its stream. It flows from West to East, combining into its channel many tributaries draining the Northern and Southern slopes of the watershed. (Figure A-5). The main tributaries are:

Tributary	Catchment area
Kali Blora	72 km^2
Kali Sambungsari	57 km^2
Kali Kenongo	80 km^2
Kali Ngawen	153 km^2
Kali Waru	113 km^2
Kali Medang	265 km^2
Kali Tambakselo	58 km^2
Kali Coyo	130 km^2
Kali Peganjing	107 km^2
Kali Glugu	80 km^2
Kali Jangkungharjo	122 km^2

Nothing is known about the movement of groundwater in the area. Similar to what has been followed in the hydrologic studies of the other basins in the Jratunseluna Project Area, it has been assumed that there is no transfer of groundwater to or from adjacent catchments.

The catchment areas of the basin are:

Banjarejo dam catchment area =	506 km^2
Purwodadi weir catchment area =	1,981 km^2
Lusi River at confluence area =	2,101 km^2

The catchment areas of the tributaries are indicated above. The catchment areas of the two damsites proposed in the tributaries are:

Kedungwaru dam catchment area =	88 km^2
Bandungharjo dam catchment area =	41 km^2

(ii) Land Use:

NEDECO [2] indicated the land use of the Lusi River Catchment (at Purwodadi) as follows:

	Area km^2	%
Forests	750	38
Ricefields	700	36
Other	416	26
Total	1,966	100

(iii) River Profiles

Figure A-6 indicates the longitudinal profile of the Lusi River transmitted from NEDECO [2]. As mentioned before, the Lusi River is exceptionally characterized by its milder slopes and meandering course. The river rises at an altitude of 400 m and combines into the Serang river at an altitude of 18 m after covering a channel distance of about 170 km.

A.2.2. Rainfall

(i) Annual Catchment Rainfall:

The mean annual rainfall on the catchment and sub-catchments for the year 1952 through 1973 are as follows:

Catchment	Annual Rainfall
Kedungwaru damsite	1,931 mm
Bandungharjo damsite	2,086 mm
Banjarejo damsite	1,750 mm
Lower Lusi	1,936 mm
Purwodadi Weir	1,873 mm

The same value for Purwodadi Weir catchment (1,981 km^2) applies to the Lusi River basin catchment (2,101 km^2). These values are calculated using the Thiessen polygon applied to monthly rainfall data, as detailed in paragraph (ii) hereof. Values for the monthly and annual rainfall for Banjarejo dam catchment for the years 1952-1970 are reproduced from those determined by Nedeco [4].

The wettest and the driest conditions on record at the above catchments are tabulated below:

Catchment	Wettest Year	Rainfall mm	Driest Year	Rainfall mm
Kedungwaru	1965-66	3,369	1966-67	1,441
Bandungharjo	1972-73	2,769	1965-66	1,466
Banjarejo	1954-55	2,206	1966-67	1,241
Lower Lusi	1967-68	2,480	1966-67	1,528
Purwodadi	1967-68	2,368	1966-67	1,543

(ii) Monthly Catchment Rainfall

Monthly rainfall data from selected raingage stations have been Thiessen-averaged to arrive at monthly rainfall for each of the 4 catchments. The values of the monthly catchment rainfall on the Banjarejo catchment, Kedungwaru catchment, Bandungharjo catchment, Lower Lusi catchment (Purwodadi catchment excluding Banjarejo catchment) and the full Purwodadi catchment (including Banjarejo catchment) are indicated in Tables A-17, A-18, A-19, and A-21 respectively.

Frequent records of rainfall gages were completely missing and could not be made available by all possible sources, including:

- LMG (Institute of Meteorology and Geophysics, Jakarta)
- DPU Wilayah Semarang
- DPU Propinsi Jateng
- Jratunseluna Project Office
- Serang Branch, Jratunseluna Project

In most of the cases, records were available for the closest 4 rain gages forming more or less the corners of a square around the point in question. These records were used to synthesize the missing data by weighing by its inverse square distance from the point.

In a few cases, only records of the 3 closest gages were available. A modified program was used. The lower quality of these data would not affect the results due to its relatively small number.

The Thiessen weights used to derive these monthly catchment rainfall values are presented in Table A-22.

The mean monthly values for the Banjarejo, Kedungwaru, Bandungharjo, Lower Lusi and the Purwodadi catchments are as follows:

MONTHLY RAINFALL

(mm/%)

Banjarejo Catchment

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
94	199	277	250	224	235	157	129	59	52	33	41	1,750
5.5	11.4	15.8	14.3	12.8	13.4	9.0	7.4	3.3	2.9	1.9	2.3	100.0

Kedungwaru Catchment

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
116	200	265	294	233	261	177	128	71	69	58	59	1,931
6.0	10.4	13.7	15.2	12.1	13.5	9.2	6.6	3.7	3.6	3.0	3.0	100.0

Bandungharjo Catchment

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
154	239	277	326	269	272	184	138	60	64	41	62	2,086
7.4	11.5	13.3	15.6	12.9	13.0	8.8	6.6	2.9	3.1	2.0	2.9	100.0

Lower Lusi Catchment

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
134	222	280	284	242	242	163	163	130	64	65	48	1,936
6.9	11.5	14.5	14.6	12.5	12.5	8.4	6.7	3.3	3.4	2.5	3.2	100.0

Purwodadi Weir Catchment

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
128	216	283	261	237	241	158	126	62	61	44	56	1,873
6.8	11.5	15.1	13.9	12.8	12.9	8.4	6.7	3.3	3.3	2.3	3.0	100.0

(iii) Maximum Daily Rainfall

The maximum recorded daily rainfall for raingage stations in and near the Lusi River and tributaries catchments, for the period of record and upto end of 1973, are shown in Table A-23. These values are transcribed from the records of the institute of Meteorology and Geophysics (LMG) in Jakarta.

The highest daily recorded station rainfall in the catchments was 375 mm, raingage 204, September 1938. The lowest daily maximum station rainfall in the catchment was 158 mm, raingage 5 Rombong (Upper Lusi catchment). The average maximum recorded daily station rainfall in the catchment from the commencement of record upto end of 1973 is 236 mm.

(iv) Probable Maximum Rainfall

Snowy Mountain Engineering Corporation [9] estimated the probable maximum 24-hour rainfall over the Serang catchment at 580 mm, using hydrometeorological approach.

Using the Hershfield method, the probable maximum daily station rainfall shown in Table A-24 are transcribed from SMEC Studies [9].

Assuming the validity of the 580 mm probable maximum station rainfall over the Lusi River catchment upstream of Banjarejo damsite, the probable maximum station 24-hour rainfall is 644 mm, and the probable maximum 24-hour catchment rainfall is 520 mm. This regional approach for estimating the probable maximum precipitation is adequate for the purpose of the model operation, but further analysis of the daily records of gages located in the vicinity of Lusi River will be necessary for the dams design. The daily records are available at the Institute of Meteorology and Geophysics (LMG), Jakarta.

(v) Annual Service Area Rainfall

The following service areas were designated for irrigation under the Lusi River waters; the mean annual rainfall on these areas are as indicated:

Service Area	Wettest Year		Driest Year		Mean Annual rainfall 1952-'73
		mm		mm	mm
South Grobogan	72-73	2,606	62-63	1,439	2,164
Juana Valley	67-68	3,313	56-57	1,845	2,375
Wedung	54-55	3,283	65-66	1,643	2,481
Pelayaran	70-71	3,052	65-66	1,787	2,342

The Thiessen percentages of the areas are shown in Table A-24. Missing data were generated using the records of the adjacent raingages by weighing by its inverse square distance.

(vi) Monthly Service Area Rainfall

The Thiessen averaged values of monthly rainfall over the designated service areas are indicated in Tables A-25, A-26, A-27 and A-28. The mean monthly values are as follows:

Average Monthly Rainfall

mm/%

1. South Grobogan Service Area:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
152	283	315	327	279	252	175	137	61	65	51	67	2,164
7.0	13.0	14.6	15.1	12.9	11.6	8.2	6.3	2.8	3.0	2.4	3.1	100.0

b. Juana Valley Service Area:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
118	257	324	476	385	285	181	126	63	56	34	68	2,375
5.0	10.8	13.6	20.0	16.2	12.0	7.6	5.4	2.7	2.4	1.4	2.9	100.0

c. Wedung Service Area:

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
77	227	376	648	469	327	147	75	40	35	22	38	2,481
3.1	9.1	15.2	26.1	18.9	13.2	5.9	3.0	1.6	1.4	0.9	1.6	100.0

d. Pelayaran Service Area

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
95	230	355	536	405	269	174	102	53	39	38	46	2,342
4.0	9.8	15.2	22.9	17.3	11.5	7.4	4.4	2.3	1.7	1.6	1.9	100.0

A.2.3. Streamflow

(i) Lusi River at Purwodadi Weir

Hourly discharges of River Lusi at Purwodadi were calculated from records of the river stage at the Purwodadi Weir as from January 1973. Unfortunately, the records were only available up to March 1976, as the measurements were not continued due to the sedimentation of the weir site. (Table A-29)

Records of the Serang River discharge at Godong, downstream the confluence of Lusi River, were available for the period 1973 - 1978. Also records of the discharge of Serang River at Sedadi Weir, upstream the Lusi River confluence are available for the same period. The corresponding monthly discharge of Lusi River at confluence was calculated. (Table A-30)

Both records were used for comparison of the results by using different methods followed for deriving the monthly streamflow throughout the period of model operation as follows.

Due to the shortness of the periods of record and to non-homogenity of the data, correlation with monthly catchment rainfall data was not possible.

However, to make the best benefit out of these data, different approaches to simulate the Lusi River discharge at Purwodadi were followed. In Figure A-7 is shown the correlation of Lusi discharge at Purwodadi based on actual measurement, runoff coefficient and the study done previously by SMEC. The respective results for the period of record were compared to the measured discharges as follows:

(a) Snowy Mountain Studies:

SMEC [9] derived the following relation between the discharge of Serang River at Godong, downstream the Lusi River confluence, and the discharge at Sedadi:

$$Q_{Godong} = 2.91\ Q_{Sedadi}$$

As far as very reliable data for the Serang River and S_1 canal discharges at Sedadi were computed by Nedeco [15] for the period 1952-1973, correlation to Sedadi discharges would be a very useful and simplified means of computing the Lusi River streamflow. Table A-31 shows the monthly discharges of Lusi River at confluence during the operations period, calculated by using the above formula.

The monthly discharges were also computed by using the same formula for the period 1973-1976 and the results were compared to the records of actual discharge measurements at Purwodadi during the same period.

The same formula was used to compute discharges at Godong throughout the period of available records for measured discharges at Godong. Comparison of the computed and actual discharges has confirmed the reservations of SMEC [9] on their formula. (Table A-32)

(b). Due to the very limited period of time during which discharge measurements of Lusi River were available, no correlation to corresponding monthly catchment rainfall data was possible.

(c) A statistical approach was used by augmenting the duration curve of the short period of Lusi River discharge data by making use of the duration curves for Serang River discharges at Sedadi. The results are presented in Table A-33 . Despite the full recommendation of many authors for the use of the duration curve method for synthesizing long period streamflow data from short period records [16], [17], yet the results are not arranged in chronological order. An attempt was made to rearrange the data so derived in respect of the weight of basin rainfall on Lusi River catchment as compared to the rainfall on Serang River at Sedadi catchment, but the comparison to the corresponding available measured records does not support the use of the above results.

(d) Application of multiple liniar correlation used by NEDECO [4] for synthesizing monthly discharges of the Serang River at Sedadi did not give closer results.

(e) The closest results to the actual records were arrived at by using the simple monthly runoff coefficients of the Serang River at Sedadi. Comparison of the results of the different approaches is shown in Figure A-8.

Twelve monthly runoff coefficients were used to derive the Lusi River runoff at Purwodadi Weir during the model operation period from the monthly averaged catchment rainfall data.

Tables A-34 and A-35 show the monthly discharges in m^3/s and the monthly yield in million cubic meters respectively.

The monthly discharge and yield of Lusi River at confluence, Tables A-36 and A-37, were calculated by pro-ratio of the catchment area at confluence to the Purwodadi Weir catchment.

The summary is as follows:

LUSI RIVER AT PURWODADI

PW	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Q m³/sa	20.1	52.8	94.0	110.0	111.0	103.3	64.6	46.4	26.6	17.2	9.6	8.1	55.4
Y MCM	53.7	136.9	251.9	294.1	268.5	276.7	167.4	124.6	71.1	46.3	25.6	21.1	1,737.9
%	3.1	7.9	14.5	16.9	15.4	15.9	9.6	7.2	4.1	2.7	1.5	1.2	100.0

LUSI RIVER AT CONFLUENCE

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Q m³/s	21.3	56.0	99.9	116.7	117.7	109.8	68.4	49.2	28.2	18.4	10.2	8.6	58.8
Y MCM	55.3	139.3	247.1	302.0	305.2	284.1	177.9	127.4	73.6	47.4	26.2	22.3	1,807.8
%	3.1	7.7	13.7	16.7	16.9	15.7	9.8	7.1	4.1	2.6	1.4	1.2	100.0

(ii) Lusi River at Banjarejo Damsite

The twelve monthly runoff coefficients of the Serang River at Ngrambat damsite were similarly applied to the Banjarejo damsite catchment rainfall to derive the monthly runoff values during the operation period. Tables A-38 and A-39 show the corresponding average monthly discharge in m^3/sec and the monthly yield in 10^6 m^3. The summary is as follows:

STREAMFLOW AT BANJAREJO DAMSITE

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Discharge m^3/s	3.1	11.3	23.4	25.5	27.3	25.0	16.4	13.9	4.7	3.3	1.8	1.7	13.1
Yield 10^6 m^3	8.3	29.3	62.7	68.3	66.0	67.0	42.5	37.2	12.2	8.8	4.8	4.4	411.5
%	2.0	7.1	15.2	16.6	16.1	16.3	10.3	9.1	2.9	2.1	1.2	1.1	100.0

(iii) Kedungwaru River at Damsite:

Table A-40 indicates the monthly runoff obtained by applying the monthly runoff coefficients. Tables A-41 and A-42 indicate the respective average monthly discharge and monthly yield, summarized as follows:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
R.O. mm	20	58	127	160	137	150	94	65	29	26	17	12	895
Q m^3/s	0.7	2.0	4.1	5.2	5.0	4.9	3.2	2.2	1.0	0.6	0.6	0.5	2.5
Y 10^6 m^3	1.8	5.1	11.1	14.0	12.0	13.2	8.3	5.8	2.6	2.3	1.5	1.1	78.8
%	2.3	6.5	14.2	17.9	15.3	16.7	10.6	7.3	3.2	2.9	1.9	1.4	100.0

(iv) Glugu River at Bandungharjo

Table A-43 indicates the monthly runoff calculated from monthly catchment rainfall by applying monthly runoff coefficients. Average monthly discharge and monthly yield are shown in Tables A-44 and A-45, respectively, summarized as follows:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
R.O. mm	33	76	124	176	154	158	99	69	34	24	12	12	971
Q m^3/s	0.5	1.2	1.9	1.7	2.6	2.4	1.6	1.0	0.5	0.4	0.2	0.2	1.3
Y 10^6 m^3	1.3	3.1	5.1	7.2	6.3	6.4	4.2	2.8	1.3	1.0	0.5	0.5	39.7
%	3.4	7.8	12.8	18.1	15.9	16.3	10.2	7.1	3.5	2.5	1.2	1.2	100.0

(v) Serang River at Wilalung

The monthly discharges of the Serang River at Wilalung were calculated by addition of the discharge of Lusi River at confluence to the discharge of the Serang River at Sedadi, pro-ratioed in respect of the catchment area. Average discharge in m^3/sec and monthly yield in million cubic meters are indicated in Tables A-46 and A-47, summarized as follows.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Q m^3/s	31.3	88.2	152.7	190.1	196.6	178.2	118.0	84.4	40.2	30.7	17.8	18.2	95.5
Y 10^6 m^6	81.2	228.7	394.7	493.0	509.8	462.1	306.0	218.9	104.2	79.6	46.2	47.2	2971.9
%	2.7	7.7	13.3	16.6	17.2	15.5	10.3	7.4	3.5	2.7	1.5	1.6	100.0

(vi) Serang River at Kedungombo Damsite:

Table A-48, as reproduced from SMEC studies [9] indicates the monthly discharges at the damsite, the mean for the operation period is as follows:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Q m^3/s	6.2	19.7	34.8	40.5	48.6	42.9	30.8	21.9	7.5	7.2	3.6	3.0	22.2
%	2.3	7.1	12.9	16.5	16.5	16.5	11.0	8.1	3.8	2.7	1.6	1.0	100.0

(vii) Serang River at Sedadi Weir:

Table A-49, as reproduced from NEDECO [4] indicates the monthly discharges of Serang River at Sedadi. The corresponding monthly runoff is indicated in Table A-50. The summary is as follows:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
R.O. mm	32	84	151	196	191	195	130	95	45	32	16	12	1,179
Q m^3/s	8.7	27.7	49.0	57.0	57.0	68.4	43.3	30.9	10.5	10.2	5.1	4.2	30.6
	2.7	7.1	12.8	16.6	16.3	16.5	11.0	8.1	3.8	2.7	1.4	1.0	100.0

Noteworthy pointing out, despite the fact that the simulated streamflow data are satisfactory for the purpose of being used as inputs for the operation model of the integrated Jratunseluna Basin, yet measures should be taken to resume the discharge measurements at the Purwodadi Weir. Suitable discharge sites equipped with automatic recorders, for periodic direct measurement are also necessary, on the Lusi River at Banjarejo damsite, Kedungwaru River at damsite and Glugu River at Bandungharjo damsite to provide data for dams design.

A.2.4. Floods

(i) Peak Discharges

Nedeco [2] estimated the peak discharges of the Lusi River.

Return Period	Q m^3/s
1,000	1,120
100	900
50	830
10	680

The design discharge for Banjarejo dam spillway (Q_{1000}) was estimated at 950 m^3/sec.

The estimated maximum discharges for the Lusi River tributaries damsites were as follows [2] .

Damsite	Q_{100} m^3/sec	Q_{1000} m^3/sec
Kedungwaru	370	500
Bandungharjo	220	300

According to the mean flood frequency curve developed in the regional flood analysis, the mean annual peak discharge of the Lusi River at Banjarejo damsite is 540 m^3/sec. The coefficient of variation is 0.305. For peak discharges with return periods 10, 25, 50 and 100 years, the flood peak magnitudes are 800, 920, 1,060, 1,160 m^3/sec respectively. The mean annual peak discharge of the Kedungwaru river at Kedungwaru damsite, according to the regional flood analysis is 270 m^3/sec. The coefficient of variation is 0.38 and the peak discharges with return periods 10, 25, 50 and 100 years are 460, 505, 620 and 690 m^3/sec respectively.

The mean annual peak discharge of the Bandungharjo damsite, according to the same analysis, is 150 m^3/sec. The coefficient of variation is 0.45 and the peak discharges with return periods of 10, 25, 50 and 100 years are 250, 305, 370, 410 and 460 m^3/sec respectively.

The flood peaks for Lusi River at Banjarejo damsite are taken from the mean regional curve rather than the envelope curve, in view of the exceptionally mild slope of the Lusi River as compared to other rivers in the region.

(ii) Flood Volumes:

Using the regional flood frequency analysis, the volume of the mean annual peak flood for rain during a single day on Lusi River catchment upstream Banjarejo damsite is 21 x 10^6 m^3. For peak return periods of 10, 25, 50 and 100 years, the flood volumes are 31, 36, 41 and 45 x 10^6 m^3 respectively. Using the same analysis, the mean annual peak flood volume for rain during a single day on Kedungwaru catchment is 2.4 x 10^6 m^3. The peaks of 10, 25, 50 and 100-year return periods are 4.1, 4.5, 5.6 and 6.2 x 10^6 m^3 respectively. Similarly the mean annual peak flood volume for rain during a single day on Bandungharjo catchment is 0.7 x 10^6 m^3. The 10, 25, 50 and 100-year return peak flood volumes are 1.2, 1.4, 1.7 and 1.9 x 10^6 m^3 respectively.

(iii) Probable Maximum Flood

The probable maximum flood peaks for Lusi River and tributaries, as estimated from the regional curve, are as follows:

Probable maximum flood peak for Lusi River catchment/upstream

"	"	"	"	for Banjarejo	=	7,100 m^3/sec
"	"	"	"	for Kedungwaru catchment	=	2,850 m^3/sec
"	"	"	"	for Bandungrejo catchment	=	1,900 m^3/sec

The probable maximum flood volume are 277, 25.6 and 8.9 x 10^6 m^3 respectively.

TABLE A-17

MONTHLY RAINFALL

LUSI RIVER CATCHMENT UPSTREAM BANJARREJO DAMSITE

(1952-1970 by NEDECO [4], 1970-1973 Thiessen Averaged)

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	300	340	327	41	92	17	4	52	91	-
1952-'53	111	312	195	318	188	202	269	161	7	54	7	1	1,825
1953-'54	16	223	352	323	367	169	166	139	53	81	56	50	1,955
1954-'55	161	252	169	292	313	228	270	181	116	143	59	22	2,206
1955-'56	131	406	273	262	179	161	142	135	160	55	160	53	2,117
1956-'57	152	118	195	161	156	379	118	65	55	141	40	1	1,581
1957-'58	32	114	378	236	332	306	143	30	74	73	75	47	1,840
1958-'59	144	132	376	124	259	246	125	247	64	44	6	16	1,785
1959-'60	25	141	400	282	215	193	172	144	48	14	15	23	1,672
1960-'61	39	310	286	256	282	160	177	74	38	5	0	6	1,633
1961-'62	20	110	303	263	315	148	300	26	49	52	47	15	1,648
1962-'63	245	230	202	292	359	172	89	35	12	0	0	14	1,650
1963-'64	38	59	280	118	139	173	171	141	35	65	31	192	1,442
1964-'65	301	314	221	295	169	229	152	78	9	27	4	0	1,799
1965-'66	25	86	399	170	118	273	67	123	61	5	3	58	1,388
1966-'67	87	161	236	265	114	152	163	25	0	19	0	19	1,241
1967-'68	20	142	376	254	190	175	151	272	175	165	86	36	2,042
1968-'69	73	269	275	229	244	273	132	42	39	7	3	70	1,647
1969-'70	71	144	150	218	162	303	200	93	52	25	4	46	1,468
1970-'71	89	131	219	310	180	162	84	308	99	70	0	64	1,716
1971-'72	157	229	262	277	152	262	105	196	13	0	24	2	1,679
1972-'73	7	153	224	207	151	345	212	239	107	91	47	66	1,849
1973	134	341	332	-	-	-	-	-	-	-	-	-	-
Mean	94	199	277	250	224	235	157	129	59	52	33	41	1,750

TABLE A-18

MONTHLY RAINFALL - KEDUNGWARU DAMSITE CATCHMENT

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Annual
1952	-	-	-	302	234	264	118	62	27	6	41	101	-
1952-'53	106	293	157	192	160	157	255	92	80	31	5	17	1,545
1953-'54	58	215	212	232	312	127	203	86	104	59	190	104	1,902
1954-'55	169	262	283	301	379	262	326	210	133	162	58	9	2,554
1955-'56	168	314	294	223	203	207	96	99	317	34	152	119	2,226
1956-'57	222	196	193	126	158	302	149	83	87	293	37	3	1,849
1957-'58	99	157	350	178	271	495	190	67	46	168	159	41	2,221
1958-'59	195	91	440	246	364	500	86	326	61	111	20	28	2,468
1959-'60	70	128	264	384	250	107	225	83	9	19	45	41	1,625
1960-'61	56	360	342	421	205	142	161	145	42	4	0	0	1,880
1961-'62	43	145	191	473	262	196	218	38	56	172	203	70	2,067
1962-'63	177	249	248	343	289	191	103	80	19	0	0	10	1,709
1963-'64	41	94	316	233	232	206	210	167	67	13	45	252	1,876
1964-'65	261	247	219	412	198	261	92	77	11	29	9	3	1,819
1965-'66	0	38	299	314	229	353	64	116	74	5	14	44	3,369
1966-'67	96	153	189	400	143	184	247	25	0	0	3	11	1,441
1967-'68	95	120	405	272	170	226	160	239	100	277	174	115	2,353
1968-'69	99	260	297	191	243	344	197	81	35	39	25	40	1,851
1969-'70	101	135	241	258	159	274	208	143	50	25	1	79	1,674
1970-'71	42	205	202	349	289	278	182	211	159	11	0	61	1,989
1971-'72	278	187	259	388	170	332	115	130	0	0	64	0	1,923
1972-'73	10	186	244	218	215	328	282	352	94	68	41	141	2,173
1973	156	370	584	-	-	-	-	-	-	-	-	-	-
Mean	116	200	265	294	233	261	177	128	71	69	58	59	1,931

TABLE A-19

MONTHLY RAINFALL - BENDUNGHARJO DAMSITE

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	371	266	405	144	67	20	24	92	45	-
1952-'53	149	408	251	360	327	226	318	132	36	59	7	213	2,486
1953-'54	18	207	234	365	316	243	268	136	37	129	111	72	2,136
1954-'55	128	424	172	369	276	138	189	118	59	173	32	82	2,130
1955-'56	257	224	219	324	260	243	88	118	206	10	94	71	2,114
1956-'57	94	167	332	237	228	553	224	33	44	102	5	0	2,019
1957-'58	119	199	333	277	391	405	176	123	87	219	124	137	2,590
1958-'59	303	242	389	394	220	269	207	240	127	50	14	19	2,474
1959-'60	92	205	247	241	223	138	118	155	50	35	5	75	1,584
1960-'61	54	287	260	267	233	336	89	310	18	0	0	11	1,865
1961-'62	64	246	168	416	187	193	363	47	105	66	82	137	2,074
1962-'63	207	189	296	436	270	206	152	17	11	0	0	5	1,806
1963-'64	77	128	351	114	349	182	143	147	63	19	42	87	1,702
1964-'65	188	70	169	243	260	252	354	43	35	21	1	1	1,637
1965-'66	105	206	260	239	161	262	62	52	102	0	12	5	1,466
1966-'67	204	209	185	374	199	257	194	28	0	0	31	0	1,681
1967-'68	64	215	434	306	405	198	184	269	54	228	99	102	2,558
1968-'69	141	377	183	126	290	237	75	0	13	58	0	0	1,500
1969-'70	292	181	325	327	262	408	163	192	19	49	0	125	2,343
1970-'71	218	219	288	539	234	246	196	231	142	6	45	41	2,405
1971-'72	372	231	295	492	250	246	172	147	38	3	21	3	2,270
1972-'73	57	301	324	358	316	348	174	424	58	156	89	164	2,769
1973	177	329	375	-	-	-	-	-	-	-	-	-	-
Mean	154	239	277	326	269	272	184	138	60	64	41	62	2,086

TABLE A-20

MONTHLY RAINFALL

LOWER LUSI CATCHMENT (BETWEEN BANJAREJO AND PURWODADI)

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	315	239	251	125	66	17	15	56	74	-
1952-'53	160	331	214	240	215	156	243	136	153	70	5	9	1,932
1953-'54	43	243	273	297	254	196	183	125	58	69	110	66	1,917
1954-'55	139	264	173	338	340	190	227	157	80	166	56	33	2,163
1955-'56	183	294	303	270	180	164	78	80	181	32	108	75	1,948
1956-'57	132	122	202	118	164	348	180	57	121	201	33	3	1,681
1957-'58	84	175	361	217	384	381	191	68	67	170	113	82	2,293
1958-'59	215	206	424	231	293	242	125	258	90	91	30	70	2,275
1959-'60	90	169	316	289	249	183	182	99	27	15	23	50	1,702
1960-'61	58	321	259	323	252	201	155	182	17	12	0	8	1,788
1961-'62	74	161	230	379	320	184	279	26	58	83	83	57	1,934
1962-'63	195	220	229	274	264	191	123	50	25	1	0	9	1,581
1963-'64	88	142	300	183	201	194	178	161	70	28	78	185	1,808
1964-'65	236	177	211	352	205	240	77	54	39	13	2	1	1,607
1965-'66	73	195	279	250	181	324	65	91	78	3	24	34	1,599
1966-'67	150	176	225	366	135	228	193	19	6	0	19	11	1,528
1967-'68	77	165	367	302	279	208	200	248	98	275	165	96	2,480
1968-'69	168	324	274	266	292	303	124	34	31	21	15	133	1,985
1969-'70	155	209	250	314	204	361	197	183	50	30	7	132	2,089
1970-'71	145	254	208	340	251	203	139	268	34	15	17	62	1,936
1971-'72	293	213	299	351	174	257	120	145	15	0	35	1	1,903
1972-'73	27	232	273	242	239	329	194	344	103	111	84	163	2,341
1973	158	298	492	-	-	-	-	-	-	-	-	-	-
Mean	134	222	280	284	242	242	163	130	64	65	48	62	1,936

TABLE A-21

MONTHLY RAINFALL

PURWODADI WEIR CATCHMENT AREA

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	311	265	270	103	73	17	12	55	75	-
1952-1953	147	326	209	260	208	168	250	142	116	66	6	7	1,905
1953-1954	36	238	332	304	283	189	179	129	57	72	96	62	1,937
1954-1955	145	261	172	326	333	200	238	163	89	160	57	30	2,174
1955-1956	170	323	295	268	180	163	94	94	150	38	121	69	1,991
1956-1957	137	121	200	129	162	356	164	59	104	186	35	2	1,655
1957-1958	71	159	365	222	371	362	179	58	69	145	103	73	2,177
1958-1959	197	187	412	204	284	243	125	255	83	79	24	57	2,150
1959-1960	73	162	379	287	240	186	179	110	32	15	21	43	1,694
1960-1961	52	319	266	306	260	191	161	154	22	10	0	8	1,748
1961-1962	60	148	249	349	318	175	284	26	56	75	74	46	1,861
1962-1963	208	223	222	279	288	186	114	46	22	1	0	10	1,599
1963-1964	175	121	295	166	185	228	103	81	61	37	66	187	1,715
1964-1965	253	212	214	337	196	237	96	60	31	17	2	1	1,656
1965-1966	61	167	310	230	165	311	65	99	74	3	19	40	1,543
1966-1967	134	172	228	340	130	209	185	21	5	5	14	13	1,455
1967-1968	62	161	369	290	256	200	187	254	118	247	145	81	2,368
1968-1969	144	310	274	257	280	295	124	37	34	17	12	117	1,899
1969-1970	134	192	224	289	193	346	198	160	50	29	6	110	1,930
1970-1971	131	223	211	332	233	193	125	278	51	29	13	62	1,880
1971-1972	258	217	290	332	168	258	116	158	15	0	32	1	1,846
1972-1973	22	212	260	233	217	333	199	317	104	106	75	138	2,215
1973	152	309	451	-	-	-	-	-	-	-	-	-	-
Mean	128	216	283	261	237	241	158	126	62	61	44	56	1,873

TABLE A-22

THIESSEN WEIGHTS FOR RAINGAGES
USED FOR AVERAGING RAINFALL
OVER LUSI RIVER AND TRIBUTARIES CATCHMENT

Upper Lusi Catchment: (Banjarrejo Dam Catchment)

Gauge No.	% Area
5 R	20.13
6 R	21.37
8 R	17.19
22 R	25.64
23 R	15.67
	100.00

Kedungwaru Dam Catchment:

Gauge No.	% Area
210	31.17
220	15.58
3 Rb	53.25
	100.00

Badungharjo Dam Catchment:

Gauge No.	% Area
207	47.06
208	52.94
	100.00

Lower Lusi Catchment:

Gauge No.	% Area
3 R	8.47
5 R	3.65
7 R	10.85
206	6.26
210	6.22
211	4.27
212	3.26
213	10.30
214	5.64
217	9.91
218	10.23
220	9.77
221	7.88
222	3.29
	100.00

TABLE A-22'

THIESSEN WEIGHTS FOR RAINGAGES USED

RAINFALL ON SERVICE AREAS

Service Area	Gross Area (ha)	Net Irrigable Area (ha)	Rain Gage	Thiessen % Area
South Grobogan	16,300	7,200	196	3.84
			201	9.73
			202	12.39
			204	27.73
			205B	25.07
			213	21.24
Juana	29,130	10,000 - 15,000	126	3.63
			129	23.60
			165	17.82
			184	11.22
			186	10.23
			188	5.28
			194	28.22
Wedung	13,900	10,500	106	14.47
			109	39.66
			110	18.97
			165	26.90
Pelayaran	11,800	7,440	78	31.84
			68	27.76
			56	22.86
			43	17.54

TABLE A-23

MAXIMUM RECORDED DAILY STATION RAINFALL

FOR THE PERIOD OF RECORD UPTO END OF 1973

LUSI RIVER AND TRIBUTARIES

Raingage	Year of Commencement of Record	Maximum Recorded Daily Rainfall (mm)	Month of Occurence
3 Rmb	1897	238	Nov 1931
5 Rmb	1898	158	Apr 1936
6 Rmb	1892	252	Aug 1899
7 Rmb	1894	283	Dec 1973
8 Rmb	1898	370	Dec 1919
22 Rmb	1898	170	Dec 1933
23 Rmb	1901	170	Dec 1933
196	1911	182	Dec 1927
201	1991	261	Feb 1893
202	1889	240	Oct 1896
204	1894	375	Sep 1938
206	1910	217	Jan 1921
207	1897	256	Nov 1913
210	1889	197	Jul 1957
211	1910	210	Dec 1910
212	1892	350	Dec 1904
213	1910	199	Feb 1962
214	1898	232	Jun 1928
217	1912	187	May 1959
218	1912	212	Oct 1920
220	1908	222	Oct 1920
221	1898	204	Mar 1943
222	2097	240	Aug 1918

TABLE A-24

PROBABLE MAXIMUM DAILY STATION RAINFALL

SERANG CATCHMENT

(Transcribed from SMEC [9])

Station No.	Mean Annual Maximum Daily Rainfall (mm)	Coefficient of Variation (Cv)	Probable Maximum Precipitation (mm)
209	124	0.217	529
1006 SKA	118	0.243	548
00 a SKA	119	0.254	571
207	118	0.337	716
202	102	0.284	539
56 SKA	114	0.244	530
57 SKA	100	0.254	523
57 a SKA	96	0.202	387
58 a SKA	107	0.226	470
91	120	0.287	638
89	104	0.273	528

TABLE A-25

MONTHLY RAINFALL

SOUTH GROBOGAN SERVICE AREA

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	381	326	405	146	126	7	54	122	84	-
1952-1953	190	326	240	271	218	244	275	218	31	140	0	11	2,164
1953-1954	36	234	279	332	398	247	234	217	95	81	98	140	2,391
1954-1955	204	441	269	392	369	171	205	160	66	112	60	111	2,560
1955-1956	150	341	345	382	212	166	114	94	147	29	112	73	2,165
1956-1957	211	190	414	148	233	434	155	44	52	161	18	4	2,064
1957-1958	108	229	347	299	427	375	246	92	75	170	123	95	2,586
1958-1959	224	147	540	284	255	182	184	285	68	85	37	82	2,393
1959-1960	93	207	317	268	267	326	182	125	33	36	25	62	1,941
1960-1961	103	328	297	314	205	55	196	222	15	12	1	8	1,756
1961-1962	95	153	168	403	406	178	265	34	76	63	111	26	1,978
1962-1963	220	207	243	266	210	183	228	41	13	0	0	28	1,439
1963-1964	102	201	326	162	194	225	150	146	67	46	87	201	1,907
1964-1965	223	198	235	348	197	315	58	50	27	21	3	4	1,679
1965-1966	73	289	232	303	243	443	102	72	112	0	18	20	1,907
1966-1967	209	225	349	475	255	226	196	22	13	1	1	4	1,976
1967-1968	86	244	454	302	262	201	155	169	102	216	163	96	2,450
1968-1969	182	317	274	341	335	319	151	18	52	12	22	13	2,063
1969-1970	163	237	267	285	237	220	154	245	50	40	20	129	2,107
1970-1971	282	263	338	403	322	166	111	339	111	11	13	95	2,454
1971-1972	164	215	269	433	231	194	133	64	9	0	20	4	1,736
1972-1973	25	278	234	411	340	262	200	333	122	145	68	188	2,606
1973	208	263	487	-	-	-	-	-	-	-	-	-	-
Mean	152	283	315	327	279	252	175	137	61	65	51	67	2,164

TABLE A-26

MONTHLY RAINFALL

JUANA VALLEY SERVICE AREA

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
1952	-	-	-	507	274	307	128	111	44	5	73	101	-
1952-'53	139	216	274	281	250	194	273	118	21	70	7	23	1,866
1953-'54	29	285	210	413	362	215	136	227	48	46	133	84	2,188
1954-'55	199	331	263	391	682	221	173	95	79	83	97	48	2,662
1955-'56	146	338	322	361	266	171	105	72	175	25	109	55	2,145
1956-'57	139	141	243	177	338	345	127	63	37	177	52	6	1,845
1957-'58	34	159	321	239	441	331	167	51	52	95	116	22	2,028
1958-'59	177	141	476	390	289	429	255	178	84	105	7	46	2,577
1959-'60	36	185	300	605	576	222	285	151	22	24	10	50	2,008
1960-'61	96	403	391	796	373	213	163	136	33	8	0	2	2,614
1961-'62	41	115	292	628	580	225	340	34	57	78	89	17	2,496
1962-'63	162	616	259	831	488	182	166	49	4	1	0	8	2,766
1963-'64	63	207	210	189	297	217	203	125	50	57	25	236	1,879
1964-'65	334	339	288	687	350	234	57	65	40	21	1	2	2,309
1965-'66	27	175	314	224	346	356	143	95	117	16	8	36	1,857
1966-'67	174	176	402	744	361	281	240	53	3	0	1	4	2,439
1967-'68	95	240	465	762	318	193	216	277	194	272	147	134	3,313
1968-'69	110	303	458	248	398	290	206	33	72	0	7	56	2,181
1969-'70	121	236	232	330	295	370	262	227	79	54	10	70	2,286
1970-'71	76	288	374	655	571	427	182	216	81	27	0	339	3,236
1971-'72	264	278	309	675	265	484	129	78	1	0	1	0	2,484
1972-'73	2	151	283	343	353	371	200	311	79	62	59	162	2,376
1973	126	321	448	-	-	-	-	-	-	-	-	-	-
Mean	118	257	324	476	385	285	181	126	63	56	34	68	2,375

TABLE A-27

MONTHLY RAINFALL

WEDUNG SERVICE AREA

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	892	452	269	104	72	6	6	54	131	-
1952-1953	79	350	493	386	399	386	315	69	13	13	2	5	2,500
1953-1954	21	350	154	582	659	293	150	128	49	45	54	104	2,717
1954-1955	134	630	344	600	836	326	122	71	88	62	54	16	3,283
1955-1956	109	281	405	437	325	419	57	60	58	34	60	52	2,297
1956-1957	161	136	423	363	344	292	80	6	8	110	27	0	1,950
1957-1958	12	98	225	344	544	433	98	58	42	58	40	11	1,963
1958-1959	108	150	831	608	302	372	206	51	67	89	5	33	2,822
1959-1960	17	177	495	478	511	146	189	149	15	14	4	27	2,222
1960-1961	26	313	290	1,096	350	61	154	93	5	6	0	0	2,294
1961-1962	13	105	138	947	681	136	262	2	37	51	33	8	2,413
1962-1963	72	165	337	1,224	668	312	174	2	9	1	0	3	2,967
1963-1964	27	125	239	211	333	173	155	90	34	5	8	165	1,563
1964-1965	250	180	322	804	253	281	39	58	12	1	1	0	2,201
1965-1966	11	182	298	280	343	307	66	68	78	2	0	8	1,643
1966-1967	124	155	410	759	402	383	142	41	0	0	3	1	2,420
1967-1968	14	127	467	742	371	184	157	162	127	178	57	64	2,650
1968-1969	46	250	524	330	376	325	211	7	33	0	11	19	2,132
1969-1970	89	254	222	458	594	275	273	157	55	55	10	37	2,479
1970-1971	16	134	426	1,050	674	478	111	113	45	2	0	16	3,065
1971-1972	209	321	297	1,092	370	667	78	47	14	0	0	0	3,095
1972-1973	0	185	242	628	526	669	100	227	77	38	81	142	2,915
1973	146	324	699	-	-	-	-	-	-	-	-	-	2,915
Mean	77	227	376	648	469	327	147	75	40	35	22	38	2,481

TABLE A-28

MONTHLY RAINFALL

PELAYARAN SERVICE AREA

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	605	359	248	104	85	1	12	98	113	-
1952-1953	67	236	298	306	272	227	254	111	21	37	1	8	1,838
1953-1954	16	217	201	484	349	146	136	149	87	88	78	86	2,037
1954-1955	150	494	302	351	685	283	184	132	46	104	97	46	2,874
1955-1956	111	292	398	498	353	139	68	75	79	56	104	48	2,063
1956-1957	169	179	509	252	293	289	107	4	53	139	32	1	2,027
1957-1958	21	152	214	240	442	348	191	27	74	77	181	63	2,030
1958-1959	138	132	737	393	258	359	264	71	94	62	11	25	2,544
1959-1960	16	202	297	546	437	129	92	102	21	12	2	29	1,885
1960-1961	53	300	257	704	355	135	232	137	9	2	0	0	2,484
1961-1962	20	79	234	791	703	105	295	2	14	26	61	12	2,342
1962-1963	121	143	285	1,047	572	219	145	2	12	2	0	0	2,548
1963-1964	27	110	338	230	260	203	288	108	26	14	22	198	1,824
1964-1965	307	244	278	850	307	232	48	73	61	0	0	1	2,401
1965-1966	7	194	421	209	375	217	107	134	118	0	3	2	1,787
1966-1967	140	166	348	871	344	236	260	27	12	0	0	1	2,405
1967-1968	67	241	396	734	315	190	173	317	181	116	72	79	2,881
1968-1969	86	312	404	280	354	303	204	32	64	7	9	48	2,103
1969-1970	46	289	265	430	505	328	260	178	44	63	3	28	2,439
1970-1971	78	250	389	874	600	448	159	170	56	3	0	25	3,052
1971-1972	157	295	244	763	228	557	70	88	0	0	5	6	2,413
1972-1973	0	199	322	334	321	566	182	214	96	46	64	190	2,534
1973	296	325	687	-	-	-	-	-	-	-	-	-	-
Mean	95	230	355	536	405	269	174	102	53	39	38	46	2,342

TABLE A-29

MEASURED MONTHLY DISCHARGE

LUSI RIVER AT PURWODADI

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
1973	-	-	-	82.93	91.37	139.21	68.59	151.00	35.81	27.17	11.80	27.12	-
1973-'74	19.28	167.20	195.80	104.40	86.08	132.20	93.70	21.10	9.38	9.01	15.20	22.72	76.01
1974-'75	58.47	49.01	55.01	107.60	105.20	160.70	140.60	76.19	9.74	6.81	5.67	9.19	65.35
1975-'76	79.11	103.50	116.50	52.92	16.89	102.50							
1976-'77	5.10												

TABLE A-30

MONTHLY DISCHARGE LUSI RIVER AT PURWODADI

CALCULATED FROM SERANG RIVER DISCHARGES AT GODONG AND SEDADI

(Units in m^3/s)

Month	Q_{Godong}	Q_{Sedadi} (Total)	Q_{S1}	$Q_{D.S.Sedadi}$	Runoff (Sedadi-Godong)	$Q_{Lusi\ at\ Conf.}$	$Q_{Lusi\ at\ Purwodadi}$
	(1)	(2)	(3)	(4)=(2)-(3)	$(5)=\frac{122}{861}\times(2)$	(5)=(1)-(4)-(5)	$(7)=\frac{1981}{2101}\times(6)$
Apr 76	48.77	41.89	11.18	30.71	5.90	12.16	11.47
May	65.48	6.59	4.10	2.49	0.93	12.06	11.37
Jun	22.56	1.90	1.92	-	0.27	22.29	21.02
Jul	-	1.51	1.49	-	-	-	-
Aug	-	1.30	1.26	-	-	-	-
Sep	-	0.70	.73	-	-	-	-
Oct	-	10.61	5.23	-	-	-	-
Nov	26.15	27.61	5.15	22.46	3.89	-	-
Dec	22.06	16.30	5.81	10.49	3.30	8.27	7.80
Jan 77	115.46	49.00	9.52	39.48	6.90	69.08	65.13
Feb	154.50	86.80	9.27	77.53	12.23	64.74	61.04
Mar	193.66	62.10	10.38	51.72	8.75	133.19	125.58
Apr	45.48	27.10	10.95	16.15	3.82	25.51	24.05
May	63.27	(14.37)	10.14	4.23	2.02	57.02	53.76
Jun	42.09	(13.64)	9.46	4.18	1.90	36.01	33.95
Jul	-	-	2.49	-	-	-	-
Aug	-	-	1.29	-	-	-	-
Sep	-	-	0.58	-	-	-	-
Oct	-	-	0.50	-	-	-	-
Nov	46.47	[7.19]	3.02	4.17	1.01	41.29	38.93
Dec	23.79	113.10	7.18	23.90	1.85	-	-

TABLE A-30
(Cont.)

MONTHLY DISCHARGE LUSI RIVER AT PURWODADI

CALCULATED FROM SERANG RIVER DISCHARGES AT GODONG AND SEDADI

(Cont.)

(Units in m^3/s)

Month	Q_{Godong}	Q_{Sedadi} (Total)	Q_{S1}	$Q_{D.S.Sedadi}$	Runoff (Sedadi-Godong)	$Q_{Lusi\ at\ Conf.}$	$Q_{Lusi\ at\ Purwodadi}$
	(1)	(2)	(3)	(4)=(2)-(3)	$(5)=\frac{122}{861}\times(2)$	(5)=(1)-(4)-(5)	$(7)=\frac{1981}{2101}\times(6)$
Oct 77	-	-	0.50	-	-	-	-
Nov	46.47	[7.19]	3.02	4.17	1.01	41.29	38.93
Dec	23.79	133.10	7.18	23.90	1.85	-	-
Jan 78	298.25	68.47	9.25	59.22	9.65	229.58	216.28
Feb	190.99	84.06	9.96	74.10	11.84	105.05	99.05
Mar	148.40	55.45	14.37	41.08	7.81	99.51	93.83
Apr	32.35	25.78	10.55	15.28	3.63	13.44	12.67
May	46.10	18.43	9.06	9.37	2.60	34.13	32.18
Jun	-						
Jul	-						
Aug	-						
Sep	-						
Oct	-						
Nov	-						
Dec	166.60		8.6	not available			

TABLE A-31

AVERAGE MONTHLY DISCHARGE OF LUSI RIVER AT CONFLUENCE* WITH SERANG RIVER

(Based on SMEC Studies 1978/1979)

(Not Recommended)

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
1952	-	-	-	97.59	96.60	118.40	36.83	22.40	6.76	1.89	5.26	5.89	-
1952-'53	11.65	78.93	79.93	63.52	52.62	49.11	62.64	37.83	6.39	11.91	1.26	0.88	38.06
1953-'54	0.49	10.66	36.96	74.02	92.06	52.97	79.15	56.13	11.15	14.54	4.89	7.64	36.74
1954-'55	18.79	94.72	62.15	124.15	73.19	57.63	42.84	17.54	9.53	24.30	8.77	9.53	45.29
1955-'56	17.79	56.25	50.48	101.60	117.64	63.13	17.54	21.67	21.17	7.52	10.02	7.02	40.99
1956-'57	14.66	26.19	91.95	75.66	45.99	118.13	67.90	17.66	5.77	15.79	3.14	2.14	40.39
1957-'58	1.89	5.26	55.76	63.85	140.19	123.90	82.81	78.93	16.04	39.84	44.34	7.39	55.11
1958-'59	39.97	44.98	116.51	127.91	97.35	95.09	71.66	69.54	19.43	27.44	2.88	1.75	59.53
1959-'60	4.68	33.33	110.12	48.86	99.09	53.38	52.99	59.64	12.53	9.78	1.89	1.01	40.60
1960-'61	4.13	40.21	35.57	60.01	58.88	70.03	31.69	73.79	8.89	2.38	0.49	0.25	32.20
1961-'62	0.37	30.56	35.96	82.68	72.42	51.49	83.18	23.19	11.40	9.40	7.27	0.76	34.05
1962-'63	4.25	40.09	71.78	103.75	74.41	99.59	60.89	7.52	2.01	1.25	0.49	0.12	38.80
1963-'64	0.81	10.39	33.95	29.31	79.30	71.16	86.32	37.46	17.29	11.03	6.76	5.89	32.41
1964-'65	28.70	30.07	25.55	79.81	92.21	97.72	53.25	12.28	4.13	2.88	0.37	0.25	35.61
1965-'66	3.00	20.04	36.08	74.41	100.72	146.08	43.48	19.55	33.21	9.14	7.27	1.89	41.24
1966-'67	25.55	31.30	57.12	117.89	120.39	59.76	49.99	9.53	1.38	0.12	0.12	0.12	39.37
1967-'68	0.12	14.91	65.25	81.80	122.16	86.20	71.78	70.40	17.79	30.95	21.17	5.38	49.00
1968-'69	17.15	62.52	74.17	69.54	88.81	64.39	50.24	11.15	10.27	4.52	1.25	0.64	37.88
1969-'70	14.15	12.90	65.37	38.84	43.97	66.15	27.81	44.61	12.77	9.26	6.26	20.29	30.21
1970-'71	9.90	24.30	61.74	104.86	72.04	73.91	51.49	57.13	33.95	0.76	0.12	0.12	40.87
1971-'72	6.63	17.54	50.76	89.71	55.49	46.35	27.93	20.68	7.15	6.76	1.25	0.12	27.84
1972-'73	0.12	16.92	45.72	66.77	90.45	75.66	41.59	81.80	27.93	38.22	5.77	35.45	43.78
1973	14.52	60.01	83.03	-	-	-	-	-	-	-	-	-	-
Mean	10.88	34.64	61.18	80.76	85.71	79.10	54.27	37.74	12.57	12.66	6.41	5.21	40.09

* Computed as area pro-ratio of monthly flow of Serang River at Godong (SMEC; Serang River Development: Definite Scheme, Vol. 4 Water Investigations, September 1978).

TABLE A-32

COMPARISON OF SERANG DISCHARGE AT GODONG & LUSI DISCHARGE AT PURWODADI

(Units in m^3/s)

	Q_{Godong} (Measure)	Q_{Sedadi} Total	Q_{S1}	$Q_{D.S.Sedadi}$	Runoff Sedadi-God.	$Q_{Lusi\ C}$ Confluence	$Q_{Lusi\ C}$ Purwodadi	$Q_{Purwodadi}$ Measured	% (7)(8)	Q_{Power} Calculated from SMEC Correl.	% (10)(8)
				=(2)-(3)	$= \frac{122}{868} \times (2)$	=(1)-(4)-(5)	$= 6 \times \frac{1981}{2101}$				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Jan '73	159.30	53.30	3.54	41.76	7.51	102.03	96.20	83.4	114	66.77	79
Feb	178.89	72.20	7.46	64.74	10.17	103.98	98.04	91.40	107	90.45	99
Mar	218.54	60.39	6.85	53.54	8.51	156.49	147.55	139.21	106	79.66	54
Apr	122.45	33.20	8.44	24.76	4.68	93.01	87.70	69.10	127	41.59	60
May	246.52	65.30	7.62	57.68	9.20	179.64	169.38	151.00	112	81.30	54
Jun	39.70	22.30	7.57	14.73	3.14	41.83	39.02	35.80	109	27.93	77
Jul	62.75	30.51	5.49	25.02	4.30	33.43	31.52	33.30	95	38.12	115
Aug	14.53	4.61	3.39	1.22	0.65	12.66	11.94	11.80	101	5.77	49
Sep	41.73	28.30	4.40	23.90	3.99	13.84	13.05	24.10	54	35.45	147
Oct	29.75	11.59	3.60	7.99	1.63	20.13	18.98	19.28	98	14.52	75
Nov	141.50	47.90	6.49	41.41	6.75	93.34	88.01	93.70	94	60.01	64
Dec	282.50	66.30	6.32	59.98	9.34	213.18	201.00	195.80	103	83.03	42
								Average	102		76

TABLE A-33

AVERAGE MONTHLY DISCHARGE
LUSI RIVER AT PURWODADI DEDUCED FROM DURATION CURVES

(Not Recommended)

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	127.2	123.6	204.1	52.7	40.7	15.3	3.7	9.6	13.8	-
1952-'53	25.9	98.6	100.6	78.4	68.8	63.6	78.0	68.8	14.5	21.4	2.2	1.5	622.3
1953-'54	0.7	23.7	52.5	92.4	116.2	68.0	99.4	102.1	25.2	26.6	8.9	17.6	633.3
1954-'55	34.8	122.3	76.9	226.3	90.9	72.5	58.8	31.8	21.4	44.4	16.3	21.4	817.8
1955-'56	34.0	71.1	65.1	133.1	171.1	78.4	33.6	39.2	39.0	14.0	18.5	16.0	713.1
1956-'57	29.6	42.8	118.3	94.7	62.2	202.6	84.8	32.5	13.8	28.8	5.9	4.6	720.6
1957-'58	4.4	14.5	70.3	79.1	304.6	225.6	104.7	143.5	32.1	72.5	80.6	17.6	1,149.5
1958-'59	54.7	60.4	198.9	233.0	125.3	123.5	89.4	126.5	35.9	50.3	5.2	3.8	1,106.9
1959-'60	10.3	49.7	170.1	93.2	126.9	68.0	68.0	108.7	27.5	17.8	3.7	1.5	745.4
1960-'61	9.6	55.8	51.0	74.0	75.3	87.3	48.2	134.6	19.9	4.4	0.7	0.8	561.6
1961-'62	0.7	47.4	51.8	104.3	90.1	66.6	103.9	42.2	25.2	17.0	13.3	1.5	564.0
1962-'63	9.6	55.8	89.5	140.5	93.4	130.2	75.2	14.0	4.6	2.2	0.7	0.0	615.7
1963-'64	1.5	23.7	49.6	45.1	99.1	88.7	109.3	68.0	33.6	20.0	12.6	13.8	565.0
1964-'65	45.1	46.6	47.2	55.5	116.3	127.2	68.8	22.2	9.9	5.2	0.7	0.8	545.5
1965-'66	6.7	50.4	51.8	68.8	54.0	266.3	61.9	35.5	49.7	17.6	13.3	4.6	680.6
1966-'67	42.2	48.8	71.7	284.1	182.6	74.0	65.0	17.0	3.1	0.0	0.0	0.0	788.5
1967-'68	2.2	30.6	81.4	88.0	190.8	109.5	89.4	128.0	33.6	56.2	38.5	12.2	860.4
1968-'69	32.6	77.2	93.2	85.5	111.4	79.9	65.7	20.0	22.2	8.1	2.2	1.5	599.5
1969-'70	29.6	28.3	81.4	54.0	60.6	82.1	43.6	81.4	59.6	17.0	11.8	36.7	586.1
1970-'71	21.4	41.3	76.9	143.5	90.1	92.4	66.5	104.3	71.8	1.5	0.0	0.0	709.7
1971-'72	67.3	33.7	71.0	115.4	71.2	61.4	45.3	37.7	37.4	12.6	2.2	0.0	555.2
1972-'73	2.2	32.9	60.6	82.8	113.8	94.7	57.3	148.7	102.4	69.5	10.4	52.0	847.3
1973	29.6	74.9	105.0	-	-	-	-	-	-	-	-	-	-
Mean	22.5	51.4	83.4	113.6	115.4	113.0	71.3	70.3	31.7	23.2	11.7	10.1	59.8

TABLE A-34

AVERAGE MONTHLY DISCHARGE - LUSI RIVER AT PURWODADI

(Using Runoff Coefficient)

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Average
1952	-	-	-	124.2	124.1	115.8	42.3	26.8	7.3	3.4	11.8	10.9	-
1952-'53	23.0	79.5	69.4	103.8	97.4	72.1	102.6	52.2	49.9	18.6	1.3	1.0	55.9
1953-'54	5.6	58.0	110.2	121.4	132.4	81.1	73.5	47.4	24.5	20.3	20.7	9.0	58.3
1954-'55	22.7	63.6	57.1	130.2	156.0	85.8	97.7	59.9	38.3	45.1	12.3	4.4	64.4
1955-'56	26.7	78.8	98.0	107.0	84.3	69.9	38.6	34.6	64.6	10.7	26.0	10.0	54.1
1956-'57	21.5	29.5	66.4	51.5	75.8	152.7	67.3	21.7	44.8	52.4	7.5	0.3	49.3
1957-'58	11.1	38.8	121.2	88.7	173.8	155.3	73.5	21.3	29.7	40.9	22.2	10.6	65.6
1958-'59	30.9	45.6	136.8	81.5	133.0	104.2	51.3	93.7	35.7	21.4	5.2	8.3	62.3
1959-'60	11.4	39.5	125.9	114.6	112.4	79.8	33.5	40.4	13.8	4.2	4.5	6.2	52.2
1960-'61	8.1	77.8	88.3	127.2	121.8	81.9	66.1	56.6	9.5	2.8	0.0	1.2	53.0
1961-'62	9.4	36.0	82.7	139.4	148.9	75.1	116.6	9.6	24.1	21.1	15.9	6.7	57.1
1962-'63	32.6	54.4	73.7	111.4	134.9	79.8	46.8	16.9	9.5	0.3	0.0	1.4	46.8
1963-'64	27.4	29.5	98.0	66.3	86.7	97.8	42.3	29.8	26.2	10.4	14.2	27.2	12.0
1964-'65	39.7	51.7	71.1	134.6	91.8	101.7	39.4	22.0	13.3	4.8	0.4	0.2	47.6
1965-'66	9.6	40.7	102.9	91.9	77.3	133.4	26.7	36.4	31.8	0.8	4.1	5.8	47.1
1966-'67	21.0	41.9	75.7	135.8	60.9	89.6	75.9	7.7	2.2	1.4	3.0	1.9	43.1
1967-'68	9.7	39.2	122.5	115.8	119.9	85.8	76.8	93.4	50.8	69.6	31.2	11.8	68.9
1968-'69	22.6	75.6	91.0	102.6	131.2	126.6	50.9	13.6	14.6	4.8	2.6	17.0	54.4
1969-'70	21.0	46.8	74.4	115.4	90.4	148.4	81.3	58.8	21.5	8.2	1.3	16.0	57.0
1970-'71	20.5	54.4	70.1	132.6	109.1	82.8	51.3	102.2	22.0	8.2	2.8	9.0	55.4
1971-'72	40.4	52.9	96.3	132.6	78.7	110.7	47.6	58.1	6.4	0.0	6.9	0.2	52.6
1972-'73	3.4	51.7	86.3	93.1	101.6	142.8	81.6	116.5	44.8	29.9	16.1	20.0	65.7
1973	23.8	75.3	149.8	-	-	-	-	-	-	-	-	-	-
Mean	20.1	52.8	94.0	110.0	111.0	103.3	64.6	46.4	26.6	17.3	9.6	8.1	55.4

TABLE A-35

MONTHLY YIELD - LUSI RIVER AT PURWODADI

(Units in 10^6 m^3)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	332.7	300.3	310.2	109.6	71.9	19.0	9.1	31.7	29.4	-
1952-'53	61.7	206.0	185.9	278.1	235.7	193.0	265.9	139.8	129.4	49.8	3.5	2.6	1,751.4
1953-'54	15.1	150.4	295.3	325.2	320.7	217.2	190.4	127.0	63.6	54.3	55.3	23.3	1,837.8
1954-'55	60.9	164.9	153.0	348.7	377.3	229.8	253.2	160.5	99.3	120.8	32.9	11.3	2,012.6
1955-'56	71.4	204.1	262.4	286.7	204.0	187.3	100.0	92.5	167.3	28.7	69.8	26.0	1,700.2
1956-'57	57.5	76.5	177.9	138.0	183.6	409.0	174.5	58.1	116.0	140.4	20.2	0.8	1,552.5
1957-'58	29.8	100.5	324.7	237.5	420.4	415.9	190.4	57.1	77.0	109.4	59.4	27.5	2,049.6
1958-'59	82.7	118.2	386.5	218.2	321.8	279.2	133.0	251.1	92.6	59.6	13.8	21.5	1,978.2
1959-'60	30.7	102.4	337.1	307.0	272.0	213.7	190.4	108.3	35.7	11.3	12.1	16.2	1,636.9
1960-'61	21.8	201.6	236.6	327.3	294.6	219.5	171.3	151.6	24.5	7.5	0.0	3.0	1,659.3
1961-'62	25.2	93.5	221.5	373.3	360.3	201.1	302.1	25.6	62.5	56.6	42.7	17.3	1,781.7
1962-'63	67.4	140.9	197.5	298.5	326.3	213.7	121.3	49.3	24.5	0.8	0.0	3.8	1,440.0
1963-'64	73.5	76.5	262.4	177.6	209.6	262.0	103.6	79.7	68.0	27.9	38.0	70.4	1,449.2
1964-'65	100.3	134.0	190.3	360.5	222.1	272.3	102.1	59.1	34.6	12.8	1.2	0.4	1,489.7
1965-'66	25.6	105.5	275.7	246.0	187.0	357.3	69.1	97.5	82.5	2.3	11.0	15.1	1,474.6
1966-'67	56.3	108.7	202.8	363.7	147.3	240.1	196.8	20.7	5.6	3.8	8.1	4.9	1,358.8
1967-'68	26.0	101.7	328.2	310.2	290.1	229.8	198.9	250.1	131.6	186.4	83.6	30.5	2,167.1
1968-'69	60.9	195.9	243.7	274.9	317.3	338.9	131.9	36.4	37.9	12.8	6.9	44.0	1,701.5
1969-'70	56.3	121.3	199.2	[illegible]	218.7	397.5	210.6	157.9	55.6	21.9	3.5	41.4	1,793.1
1970-'71	55.0	140.9	187.7	355.2	264.0	221.8	133.0	273.7	26.9	21.9	7.5	23.3	1,710.9
1971-'72	108.4	137.1	257.9	355.2	190.4	296.4	123.4	155.6	16.7	0.0	18.4	0.4	1,659.9
1972-'73	9.2	67.6	231.3	249.2	245.9	382.6	211.7	312.1	116.0	80.0	43.2	51.9	2,000.7
1973	63.8	195.3	401.2	-	-	-	-	-	-	-	-	-	-
Mean	53.7	136.9	251.9	294.1	268.5	276.7	167.4	124.6	71.1	46.3	25.6	21.1	1,737.9

TABLE A-36

AVERAGE MONTHLY DISCHARGE - LUSI RIVER AT CONFLUENCE

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1952	-	-	-	131.7	131.6	122.8	44.9	28.5	7.7	3.6	12.6	11.5	-
1952-'53	24.4	84.3	73.6	110.1	103.3	76.4	108.8	55.4	52.9	19.7	1.4	1.1	59.3
1953-'54	6.0	61.5	116.9	128.9	140.0	86.0	78.0	50.3	26.0	21.5	21.9	9.5	61.8
1954-'55	24.1	67.5	60.6	138.1	165.4	91.0	103.6	63.5	40.6	47.8	13.0	4.6	68.3
1955-'56	28.3	83.5	103.9	113.5	89.4	74.1	40.9	36.6	68.5	11.4	27.6	10.6	57.1
1956-'57	22.8	31.3	70.4	54.6	80.4	162.0	71.4	23.0	47.5	55.6	8.0	0.3	52.3
1957-'58	11.8	41.1	128.4	94.0	184.3	164.7	77.9	22.6	31.5	43.4	23.5	11.7	69.5
1958-'59	32.8	48.4	145.1	86.4	141.1	110.6	54.4	99.4	37.9	22.7	5.5	8.8	66.1
1959-'60	12.1	41.9	133.5	121.6	119.2	84.6	77.9	42.9	14.6	4.5	4.8	6.5	55.3
1960-'61	8.6	82.5	93.7	129.6	129.2	86.9	70.1	60.0	10.0	3.0	0.0	1.2	56.2
1961-'62	10.0	38.3	87.7	147.8	158.0	79.7	123.7	10.2	25.6	22.4	16.9	7.1	60.6
1962-'63	34.6	57.7	78.2	118.2	143.1	84.6	49.6	17.9	10.1	0.3	0.0	1.5	49.7
1963-'64	29.1	31.3	103.9	70.3	91.9	103.7	44.8	31.6	27.8	11.1	15.1	28.8	51.0
1964-'65	42.1	54.8	75.4	142.7	97.4	107.8	41.8	23.4	14.1	5.1	0.5	0.2	50.4
1965-'66	10.2	43.2	109.2	97.5	82.0	141.5	28.3	38.6	33.7	0.9	4.3	6.2	49.6
1966-'67	22.3	44.5	80.3	144.0	64.6	95.1	80.5	8.2	2.3	1.5	3.2	2.0	45.7
1967-'68	10.3	41.6	130.0	122.8	127.2	91.0	81.4	99.0	53.9	73.8	33.1	12.5	73.0
1968-'69	23.9	80.2	96.5	108.8	139.1	134.2	54.0	14.4	15.5	5.1	2.8	18.0	57.7
1969-'70	22.3	49.6	78.9	122.4	95.9	157.4	86.2	62.4	22.8	8.7	1.4	17.0	60.4
1970-'71	21.7	57.7	74.3	140.6	115.8	87.8	54.4	108.4	23.3	8.7	3.0	9.5	58.8
1971-'72	42.9	56.1	102.1	140.6	83.5	117.4	50.5	61.6	6.8	0.0	7.3	0.2	55.8
1972-'73	3.7	54.8	91.6	98.7	107.8	151.5	86.5	123.6	47.5	31.7	17.1	21.3	69.6
1973	25.3	79.9	158.8	-	-	-	-	-	-	-	-	-	-
Mean	21.3	56.0	99.7	116.7	117.7	109.8	68.4	49.2	28.2	18.4	10.2	8.6	58.8

TABLE A-37

MONTHLY YIELD - LUSI RIVER AT CONFLUENCE

(Units in 10^3 m^3)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Annual
1952	-	-	-	341.4	341.2	318.4	116.2	73.8	20.2	9.3	32.5	29.9	-
1952-'53	63.4	218.5	190.8	285.5	267.8	198.1	282.1	143.5	137.2	51.1	3.6	2.8	1,844.3
1953-'54	15.5	159.5	303.1	333.7	364.4	223.9	202.1	130.3	67.4	55.8	56.8	24.7	1,936.2
1954-'55	62.5	174.9	157.0	357.9	428.6	235.9	268.6	164.7	105.3	124.0	33.8	12.0	2,125.2
1955-'56	73.3	216.5	269.3	294.2	231.8	192.2	106.1	95.0	177.5	29.4	71.6	27.5	1,784.4
1956-'57	59.1	81.1	182.5	141.6	208.4	419.0	185.0	59.7	123.0	144.1	20.7	0.8	1,626.0
1957-'58	30.5	106.6	332.9	243.7	477.8	426.9	202.0	58.6	81.6	112.4	60.9	29.1	2,163.1
1958-'59	84.9	125.4	376.1	224.0	365.6	286.6	141.0	257.7	98.1	58.8	14.2	22.8	2,055.2
1959-'60	31.1	108.6	346.0	315.2	309.0	219.3	201.9	111.2	37.8	11.7	12.4	16.8	1,721.3
1960-'61	22.4	213.8	242.8	335.9	334.8	225.2	181.7	155.6	26.0	7.8	0.0	3.2	1,749.2
1961-'62	25.9	99.2	227.3	383.2	409.6	206.5	320.5	26.4	66.3	58.0	43.7	18.4	1,885.0
1962-'63	89.6	149.5	202.6	306.2	370.9	219.4	128.7	46.5	26.1	0.8	0.0	4.0	1,544.3
1963-'64	75.4	81.1	269.3	182.3	238.2	268.9	116.2	81.8	73.2	28.7	39.0	74.2	1,527.8
1964-'65	109.1	142.1	195.5	370.0	252.4	279.5	108.3	60.6	36.7	13.2	1.2	0.4	1,568.9
1965-'66	27.2	111.9	283.0	252.6	212.5	366.7	73.3	100.1	97.4	2.3	11.2	16.0	1,554.2
1966-'67	57.9	115.3	208.1	373.3	167.4	246.5	208.7	21.2	5.9	3.9	8.2	5.2	1,422.0
1967-'68	26.7	107.9	336.9	318.4	329.6	235.9	211.0	256.7	139.6	191.3	85.8	32.3	2,272.1
1968-'69	62.1	207.8	250.2	282.1	360.6	347.9	139.9	37.4	40.2	13.2	7.1	46.7	1,795.2
1969-'70	57.8	128.7	204.5	317.3	248.5	408.0	223.4	161.6	59.2	22.5	3.5	44.0	1,89.2
1970-'71	56.4	149.5	192.7	364.5	300.0	227.6	141.0	281.0	60.3	22.5	7.7	24.7	1,828.0
1971-'72	111.2	145.5	264.7	364.5	216.4	304.3	130.9	159.7	17.7	0.0	18.9	0.4	1,734.2
1972-'73	9.5	142.1	237.4	255.8	279.4	392.7	224.3	320.3	123.0	82.2	44.4	55.1	2,166.2
1973	65.5	79.9	158.8	-	-	-	-	-	-	-	-	-	-
Mean	55.3	139.3	247.1	302.0	305.2	284.1	177.9	127.4	73.6	47.4	26.2	22.3	1,807.8

TABLE A-38

AVERAGE MONTHLY DISCHARGE

LUSI RIVER BANJAREJO DAMSITE

(Units in m^3/sec)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	30.8	41.5	35.7	4.3	8.7	1.4	0.3	2.9	3.9	-
1952-1953	3.6	17.7	16.5	32.7	22.9	22.1	28.1	15.2	0.6	3.8	0.4	0	13.6
1953-1954	0.5	12.7	29.8	33.2	44.8	18.5	17.3	13.1	4.2	5.7	3.1	2.1	15.4
1954-1955	5.2	14.3	14.3	30.0	38.2	24.9	28.2	17.1	9.3	3.0	3.2	0.9	15.7
1955-1956	4.3	23.1	23.1	26.9	21.8	17.6	14.8	12.8	12.8	3.8	8.8	2.3	14.3
1956-1957	4.9	6.7	16.5	16.5	19.0	41.4	12.3	6.1	4.4	9.9	3.2	0	11.7
1957-1958	1.0	6.5	32.0	24.3	48.5	33.4	14.9	2.8	5.9	5.1	4.1	2.0	15.0
1958-1959	4.7	7.5	31.8	12.7	31.6	26.9	13.1	23.3	5.1	3.1	0.3	0.8	13.4
1959-1960	0.8	8.0	33.9	29.0	26.2	21.1	18.0	13.6	3.8	1.0	0.8	1	13.1
1960-1961	1.3	17.6	24.2	26.3	34.4	17.5	18.5	7.0	3.0	0.4	0	0.3	12.5
1961-1962	0.6	6.2	25.6	27.0	38.4	16.2	31.3	2.5	3.9	3.6	2.6	0.6	13.2
1962-1963	8.0	13.1	17.1	30.0	43.8	18.8	9.3	3.3	1.0	0	0	0.6	12.1
1963-1964	1.2	3.4	27.7	12.1	17.0	18.9	17.9	13.3	2.8	4.6	1.7	8.2	10.7
1964-1965	9.8	17.8	18.7	30.3	20.6	25.0	15.9	7.4	0.7	1.9	0.2	0	12.4
1965-1966	0.8	4.9	33.8	17.5	14.4	29.8	7.0	11.6	4.9	0.4	0.1	2.5	10.6
1966-1967	2.8	9.2	30.0	27.2	13.9	16.6	17.0	2.4	0	1.3	0	0.8	10.1
1967-1968	0.6	8.1	31.8	26.1	23.2	19.1	15.8	25.7	14.0	11.6	4.7	1.5	15.5
1968-1969	2.4	15.3	23.3	23.5	29.8	29.8	13.8	4.0	3.1	0.5	0.2	3.0	12.4
1969-1970	2.3	8.2	12.7	22.4	19.8	33.1	20.9	8.8	4.2	1.8	0.2	2.0	11.4
1970-1971	2.9	7.4	18.3	31.9	22.0	17.7	8.8	29.1	7.9	4.9	0	2.7	12.8
1971-1972	5.1	13.0	22.2	28.5	18.5	28.6	11.0	18.5	1.0	0	1.3	0.1	12.5
1972-1973	0.2	8.7	18.9	21.3	18.4	37.7	22.1	22.6	8.6	6.4	2.6	2.8	14.1
1973	4.4	19.4	28.0	-	-	-	-	-	-	-	-	-	-
Mean	3.1	11.3	23.4	25.5	27.3	25.0	16.4	13.9	4.7	3.3	1.8	1.7	13.1

TABLE A-39

MONTHLY YIELD - LUSI RIVER AT BANJAREJO DAMSITE

(units in $10^6 \times m^3$)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	82.5	100.4	95.6	11.1	23.3	3.6	0.8	7.7	9.0	-
1952-'53	9.6	45.9	44.2	87.6	55.4	59.2	72.8	40.7	1.6	10.1	1.0	0.1	428.2
1953-'54	1.3	32.9	79.8	88.9	108.4	49.6	44.8	35.2	10.9	15.2	8.2	4.9	480.1
1954-'55	13.9	37.1	38.3	80.4	92.4	66.7	73.1	45.8	24.1	8.1	8.7	3.2	491.8
1955-'56	11.5	59.9	61.9	72.0	52.7	47.1	38.4	34.2	33.2	10.3	23.6	5.2	450.0
1956-'57	13.1	17.4	44.2	44.2	46.0	110.9	31.9	16.4	11.4	26.5	5.9	0.1	368.0
1957-'58	2.6	16.8	85.7	65.1	117.3	89.5	38.6	7.6	15.3	13.7	11.0	4.6	467.8
1958-'59	12.6	19.4	85.2	34.0	76.4	72.0	34.0	62.5	13.2	8.3	0.9	1.8	420.3
1959-'60	2.1	20.7	90.8	77.7	63.4	56.5	46.7	36.4	9.8	2.6	2.2	2.8	411.2
1960-'61	3.5	45.6	64.8	70.4	83.2	46.9	48.0	18.7	7.8	0.9	0.0	0.6	390.4
1961-'62	1.6	16.1	68.6	72.3	92.9	43.4	81.1	6.6	10.1	9.8	6.9	1.5	410.9
1962-'63	21.4	34.0	45.8	80.4	106.0	50.4	24.1	8.9	2.6	0.0	0.0	1.4	375.0
1963-'64	3.2	8.8	74.2	32.1	41.1	50.6	46.4	35.7	7.3	12.2	4.6	19.0	335.2
1964-'65	7.5	46.1	50.1	81.2	49.8	67.0	41.2	19.7	1.8	5.1	0.6	0.0	370.1
1965-'66	1.6	12.7	90.5	46.9	33.9	79.8	18.1	31.1	12.7	0.9	0.4	5.7	334.3
1966-'67	6.4	23.8	80.4	72.9	33.6	44.5	44.1	6.3	0.0	3.6	0.0	1.9	317.5
1967-'68	6.2	21.0	85.2	69.9	56.1	51.2	41.0	68.8	36.3	31.0	12.7	3.6	483.0
1968-'69	7.8	29.7	62.4	62.9	72.1	79.8	35.8	10.6	8.0	1.3	0.4	6.9	377.7
1969-'70	6.2	21.3	34.0	60.0	47.9	88.7	54.2	23.5	10.9	4.7	0.6	4.5	356.5
1970-'71	7.8	19.2	49.0	85.4	53.2	47.4	22.8	77.9	20.5	13.1	0.0	6.3	402.6
1971-'72	13.7	33.7	59.5	76.3	44.8	76.3	28.5	49.6	2.6	0.0	3.5	0.2	389.1
1972-'73	0.5	22.6	50.6	57.0	44.5	57.0	57.3	60.5	22.3	17.1	6.9	6.5	402.8
1973	11.8	50.3	75.0	-	-	-	-	-	-	-	-	-	-
Mean	8.3	29.3	62.7	68.3	66.0	67.0	42.5	37.2	12.2	8.8	4.8	4.4	411.5

TABLE A-40

MONTHLY RUNOFF

KEDUNGWARU RIVER AT KEDUNGWARU DAMSITE

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Annual
1952	-	-	-	164	136	153	63	31	11	2	12	20	-
1952-1953	18	85	70	104	93	91	136	46	33	11	2	4	693
1953-1954	10	62	95	126	184	73	109	43	43	22	55	21	843
1954-1955	29	76	127	164	221	151	174	105	54	60	17	2	1,180
1955-1956	29	91	132	121	118	120	51	50	130	13	44	24	923
1955-1957	38	57	86	68	92	175	80	42	36	109	11	1	795
1957-1958	17	46	156	92	158	266	102	34	19	62	46	8	1,011
1958-1959	34	26	197	134	212	269	46	163	25	41	6	6	1,179
1959-1960	12	37	118	209	146	62	120	42	4	7	13	8	778
1960-1961	10	105	153	229	120	82	86	72	17	2	0	0	876
1961-1962	7	42	85	257	153	113	117	19	23	64	59	14	953
1962-1963	30	72	111	187	168	110	55	40	8	0	0	2	783
1963-1964	12	27	142	127	135	119	112	84	28	5	13	51	859
1964-1965	45	72	98	224	115	151	49	38	4	11	3	1	811
1965-1966	0	11	134	171	134	204	34	38	30	2	4	9	771
1966-1967	17	45	95	218	93	106	132	12	0	0	1	2	721
1967-1968	16	35	181	148	99	131	86	120	41	103	51	23	1,034
1968-1969	17	76	133	[illegible]	142	199	105	40	14	14	7	8	859
1969-1970	17	39	108	140	93	156	111	72	20	8	0	16	783
1970-1971	7	60	90	190	168	161	97	106	65	4	0	12	960
1971-1972	48	54	116	211	99	192	62	65	0	0	19	0	866
1972-1973	2	54	109	119	125	190	151	176	38	25	12	29	1,030
1973	27	108	262	-	-	-	-	-	-	-	-	-	-
Mean	20	58	127	160	137	150	94	65	29	26	17	12	895

TABLE A-41

AVERAGE MONTHLY DISCHARGE KEDUNGWARU RIVER AT KEDUNGWARU DAMSITE

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	5.4	5.0	5.0	2.1	1.0	0.4	0.1	0.4	0.7	-
1952-'53	0.6	2.9	2.3	3.4	3.4	3.0	4.6	1.5	1.1	0.4	0.0	0.1	1.9
1953-'54	0.3	2.1	3.1	4.1	6.7	2.4	3.7	1.4	1.4	0.7	1.8	0.7	2.4
1954-'55	1.0	2.6	4.2	5.4	8.0	5.0	5.9	3.5	1.9	2.0	0.6	0.1	3.3
1955-'56	0.9	3.1	4.3	4.0	0.4	3.9	1.7	1.6	4.4	0.4	1.5	0.8	2.6
1956-'57	1.3	1.9	2.8	2.2	3.3	5.7	2.7	1.4	1.2	3.6	0.4	0.0	2.4
1957-'58	0.6	1.5	4.9	3.2	5.7	9.4	3.5	1.1	0.6	2.1	1.5	0.3	2.9
1958-'59	1.1	0.9	6.5	4.4	7.7	9.5	1.6	5.4	0.8	1.4	0.2	0.2	3.3
1959-'60	0.4	1.3	3.7	6.9	5.3	2.0	4.1	1.4	0.1	0.2	0.4	0.3	2.2
1960-'61	0.3	3.6	5.0	7.5	4.3	2.7	2.9	2.4	0.6	0.0	0.0	0.0	2.5
1961-'62	0.2	1.4	2.8	8.4	5.5	3.7	4.0	0.6	0.8	2.1	1.9	0.5	2.6
1962-'63	1.0	2.5	3.7	6.1	6.1	3.6	1.9	1.3	0.3	0.0	0.0	0.1	2.2
1963-'64	0.4	0.9	4.7	4.2	4.9	3.9	3.8	2.7	0.9	0.2	0.4	1.7	2.4
1964-'65	0.1	2.4	3.2	7.4	4.2	5.0	1.7	1.3	0.2	0.4	0.1	0.0	2.3
1965-'66	0.0	0.4	4.4	5.6	4.8	6.7	1.2	1.9	1.0	0.1	0.1	0.3	2.2
1966-'67	0.5	1.5	2.8	7.1	3.0	3.0	3.1	4.5	0.4	0.0	0.0	0.1	1.9
1967-'68	0.5	1.2	6.0	4.9	3.6	4.3	2.9	3.9	1.4	3.4	1.7	0.8	2.9
1968-'69	0.6	2.6	4.4	3.4	5.2	6.5	3.6	1.3	0.5	0.5	0.2	0.3	2.4
1969-'70	0.6	1.4	3.5	4.6	3.4	5.2	3.8	2.4	0.7	0.3	0.0	0.5	2.2
1970-'71	0.2	2.0	3.0	6.2	6.1	5.3	3.3	3.5	2.2	0.1	0.0	0.4	2.7
1971-'72	1.6	1.9	3.8	6.9	3.6	6.3	2.1	2.1	0.0	0.0	0.6	0.0	2.4
1972-'73	0.1	1.9	3.6	3.9	4.5	6.2	5.1	5.8	1.3	0.8	0.4	1.0	2.9
1973	0.9	3.7	8.6	-	-	-	-	-	-	-	-	-	-
Mean	0.7	2.0	4.1	5.2	5.0	4.9	3.2	2.2	1.0	0.6	0.6	0.5	2.5

TABLE A-42

MONTHLY YIELD

KEDUNGWARU RIVER AT KEDUNGWARU DAMSITE

(Units in 10^6 m^3)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	14.5	12.0	13.4	5.6	2.7	1.0	0.2	1.0	1.8	61.0
1952-1953	1.6	7.5	6.2	9.2	8.2	8.0	12.0	4.0	2.9	1.0	0.1	0.3	61.0
1953-1954	0.9	5.5	8.4	11.1	16.3	6.5	9.6	3.8	3.8	1.9	4.9	1.9	74.6
1954-1955	2.6	6.7	11.2	14.4	19.4	13.3	15.3	9.2	4.8	5.3	1.5	0.2	103.9
1955-1956	2.5	8.0	11.6	10.7	10.4	10.5	4.5	4.4	11.4	1.1	3.9	2.1	82.2
1956-1957	3.4	5.0	7.6	6.0	8.1	15.4	7.0	3.7	3.1	9.6	0.9	0.1	76.9
1957-1958	1.5	4.0	13.0	8.5	13.9	25.2	8.9	2.9	1.7	5.5	4.1	0.7	89.9
1958-1959	3.0	2.3	17.4	11.8	18.7	25.4	4.0	14.3	2.2	3.6	0.5	0.5	103.7
1959-1960	1.1	3.3	10.0	18.4	12.8	5.4	10.6	3.7	0.3	0.6	1.2	0.7	68.2
1960-1961	0.8	9.3	13.5	20.2	10.5	7.2	7.6	6.4	1.5	0.1	0	0	79.1
1961-1962	0.6	3.7	7.5	22.6	13.4	10.0	10.3	1.7	2.0	5.6	5.2	1.3	81.9
1962-1963	2.7	6.4	9.8	16.4	14.8	9.7	4.8	3.5	0.7	0	0	0.2	69.0
1963-1964	1.1	2.4	12.5	11.2	11.9	10.5	9.9	7.3	2.4	0.4	1.2	4.5	75.3
1964-1965	4.0	6.3	8.6	19.7	10.2	13.3	4.3	3.4	0.4	0.9	0.2	0.1	71.4
1965-1966	0	1.0	11.8	15.0	11.7	18.0	3.0	5.1	2.7	0.2	0.4	0.8	69.7
1966-1967	1.4	4.0	7.5	19.1	7.3	8.4	11.6	1.1	0	0	0.1	0.2	60.7
1967-1968	1.4	3.1	16.0	13.0	8.7	11.5	7.5	10.5	3.6	9.0	4.5	2.1	90.9
1968-1969	1.5	6.7	11.7	9.1	12.5	17.5	9.3	3.6	1.3	1.3	0.6	0.7	75.8
1969-1970	1.5	3.5	9.5	12.4	8.2	13.9	9.3	6.3	1.8	0.8	0	1.4	69.1
1970-1971	0.6	5.2	8.0	16.7	14.8	14.1	8.6	9.3	5.7	0.4	0	1.1	84.5
1971-1972	4.2	4.8	10.2	18.6	8.7	16.9	5.4	5.7	0	0	1.6	0	76.1
1972-1973	0.2	4.8	9.6	10.4	11.0	16.7	13.3	15.5	3.4	2.2	1.0	2.5	90.6
1973	2.4	9.5	23.0	-	-	-	-	-	-	-	-	-	-
Mean	1.8	5.1	11.1	14.0	12.0	13.2	8.3	5.8	2.6	2.3	1.5	1.1	78.8

TABLE A-43

MONTHLY RUNOFF - GLUGU RIVER AT BANDUNGHARJO DAMSITE

(Units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	200	152	235	77	33	11	9	27	9	-
1952-'53	32	130	113	194	187	131	171	66	20	22	2	40	1,108
1953-'54	4	66	105	197	180	141	144	68	21	49	32	14	1,021
1954-'55	27	135	77	199	158	80	102	59	33	66	9	16	961
1955-'56	54	71	98	175	149	141	47	59	116	4	27	14	955
1956-'57	20	53	149	128	130	321	120	16	25	39	2	0	1,003
1957-'58	25	63	150	150	224	235	94	61	49	83	36	26	1,046
1958-'59	64	77	175	213	126	156	111	119	72	19	4	4	1,140
1959-'60	20	65	111	130	128	80	63	77	28	13	2	14	724
1960-'61	11	92	117	144	133	195	48	154	10	0	0	2	906
1961-'62	14	78	75	225	107	112	135	23	59	25	24	26	903
1962-'63	44	60	133	235	154	120	82	8	6	0	0	1	843
1963-'64	16	41	158	62	200	106	77	73	36	7	12	16	804
1964-'65	40	22	76	131	149	146	190	21	20	8	0	0	805
1965-'66	22	66	117	129	92	152	33	26	57	0	4	1	699
1966-'67	43	67	83	202	114	149	104	14	0	0	8	0	794
1967-'68	14	69	195	165	232	116	99	134	30	87	29	19	1,257
1968-'69	30	120	82	68	166	138	40	0	7	22	0	0	673
1969-'70	62	58	146	177	150	237	88	95	11	19	0	24	1,067
1970-'71	46	70	129	291	134	143	105	115	80	2	13	8	993
1971-'72	79	74	132	266	143	143	92	78	21	1	6	1	1,063
1972-'73	12	96	146	193	181	202	93	211	33	59	26	31	1,383
1973	38	105	168	-	-	-	-	-	-	-	-	-	-
Mean	33	76	124	176	154	158	99	69	34	24	12	12	971

TABLE A-44

AVERAGE MONTHLY DISCHARGE - GLUGU RIVER AT BANDUNGHARJO DAMSITE

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1952	-	-	-	3.1	2.6	3.6	1.2	0.5	0.2	0.1	0.4	0.1	-
1952-'53	0.5	2.1	1.7	3.0	3.2	2.0	2.7	1.0	0.3	0.3	0.0	0.6	1.4
1953-'54	0.1	1.0	1.6	3.0	3.1	2.2	2.3	1.0	0.3	0.8	0.5	0.2	1.3
1954-'55	0.4	2.1	1.2	3.1	2.7	1.2	1.6	0.9	0.5	1.0	0.1	0.2	1.3
1955-'56	0.8	1.1	1.5	2.7	2.5	2.2	0.7	0.9	1.8	0.1	0.4	0.2	1.2
1956-'57	0.3	0.8	2.3	2.0	2.2	4.9	1.9	0.3	0.4	0.6	0.0	0.0	1.2
1957-'58	0.4	1.0	2.3	2.3	3.8	3.6	1.5	0.9	0.8	1.3	0.6	0.4	1.3
1958-'59	1.0	1.2	2.7	3.3	2.1	2.4	1.8	1.8	1.1	0.3	0.1	0.1	1.4
1959-'60	0.3	1.0	1.7	2.0	2.2	1.2	1.0	1.2	0.4	0.2	0.0	0.2	1.5
1960-'61	0.2	1.4	1.8	2.2	2.3	3.0	0.8	2.4	0.2	0.0	0.0	0.0	0.9
1961-'62	0.2	1.2	1.2	3.4	1.8	1.7	3.1	0.4	0.9	0.4	0.4	0.4	1.2
1962-'63	0.7	1.0	2.0	3.6	2.6	1.8	1.3	0.1	0.1	0.0	0.0	0.0	1.2
1963-'64	0.2	0.6	2.4	0.9	3.4	1.6	1.2	1.1	0.6	0.1	0.2	0.3	1.2
1964-'65	0.6	0.4	1.2	2.0	2.5	2.2	3.0	0.3	[illegible]	0.1	0.0	0.0	1.1
1965-'66	0.3	1.0	1.8	2.0	1.6	2.3	0.5	0.4	0.9	0.0	0.1	0.0	1.0
1966-'67	0.7	1.0	1.3	3.1	1.9	2.3	1.6	0.2	0.0	0.0	0.1	0.0	1.0
1967-'68	0.2	1.1	3.0	2.5	3.9	1.8	1.6	2.1	0.5	1.3	0.4	0.3	0.9
1968-'69	0.5	1.9	1.3	1.0	2.8	2.1	0.6	0.0	0.1	0.3	0.0	0.0	1.0
1969-'70	1.0	0.9	2.2	2.7	2.5	3.6	1.4	1.5	0.2	0.3	0.0	0.4	1.6
1970-'71	0.7	1.1	2.0	4.5	2.3	2.2	1.7	1.8	1.3	0.0	0.2	0.1	0.9
1971-'72	1.2	1.2	2.0	4.1	2.4	2.2	1.5	1.1	0.3	0.0	0.1	0.0	1.4
1972-'73	0.2	1.5	2.2	3.0	3.1	3.1	1.5	3.2	0.5	0.9	0.4	0.5	1.3
1973	0.6	1.7	2.6	-	-	-	-	-	-	-	-	-	1.4
Mean	0.5	1.2	1.9	2.7	2.6	2.4	1.6	1.0	0.5	0.4	0.2	0.2	1.3

TABLE A-45

MONTHLY YIELD - GLUGU RIVER AT BANDUNGHARJO DAMSITE

(Units in 10^6 m^3)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1952	-	-	-	8.2	6.2	9.6	3.2	1.4	0.5	0.4	1.1	0.4	-
1952-'53	1.3	5.3	4.6	8.0	7.7	5.4	7.0	2.7	0.8	0.9	0.1	1.7	45.5
1953-'54	0.2	2.7	4.3	8.1	7.4	5.8	5.9	2.8	0.9	2.0	1.3	0.6	41.9
1954-'55	1.1	5.6	3.2	8.2	6.5	3.3	4.2	2.4	1.4	2.7	0.4	0.6	39.4
1955-'56	2.2	2.9	4.0	7.2	6.1	5.8	1.9	2.4	4.8	0.2	1.1	0.6	39.2
1956-'57	0.8	2.2	6.1	5.2	5.3	13.2	4.9	0.7	1.0	1.6	0.1	0.0	41.1
1957-'58	1.0	2.6	6.1	6.1	9.2	9.6	3.9	2.5	2.0	3.4	1.5	1.1	42.9
1958-'59	2.6	3.2	7.2	8.7	5.2	6.4	4.6	4.9	2.9	0.8	0.2	0.1	46.7
1959-'60	0.8	2.7	4.5	5.3	5.2	3.3	2.6	3.2	1.2	0.5	0.1	0.6	29.7
1960-'61	0.5	3.8	4.8	5.9	5.5	8.0	2.0	6.3	0.4	0.0	0.0	0.1	37.1
1961-'62	0.6	3.2	3.1	9.2	4.4	4.6	8.0	1.0	2.4	1.0	1.0	1.1	37.0
1962-'63	1.8	2.5	5.4	9.7	6.3	4.9	3.3	0.3	0.3	0.0	0.0	0.0	34.6
1963-'64	0.7	1.7	6.5	2.5	8.2	4.3	3.1	3.0	1.5	0.3	0.5	0.7	33.0
1964-'65	1.6	0.9	3.1	5.4	6.1	6.0	7.8	0.9	0.8	0.3	0.0	0.0	33.0
1965-'66	0.9	2.7	4.8	5.3	3.8	6.2	1.4	1.1	2.4	0.0	0.1	0.0	28.7
1966-'67	1.8	2.7	3.4	8.3	4.7	6.1	4.3	0.6	0.0	0.0	0.4	0.0	32.6
1967-'68	0.6	2.8	8.0	6.8	9.5	4.7	4.1	5.5	1.2	3.6	1.2	0.8	51.5
1968-'69	1.2	4.9	3.4	2.8	6.8	5.6	1.7	0.0	0.3	0.9	0.0	0.0	27.6
1969-'70	2.5	2.4	6.0	7.2	6.1	9.7	3.6	3.9	0.4	0.8	0.0	1.0	43.7
1970-'71	1.9	2.9	5.3	11.9	5.5	5.8	4.3	4.7	3.3	0.1	0.5	0.3	40.7
1971-'72	3.2	3.0	5.4	10.9	5.9	5.8	3.8	3.0	0.9	0.0	0.3	0.0	43.6
1972-'73	0.5	3.9	6.0	7.9	7.4	8.3	3.8	8.6	1.3	2.4	1.1	1.3	56.7
1973	1.5	4.3	6.9	-	-	-	-	-	-	-	-	-	-
Mean	1.3	3.1	5.1	7.2	6.3	6.4	4.2	2.8	1.3	1.0	0.5	0.5	39.7

TABLE A-46

AVERAGE MONTHLY DISCHARGE SERANG RIVER AT WILALUNG

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean Annual
1952	-	-	-	221.5	220.5	231.7	78.8	49.1	13.9	5.3	17.4	17.0	-
1952-'53	34.8	150.9	147.1	168.5	151.7	121.6	166.4	90.2	58.8	30.7	2.5	1.9	94.3
1953-'54	6.4	71.4	150.9	196.9	225.3	134.7	134.7	102.2	26.3	34.9	26.4	120.3	102.5
1954-'55	41.4	154.6	117.7	252.3	232.7	115.3	143.0	72.3	49.4	70.2	21.1	13.4	106.9
1955-'56	44.6	135.3	150.3	207.0	196.9	132.2	57.0	56.6	87.9	18.3	36.8	17.1	95.0
1956-'57	36.3	55.4	155.0	124.2	122.3	207.8	133.8	39.3	52.8	70.1	10.9	2.3	84.2
1957-'58	13.5	46.9	179.8	152.8	313.3	278.6	154.4	95.2	46.2	80.0	64.3	18.0	120.3
1958-'59	69.5	89.7	252.3	204.0	230.6	198.0	120.3	163.3	55.7	47.9	8.2	10.4	120.8
1959-'60	16.3	72.6	234.8	166.5	210.4	133.7	126.6	97.7	26.1	13.5	6.5	7.5	92.7
1960-'61	12.4	119.5	126.4	184.8	183.3	151.3	99.2	127.9	18.2	5.2	8.4	1.5	85.8
1961-'62	10.3	66.4	128.8	223.9	224.6	127.0	200.2	31.5	36.0	31.0	33.5	7.8	91.9
1962-'63	38.5	94.6	121.1	213.1	211.5	176.2	105.6	24.8	11.9	1.5	0.5	1.7	83.4
1963-'64	29.9	40.9	135.1	97.3	164.8	169.2	124.2	66.0	43.7	21.2	21.3	34.2	79.0
1964-'65	68.5	82.5	98.9	183.7	182.2	197.7	90.8	34.7	18.0	7.7	0.8	0.4	83.2
1965-'66	18.0	74.5	142.4	165.9	174.6	275.8	71.5	56.6	64.3	9.3	11.0	7.9	88.9
1966-'67	45.8	73.3	132.8	252.4	175.3	150.0	126.5	17.0	3.5	1.6	3.3	2.1	81.9
1967-'68	10.4	55.3	190.0	198.1	239.5	170.3	147.4	163.8	70.2	102.1	52.6	17.4	116.1
1968-'69	39.7	137.7	102.5	172.8	220.8	193.4	100.2	24.7	25.0	9.2	3.9	18.6	87.4
1969-'70	35.3	61.5	139.0	158.1	136.3	218.2	111.8	103.4	34.6	17.2	7.1	35.6	88.2
1970-'71	30.8	80.0	131.1	236.4	182.0	155.8	101.8	160.9	54.5	9.4	3.1	9.7	96.3
1971-'72	49.0	72.2	154.0	223.1	134.5	160.0	76.2	80.6	13.4	6.2	8.5	0.3	81.5
1972-'73	3.8	70.4	133.6	160.1	191.0	221.0	124.8	198.8	73.2	82.2	44.4	55.1	110.0
1973	38.6	135.1	235.2	-	-	-	-	-	-	-	-	-	-
Mean	31.3	88.2	152.7	190.1	196.6	178.2	118.0	84.4	40.2	30.7	17.8	18.8	95.5

TABLE A-47

MONTHLY YIELD-SERANG RIVER AT WILALUNG

(Units in 10^6 m^3)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1952	-	-	-	574.1	571.4	600.6	204.2	127.3	36.0	13.8	45.1	44.0	-
1952-'53	91.1	406.6	381.3	436.9	393.3	315.2	431.4	233.7	152.4	79.5	6.6	4.9	2,932.8
1953-'54	16.7	184.9	391.2	510.2	583.9	349.3	390.8	264.1	93.9	90.4	68.4	311.7	3,255.2
1954-'55	107.3	400.7	305.1	653.9	603.2	373.2	370.7	206.5	128.0	181.9	54.7	34.7	3,419.9
1955-'56	115.7	350.6	389.6	536.3	512.2	342.7	147.9	146.6	227.9	47.4	95.5	44.3	2,956.8
1956-'57	94.0	143.5	401.7	321.9	317.1	538.6	346.9	101.8	136.8	181.7	28.2	5.9	2,618.1
1957-'58	35.0	121.5	465.8	396.0	811.9	722.2	399.4	246.7	119.9	207.4	166.7	46.8	3,739.3
1958-'59	180.2	232.5	653.8	528.9	597.7	512.9	311.8	423.3	144.4	124.2	21.2	26.9	3,757.9
1959-'60	42.23	188.1	608.5	431.6	545.3	346.6	328.2	253.3	67.7	34.9	16.9	19.5	2,882.6
1960-'61	32.3	309.7	327.6	479.0	475.2	392.2	257.2	331.5	47.2	13.4	1.2	3.8	2,670.2
1961-'62	26.8	172.1	313.0	580.3	582.2	329.2	518.8	81.6	93.4	80.4	61.0	20.2	2,859.1
1962-'63	99.8	245.1	314.0	552.3	548.2	456.8	273.8	64.4	30.9	3.8	1.2	4.3	2,594.6
1963-'64	77.4	105.9	350.2	252.1	427.3	438.0	322.0	171.1	113.4	55.0	55.1	88.7	2,456.6
1964-'65	177.4	213.8	256.4	476.1	472.2	512.4	235.2	89.9	46.5	20.0	2.1	1.0	2,587.2
1965-'66	33.6	193.2	36.9	430.0	452.6	714.9	185.3	146.7	166.6	24.1	28.6	20.5	2,765.1
1966-'67	118.8	189.9	344.3	654.3	454.4	388.9	337.9	43.9	9.2	4.2	8.5	5.5	2,547.6
1967-'68	27.0	143.4	492.5	513.4	620.8	441.3	382.1	424.5	182.0	264.7	136.3	45.2	3,673.2
1968-'69	103.0	356.8	265.7	447.8	572.3	501.4	259.6	64.0	64.7	23.9	10.1	48.2	2,717.6
1969-'70	91.5	159.4	360.4	409.9	353.3	565.7	289.7	268.0	89.6	44.6	18.5	92.4	2,743.2
1970-'71	79.9	207.5	339.9	612.7	471.7	403.8	263.8	417.1	141.3	24.3	8.0	25.0	2,995.0
1971-'72	127.0	187.3	399.1	578.3	348.6	414.8	197.4	208.9	34.8	16.1	21.9	0.7	2,535.1
1972-'73	9.8	182.4	346.4	415.0	495.1	573.0	323.5	515.3	189.6	173.3	58.1	139.6	3,421.0
1973	100.1	350.2	609.7	-	-	-	-	-	-	-	-	-	-
Mean	81.2	228.7	394.7	493.0	509.8	462.1	306.0	218.9	104.2	79.6	46.2	47.2	2,971.9

TABLE A-48

MONTHLY DISCHARGES - SERANG RIVER AT KEDUNGOMBO

(Quoted: [9] SMEC Studies 1978/1979)

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
1952	-	-	-	55.31	54.74	67.10	20.87	12.71	3.83	1.07	2.98	3.34	-
1952-'53	6.60	44.73	45.30	36.00	29.82	27.83	35.50	21.44	3.62	6.75	0.71	0.50	21.57
1953-'54	0.28	6.04	20.95	41.96	52.19	30.03	44.87	31.81	6.32	8.24	2.77	4.33	20.82
1954-'55	10.65	53.68	35.22	70.36	41.48	32.66	24.28	9.94	5.40	13.77	4.97	5.40	25.67
1955-'56	10.08	31.88	28.61	57.58	66.67	35.78	9.94	12.28	12.00	4.26	5.68	3.98	23.23
1956-'57	8.31	14.84	52.11	42.88	25.84	66.95	38.48	10.01	3.27	8.95	1.78	1.21	22.89
1957-'58	1.07	3.55	31.60	36.21	79.45	70.22	46.93	44.73	9.09	22.58	25.13	4.19	31.23
1958-'59	22.65	25.49	66.03	72.49	55.17	53.89	40.61	39.41	11.01	15.55	1.63	0.99	33.74
1959-'60	2.56	18.89	62.41	27.69	56.16	30.25	30.03	33.80	7.10	5.54	1.07	0.57	23.01
1960-'61	2.34	22.79	20.16	34.01	33.37	39.69	17.96	41.82	5.04	1.35	0.28	0.14	18.25
1961-'62	0.21	17.32	20.38	46.86	41.04	29.18	47.14	13.14	6.46	5.33	4.12	0.43	19.30
1962-'63	2.41	22.72	40.68	58.50	42.17	36.44	34.51	4.26	1.14	0.71	0.28	0.07	21.99
1963-'64	0.46	5.89	19.24	16.61	44.94	40.33	48.92	21.23	9.80	6.25	3.83	3.34	18.37
1964-'65	16.26	17.04	14.48	45.23	52.26	55.38	30.18	6.96	2.34	1.63	0.21	0.14	20.18
1965-'66	1.70	11.36	20.45	42.17	57.08	82.79	24.64	11.08	18.82	5.18	4.12	1.07	23.37
1966-'67	14.48	17.47	32.38	66.81	68.23	33.87	28.33	5.40	0.78	0.07	0.07	0.07	22.31
1967-'68	0.07	8.45	36.99	46.36	69.23	48.85	40.68	39.90	10.08	17.54	12.00	3.05	27.77
1968-'69	9.72	35.43	42.03	39.41	50.33	36.49	28.47	6.32	5.82	2.56	0.71	0.36	21.47
1969-'70	8.02	7.31	37.06	22.01	24.92	37.49	15.76	25.28	7.24	5.25	3.55	11.50	17.12
1970-'71	5.61	13.77	35.00	59.43	40.83	41.89	29.18	32.38	19.24	0.43	0.07	0.07	23.16
1971-'72	3.76	9.94	31.95	50.84	31.45	26.27	15.83	11.72	4.05	3.83	0.71	0.07	15.87
1972-'73	0.07	9.59	25.92	37.84	51.26	42.88	23.57	46.36	15.83	21.66	3.27	20.09	24.86
1973	8.23	34.01	47.07	-	-	-	-	-	-	-	-	-	-
Mean	6.16	19.66	34.82	40.51	48.57	42.93	30.76	21.91	7.48	7.21	3.63	2.95	22.19

TABLE A-49

MONTHLY DISCHARGES - SERANG RIVER AT SEDADI WEIR
(Based on NEDECO Studies [4])

(Units in m^3/s)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
1952	-	-	-	77.90	77.10	94.51	29.39	17.90	5.39	1.51	4.20	4.70	-
1952-'53	9.30	63.00	63.80	50.70	42.00	39.20	50.00	30.20	5.10	9.51	1.00	0.70	30.63
1953-'54	0.39	8.51	29.51	59.10	73.51	42.30	63.20	44.80	8.90	11.61	3.90	6.10	29.32
1954-'55	15.00	75.61	49.61	99.10	58.42	46.00	34.20	14.00	7.61	19.39	7.00	7.61	36.15
1955-'56	14.20	44.90	40.30	81.10	93.90	50.39	14.00	17.30	16.90	6.00	8.00	5.61	32.72
1956-'57	11.70	20.90	73.39	60.39	36.39	93.79	54.20	14.10	4.61	12.61	2.51	1.70	32.24
1957-'58	1.51	5.00	44.51	51.00	111.90	98.90	66.10	63.00	12.80	31.80	35.39	5.90	43.99
1958-'59	31.90	35.90	93.00	102.10	77.70	75.90	57.20	55.51	15.51	21.90	2.30	1.39	47.52
1959-'60	3.61	26.61	87.90	39.00	79.10	42.61	42.30	47.61	10.00	7.80	1.51	0.80	32.41
1960-'61	3.30	32.10	28.39	47.90	47.00	55.90	25.30	58.90	7.10	1.90	0.39	0.20	25.70
1961-'62	0.30	24.39	28.70	66.00	57.80	41.10	66.39	18.51	9.10	7.51	5.80	0.61	27.18
1962-'63	3.39	32.00	57.30	82.39	59.39	79.49	48.61	6.00	1.61	1.00	0.39	0.10	30.97
1963-'64	0.65	8.30	27.10	23.39	63.30	56.80	68.90	29.90	13.80	8.80	5.39	4.70	25.87
1964-'65	22.90	24.00	20.39	35.54	73.61	78.00	42.51	9.80	3.30	2.30	0.30	0.20	28.42
1965-'66	2.39	27.20	28.80	59.39	80.39	116.61	37.52	15.61	26.51	7.30	5.80	1.51	32.92
1966-'67	20.39	24.99	45.61	94.10	96.10	47.70	39.90	7.61	1.10	0.10	0.10	0.10	31.42
1967-'68	0.10	11.90	52.10	65.30	97.51	68.80	57.30	56.20	14.20	24.58	16.90	4.30	39.11
1968-'69	13.69	49.90	59.20	55.51	70.89	51.39	40.10	8.90	8.20	3.61	1.00	0.51	30.24
1969-'70	11.30	10.30	52.20	31.00	35.10	52.80	22.20	35.61	10.20	7.39	5.00	16.20	24.11
1970-'71	7.90	19.39	49.30	83.10	57.51	59.00	41.10	45.61	27.10	0.61	0.10	0.10	32.62
1971-'72	5.30	14.00	45.00	71.61	44.30	37.00	22.30	16.51	5.70	5.39	1.00	0.10	22.35
1972-'73	0.10	13.51	36.51	53.30	72.20	60.39	33.20	65.30	22.30	30.51	4.61	28.30	35.01
1973	11.59	47.90	66.30	-	-	-	-	-	-	-	-	-	-
Mean	8.68	27.69	49.04	57.05	57.06	68.41	43.32	30.86	10.54	10.15	5.11	4.15	30.59

TABLE A-50

MONTHLY RUNOFF SERANG RIVER AT SEDADI

(units in mm)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1952	-	-	-	240	215	292	88	55	16	5	13	14	938
1952-'53	29	188	197	156	117	121	150	93	15	29	3	2	1,100
1953-'54	1	25	91	182	205	131	189	138	27	36	12	18	1,055
1954-'55	46	226	153	306	163	142	102	43	23	60	22	23	1,309
1955-'56	44	134	124	250	262	155	42	53	51	19	25	17	1,176
1956-'57	36	62	226	186	101	289	162	44	14	39	8	5	1,172
1957-'58	5	15	137	157	312	305	198	194	38	98	109	18	1,587
1958-'59	98	107	287	315	217	234	171	171	46	68	7	4	1,725
1959-'60	11	79	271	184	220	131	126	147	30	24	5	2	1,230
1960-'61	10	26	88	148	131	172	76	182	21	6	1	1	862
1961-'62	1	73	89	204	161	127	198	57	27	23	18	2	980
1962-'63	10	96	177	254	166	245	145	19	5	3	1	0	1,121
1963-'64	2	25	84	72	176	175	206	92	41	27	17	14	931
1964-'65	71	72	63	110	205	241	127	30	10	7	1	1	938
1965-'66	7	82	89	183	224	360	112	48	80	23	18	5	1,231
1966-'67	63	75	141	290	268	147	119	23	3	0	0	0	1,129
1967-'68	3	36	161	174	272	212	171	273	42	76	52	13	1,385
1968-'69	42	149	183	171	198	159	120	27	24	11	3	2	1,039
1969-'70	35	31	161	96	98	163	67	110	106	23	16	48	954
1970-'71	24	58	152	256	161	182	123	141	136	2	0	0	1,235
1971-'72	129	42	139	221	123	114	67	51	49	17	3	0	955
1972-'73	3	40	113	164	201	186	100	201	195	94	14	85	1,396
1973	36	143	205	-	-	-	-	-	-	-	-	-	-
Mean	32	84	151	196	191	195	130	95	45	32	16	12	1,179

A.3. REGIONAL FLOOD ANALYSIS*

A.3.1. General

There are two problems in determining flood probabilities for rivers in Indonesia. First, seldom is there any actual measurements of discharge during the passage of the flood. Generally flood peaks are estimated from rating curve extensions. That is, flood peak discharges are not measured but estimated with unknown accuracy. Secondly, the period of record for many stations is very short. The statistics of the flood peaks are not accurate when the record is short.

To overcome these problems, PRC Engineering Consultants, Inc. has used regional flood curves to estimate flood statistics in Java and Sumatra. The regional flood curves are developed from existing data published in feasibility reports for water resources development.

The regional flood curves are constantly being revised as new data become available. It is critical that revisions be continued in the future. One who uses these curves without any effort to add to their validity will learn little or nothing of floods in Indonesia.

The theory behind the development of regional flood frequency curves can be found elsewhere. The users of such curves are advised to review this theory so that the interpretation of individual station data can be accomplished correctly. For example, the Jragung River catchment upstream from the Borangan Bridge is a long and very steep watershed draining one sector of Gunung Ungaran. The flood peaks from this catchment are much different than from a similar sized catchment on the flat alluvial plains downstream.

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* The analysis was done in March 1980 incorporating therein the highest flood of January 1980.

A.3.2. Data

The data used for this current regional flood frequency analysis are listed in Table A-51. Most of the data are from the Snowy Mountains Engineering Corporation's regional flood frequency study [8]. We have added four stations to the Snowy Mountains record. Also, the interpretation of the data herein are slightly different.

The data listed in Table A-52 were not used in the regional flood study because the period of record for these stations is less than 10 years.

The situation on the Jragung River is used to illustrate how the data should be revised as new records become available. The annual peak flood for the seven years of record at the Borangan Bridge are as follows:

ANNUAL PEAK FLOOD
JRAGUNG RIVER AT BORANGAN BRIDGE

Year	Date	Peak Discharge m^3/s	Volume of Flood 10^6 m^3
1*	9 Mar 1974	294	4.41
2	5 Jan 1975	280	3.13
3	18 Mar 1976	345	3.35
4	23 Apr 1977	158	1.12
5	31 Dec 1977	387	3.55
6	6 Apr 1979	358	3.13
7	22 Jan 1980	752	17.5

* Note: Record begins on 4 May 1974.

For the first six years of record, the mean annual flood is 304 m^3/s and the coefficient of variation is 0.27. Then, the flood of record occurred on 22 January 1980. The peak discharge for this flood was approximately twice the previous largest peak and its volume was 4 times greater than the previous largest volume.

Now, for the entire 7-year period of record, the mean annual flood is 368 m^3/s and the coefficient of variation is 0.50.

A.3.3. Regional Mean Annual Flood

The regional relation between mean annual flood peak and catchment area is shown in Figure A-9.

PRC Engineering Consultants, Inc. uses the enveloping curve to determine flood frequencies for the design of structures such as weirs or diversion tunnels. The lower curve is employed to evaluate and design flood control systems such as levees.

A.3.4. Regional Coefficient of Variation

The regional relation between coefficient of variation and catchment area is shown in Figure A-10. The mean curve is used for all analyses and also for design.

A.3.5. Frequency Distribution

It has been shown that the flood peal Q_T with return period T is given by the equation

$$Q_T = Q\,(1 + K_T C_v)$$

in which Q = mean annual flood peak

C_v = coefficient of variation

K_T = coefficient depending on the return period T and on the frequency distribution of the flood peaks

The frequency distribution of flood peaks in Indonesia is not known because, for most gages, the period of record is not long enough to obtain a stable mean or coefficient of variation. Estimates of the skew are totally unreliable.

PRC Engineering Consultants, Inc. assumes that the flood peaks have a Type 1 extreme distribution. The values of K_T for this distribution for 15 years of record are listed below.

VALUES OF K_T
GUMBEL DISTRIBUTION

Return Period T, Years	Value of K_T
5	0.90
10	1.60
15	1.95
20	2.20
25	2.40
50	3.10
100	3.70
200	4.40

A.3.6. Use of Curves

Suppose one wants to estimate the return period for the 22 January

1980 flood on the Jragung River at the Borangan Bridge using the regional curves. The flood peak was 752 m^3/s.

The regional mean annual flood for a catchment areas of 101 km^2 is 368 m^3/s. (The enveloping curve passes through this point). The regional coefficient of variation is 0.47. Now

$$K_T = \frac{1}{C_v} \left(\frac{Q_T}{Q} - 1 \right)$$

or

$$K_T = \frac{1}{0.47} \left(\frac{752}{368} - 1 \right) = 2.22$$

According to the table showing the variation of K_T with T for the Type 1 extreme distribution, the 22 January 1980 flood peak has a return period of approximately 20 years.

A.3.7. Update of Curves

As mentioned in the previous paragraphs, the regional flood curves are constantly being revised as new data become available. It is essential that revisions be continued in the future. Evaluation of the existing regional curves for mean annual flood and coefficient of variation should be made as soon as a large flood is recorded at a gaging station, such as the January flood at Borangan Bridge on Jragung River. It is critical that the new record be thoroughly analyzed and evaluated before applying it in the revision of the existing regional flood curves.

It should be noted that the analysis given above was done to include the data of flood which occured in the basin in January 1980. The original analysis for the Jragung River reported in Appendix A, Part I was completed in July 1979 and was, therfore, based on the information on the regional flood data known at that time.

TABLE A-51

DATA FOR THE REGIONAL ANNUAL PEAK FLOOD ANALYSIS

Designation	River	Gage	Years of Records	Drainage Area, A km^2	Mean Annual Flood, $\bar{Q}$ m^3/s	Coefficient of variation, C_v	Reference
1	Cimanuk	Leuwigeong	26	751	333	0.30	1
2	Cimanuk	Eretan	19	1,460	703	0.22	1
3	Cipeles	Suhatali	10	310	290	0.46	1
4	Cisadane	Masing	10	129	193	0.36	1
5	Cianten II	Kracak	12	143	496	0.48	1
6	Citarum	Plumbon	12	4,150	1,713	0.31	1
7	Kawah Ciwidey	Post A	11	0.43	0.543	0.26	1
8	Cipadaran	Post B	13	3.05	8.9	0.69	1
9	Ciwidey	Post C	12	10.81	7.5	0.28	1
10	Cisarua	Post D	12	4.72	5.1	0.35	1
11	Cilaki	Ciheulang	17	163	74	0.51	1
12	Cikatib	Ubrug	12	486	538	0.30	1
13	Bogowonto	Bener	12	94	102	0.48	1
14	Serayu	Garung	12	58	83	0.48	1
15	Catur	Giringan	12	458	70	0.35	1
16	Konto	Kedungrejo	12	110	49	0.53	1
17	Tuntang	Glapan	-	796	360	0.31	2
18	Serang	Kedungombo Damsite	-	614	600	0.25	3
19	Jragung	Borangan	7	101	368	0.50	4
20	Jragung	Weir	18	133	377	0.12	5

TABLE A-52

DATA NOT USED IN THE REGIONAL

ANNUAL PEAK FLOOD ANALYSIS

Designation	River	Gage	Years of Records	Drainage Area, A km^2	Mean Annual Flood, $\bar{Q}$ m^3/s	Coefficient of variation, C_v	Reference
a	Citarum	Nanjung	5	1,718	359	0.14	1
b	Ciwidey	Cukanghaur	3	167	141	0.19	1
c	Cidano	Curug Betung	7	201	77	0.13	1
d	Garang	Pudak Payung	3	59	90	1.08	1
e	Tuntang	Tuntang	7	282	62	0.15	1
f	Citanduy	Indihiang	3	414	266	0.39	1
g	Ciwulan	Lengkongjaya	3	151	186	0.32	1

BIBLIOGRAPHY

No.	Title
1	"NEDECO" Jratunseluna Basin Development Project, Feasibility Study; Water Resources Development: Jragung, Dolok and Penggaron Basins, Volume 1 Report, December 1971
2	"NEDECO" Jratunseluna Basin Development Plan; July 1973. Supporting Report No. II; Surface Water Resources Supporting Report No. III; Ground Water Resources Supporting Report No. Irrigation Supporting Report No. Morphology Supporting Report No. VII River Morphology
3	"NEDECO" Jratunseluna Basin Development Project; Explanatory Note on the Rehabilitation of the Main Drainage Systems in the Plain of East Semarang, Part 1, May 1974.
4	"NEDECO" Jratunseluna Basin Development Plan; Central Java; Ngrambat Dam, Irrigation, Flood Control and Hydro-power Project: June 1975 Volume 1: Main Report Volume 2: Appendices Volume 3: Supporting Data
5	Thaden, R.E., Harli Sumadirdja and Richards, P.W., "Geological Map of the Magelang and Semarang Quadrangles, Java, "Geological Survey of Indonesia, Directorate General of Mines, Ministry of Mines, Jakarta, 1975.
6	Engineering Consultants, Inc., "Jragung Dam Multi-Purpose Irrigation, Flood Control, Hydro-Electric and Municipal and Industrial Water Supply Project, Upgraded Feasibility Study, Appendix II, Hydrology," report prepared for Republic of Indonesia, Ministry of Public Works and Electric Power, Directorate General of Water Resources Development, Directorate of Irrigation, Jakarta, September 1976.
7	Belgian Technical Assistance Program, "Report on Activities of Project ATA 105," Soil physics report, Soil Research Institute, Bogor, West Java, 1977.

BIBLIOGRAPHY
(Cont.)

No.	Title
8	Geological Survey of Indonesia, "Geological Map of Java and Madura, Sheet Central Java," Second edition, Directorate General of Mines, Ministry of Mines, 1977.
9	Snowy Mountains Engineering Corporation, "Definite Scheme Report, Volume 4, Water Investigations. The Improvement and Development of the Serang River and Irrigation Project, Central Java," report prepared for Republic of Indonesia, Ministry of Public Works, Directorate General of Water Resources Development, Jakarta, September, 1978.
10	Engineering Consultants, Inc., "Jragung Dam Project, Final Design Report, Part I," Text, report prepared for the Directorate General of Water Resources and Development, Ministry of Public Works, Republic of Indonesia, April 1979.
11	NEDEDO, "Sedeku - Prosida Semarang - Demak - Kudus Irrigation Rehabilitation Project," Quarterly Report No. 3, prepared for the Directorate General of Water Resources Development, Ministry of Public Works, Republic of Indonesia, June, 1979.
12	Iowa Institute of Hydraulic Research, The University of Iowa: Hydrologic and Hydraulic Computations on Small Programmable Calculators, 1979.
13	Engineering Consultants, Inc. Tuntang/Jragung Rivers Basins Integrated Development Plan. Executive Summary and Appendix A - Part I ; Hydrology, November, 1979
14	Snowy Mountains Engineering Corporation, The Serang River and Irrigation Project, Central Java; Supplementary Information for Tenderers. Climate and Streamflows. Kedungombo Dam. December, 1979.
15	Chow, Handbook of Applied Hydrology, Mc.Graw Hill, 1964
16	Wisler and Brater: Hydrology, John Wiley & Sons, 1959.

BIBLIOGRAPHY (Cont.)

No.	Title
17	Snowy Mountain Engineering Consultants, "Cimanuk Project, Jatigede Dam and Power Facility, Report on Hydrology," prepared for the Ministry of Public Works and Electric Power, Directorate General of Water Resources Development, Republic of Indonesia, May 1977.
18	NEDECO, "Jratunseluna Basin Development Plan, Central Java, Glapan Dam, Irrigation, Flood Control and Hydro-Power Project Feasibility Study, Volume 2, Appendices I-IX, Part B, Tables, Annexes and Figures," prepared for Republic of Indonesia, Ministry of Public Works and Electric Power, Directorate General of Water Resources Development, Jakarta, July, 1975.
19	Snowy Mountains Engineering Corporation, "Definite Scheme Report, Volume 4, Water Investigations, The Improvement and Development of the Serang River and Irrigation Project, Central Java," prepared for Republic of Indonesia, Ministry of Public Works, Directorate General of Water Resources Development, Jakarta, September, 1978.
20	PRC Engineering Consultants, Inc., "Draft of Tuntang and Related River Basins Development Plan, Appendix H, Sedimentation Studies Jragung Watershed," prepared for the Directorate General of Water Resources Development, Ministry of Public Works, Republic of Indonesia, May 1980.
21	NEDECO, "Sedeku-Prosida Semarang-Demak-Kudus Irrigation Rehabilitation Project, Quarterly Report No. 3," prepared for the Directorate General of Water Resources Development, Ministry of Public Works, Republic of Indonesia, October 1978.

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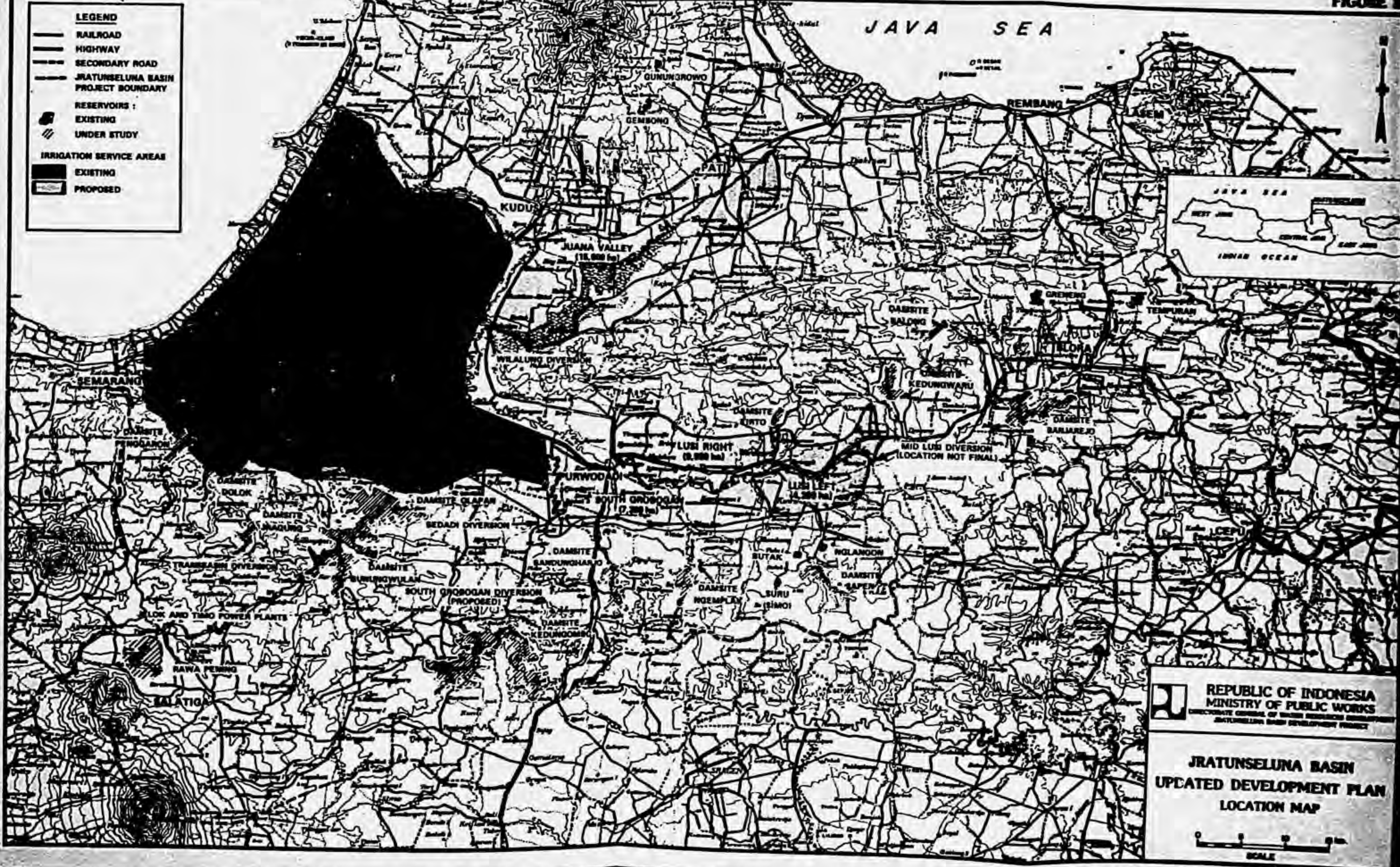
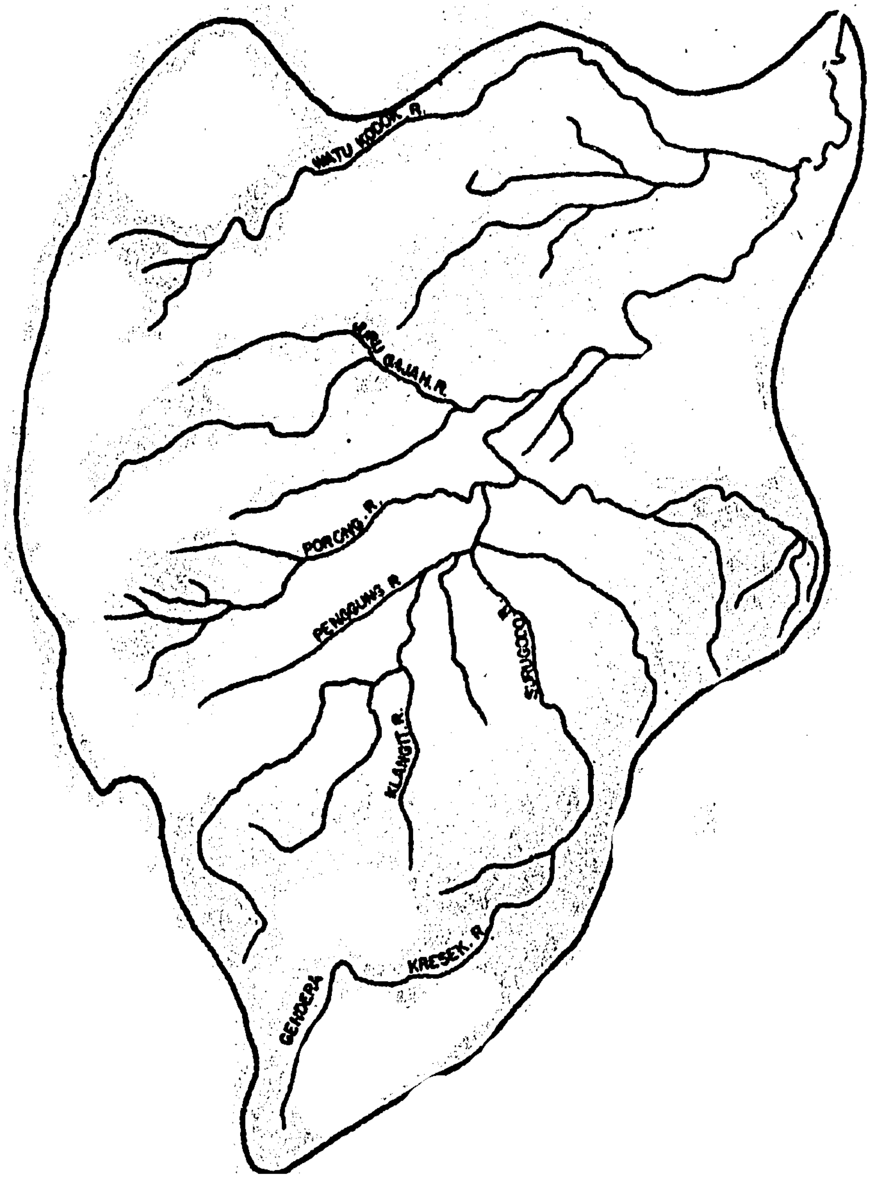
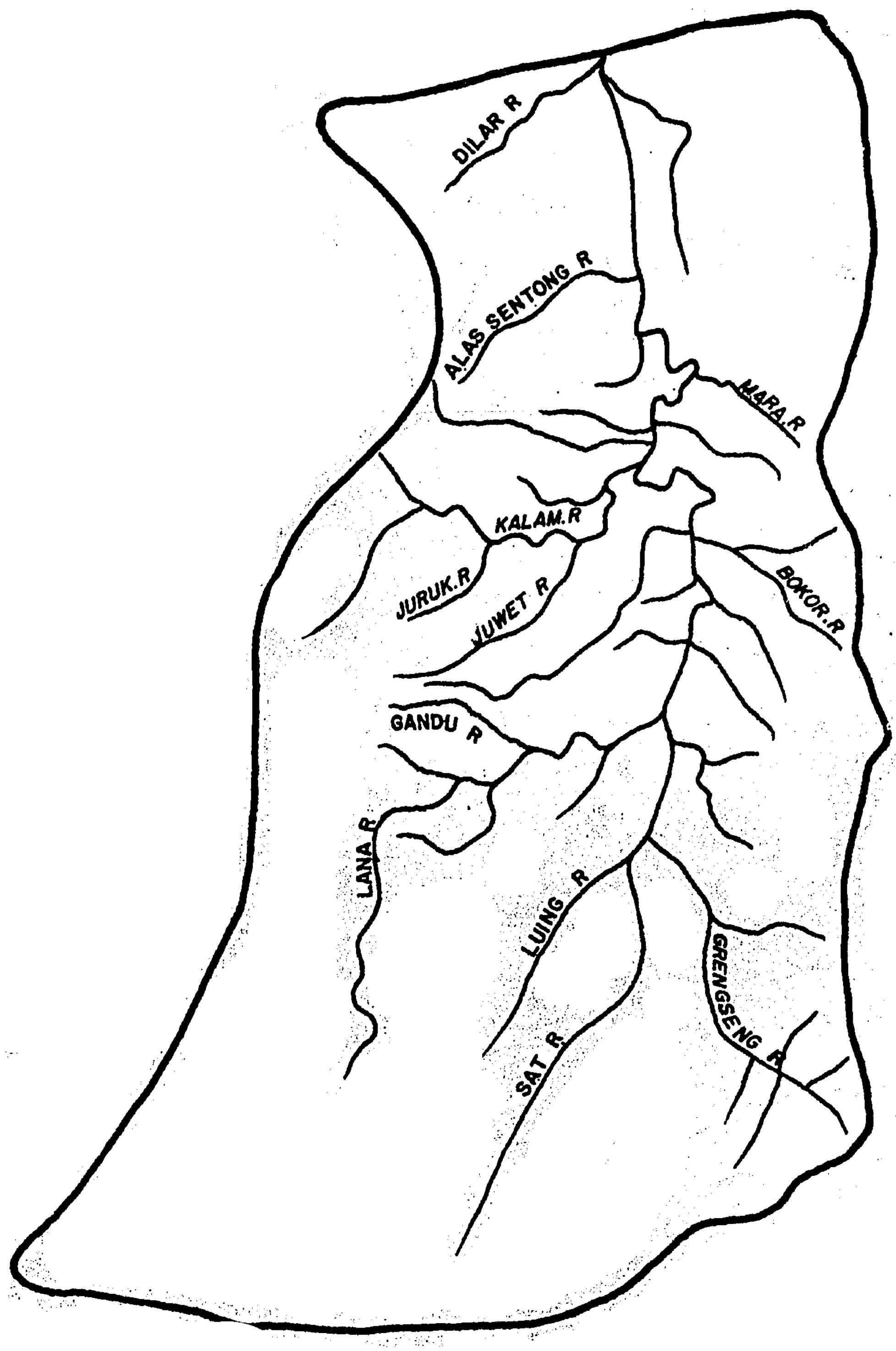




TUNTANG AND RELATED RIVERS
BASINS DEVELOPMENT PLAN
PENGGARON RIVER
AND TRIBUTARIES



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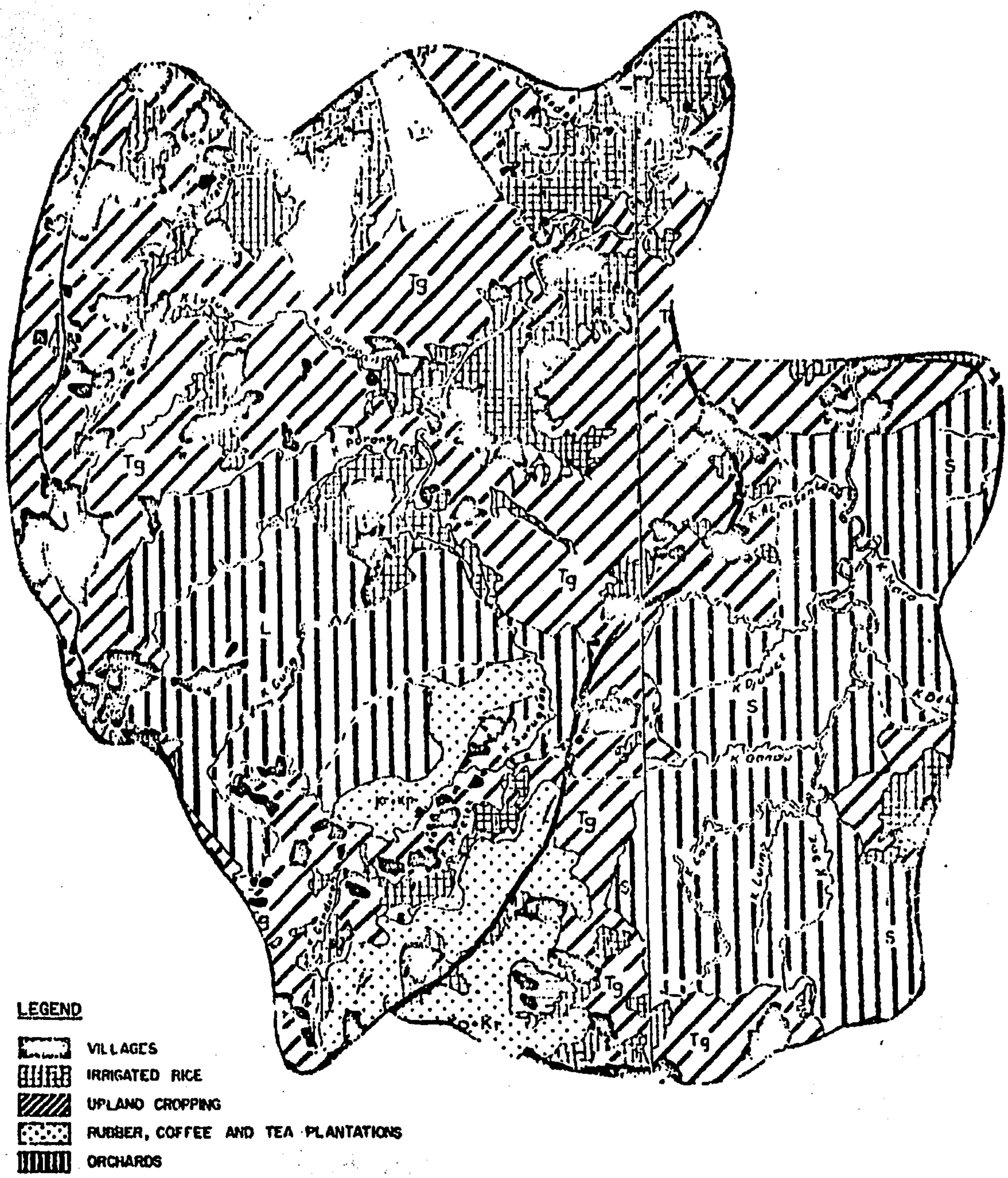
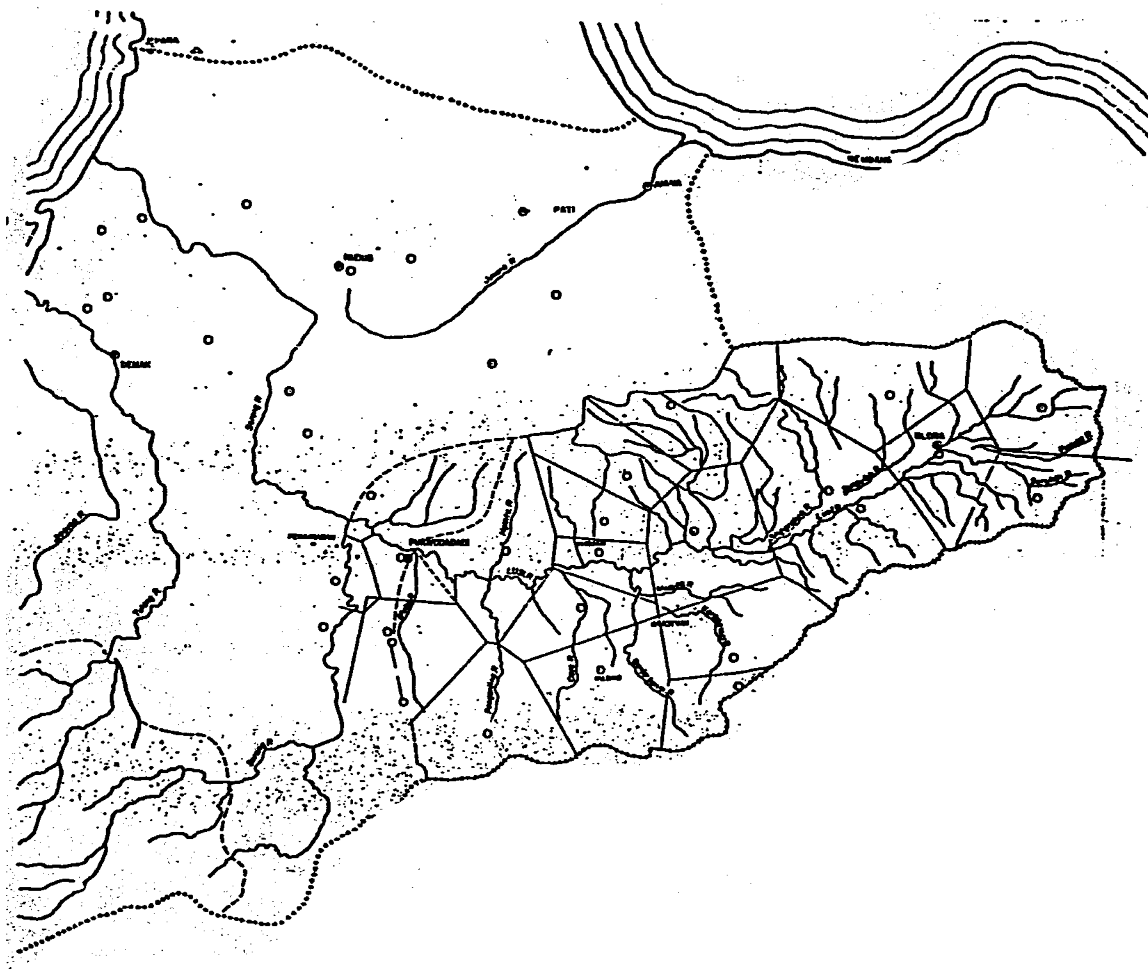
AND TRIBUTARIES



TUNTANG AND RELATED RIVERS BASINS DEVELOPMENT PLAN

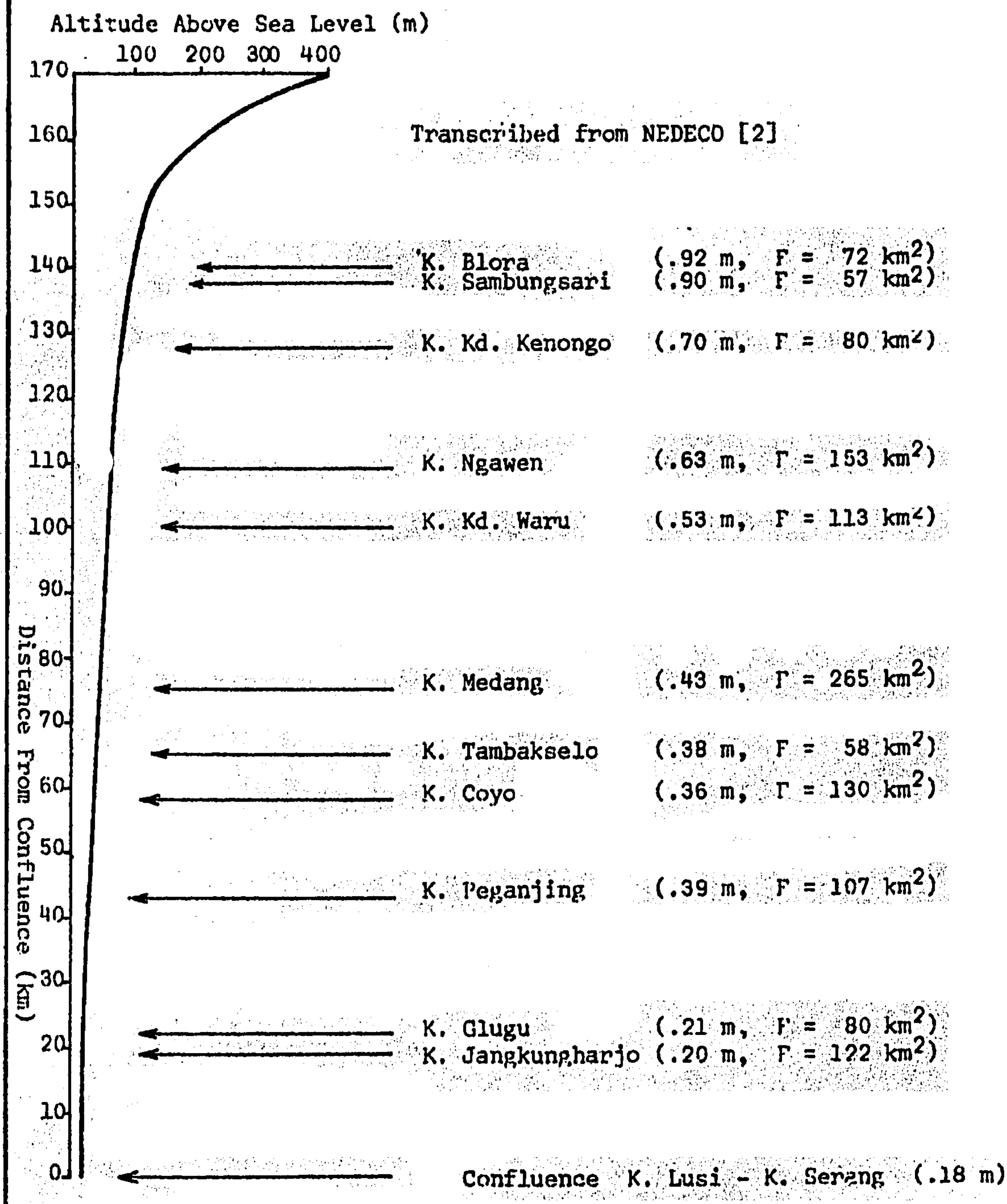
LAND USE IN PENGGARON AND DOLOK CATCHMENTS

FIGURE A-5



TUNTANG AND RELATED RIVERS
BASINS DEVELOPMENT PLAN
LUSI RIVER
AND TRIBUTARIES

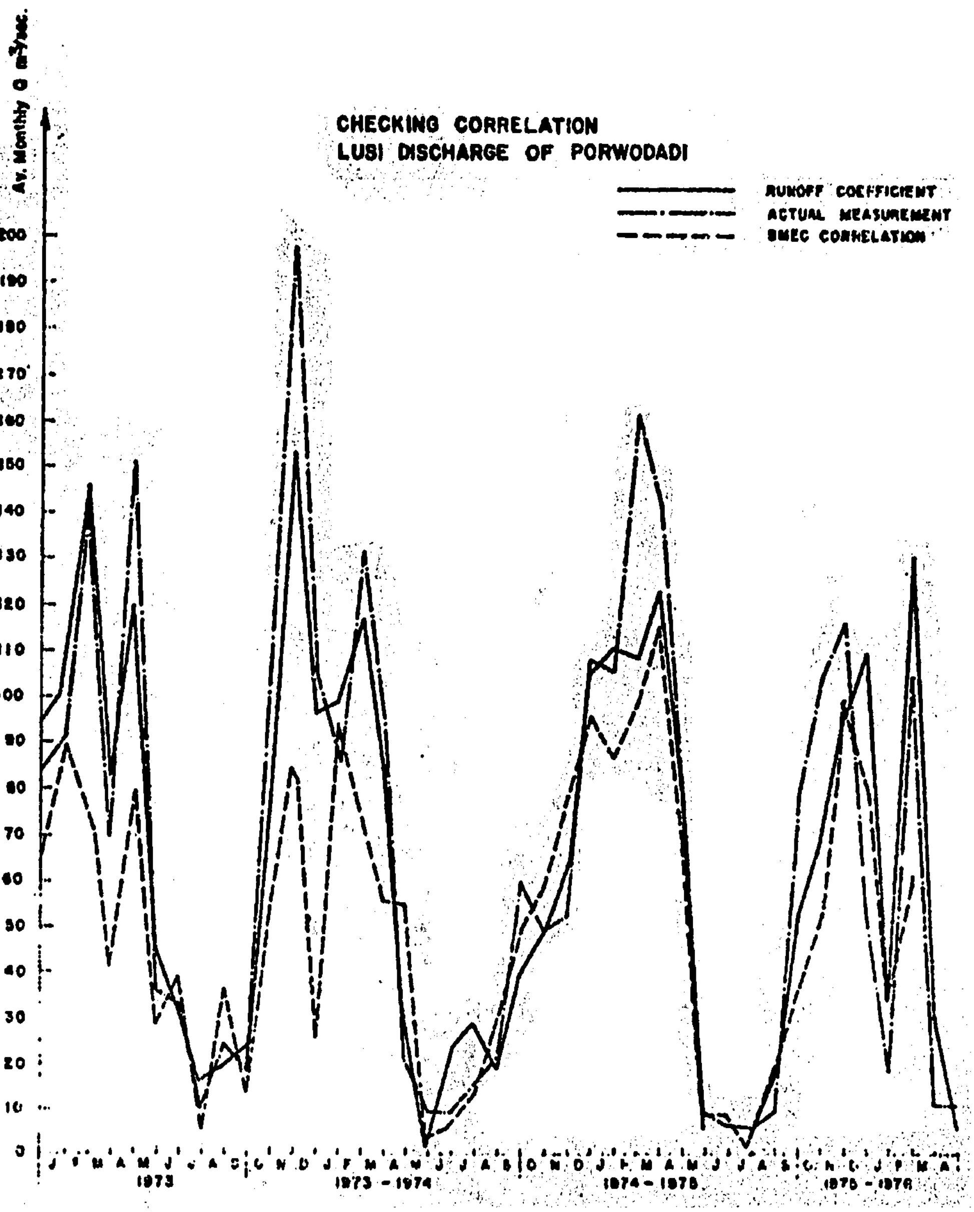
PRC ENGINEERING CONSULTANTS, INC. FIGURE A-6



TUNTANG AND RELATED RIVERS BASINS DEVELOPMENT PLAN

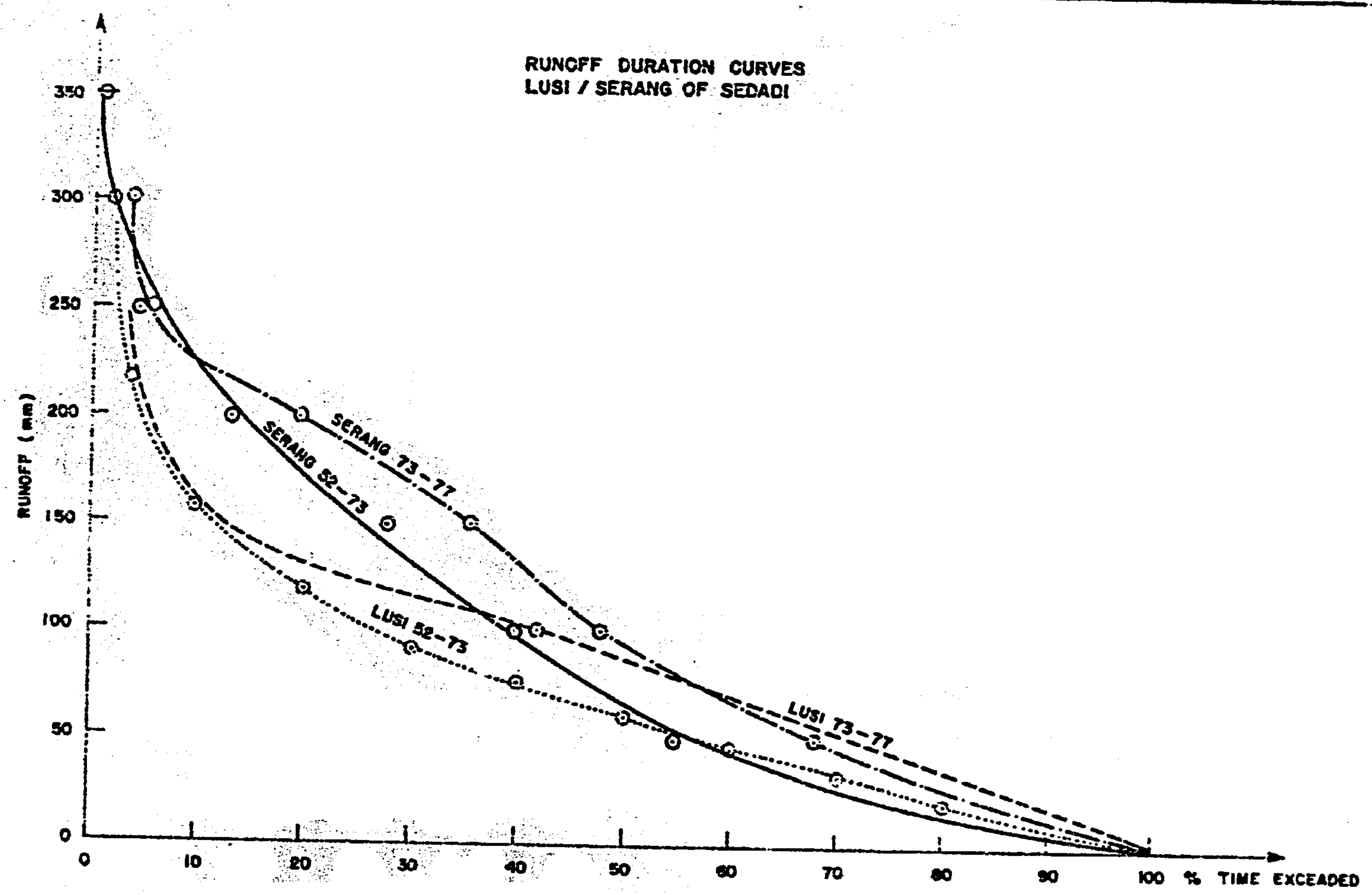
LONGITUDINAL SECTION LUSI RIVER

FIGURE A-7



TUNTANG AND RELATED RIVERS
BASINS DEVELOPMENT PLAN

CHECKING CORRELATION
LUSI DISCHARGE AT PURWODADI

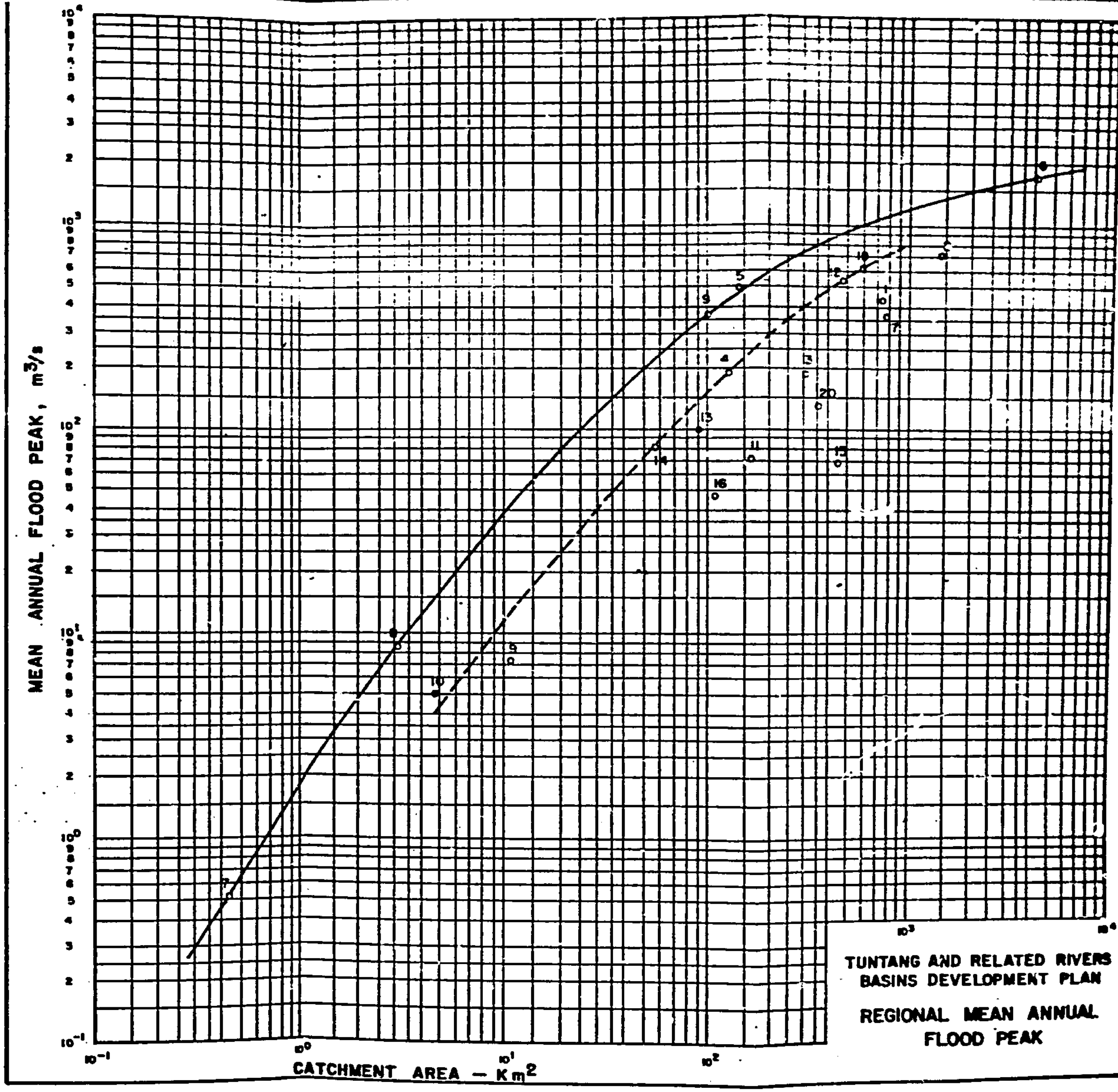


TUNTANG AND RELATED RIVERS
BASINS DEVELOPMENT PLAN

RUNOFF DURATION CURVES
LUSI / SERANG AT SEDADI

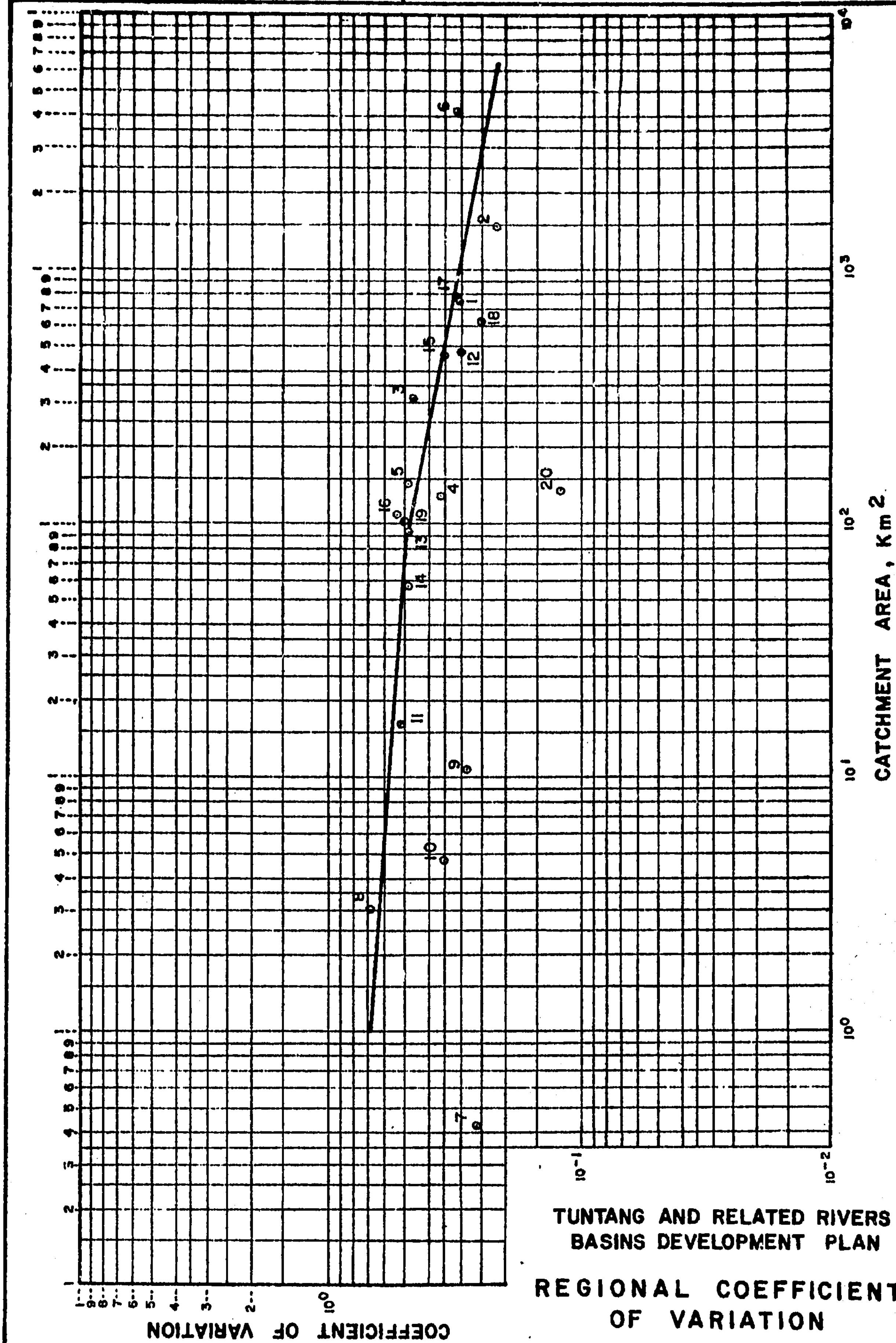
PRC ENGINEERING CONSULTANTS, INC.

FIGURE A-8



TUNTANG AND RELATED RIVERS BASINS DEVELOPMENT PLAN

REGIONAL MEAN ANNUAL FLOOD PEAK



TUNTANG AND RELATED RIVERS
BASINS DEVELOPMENT PLAN

REGIONAL COEFFICIENT OF VARIATION