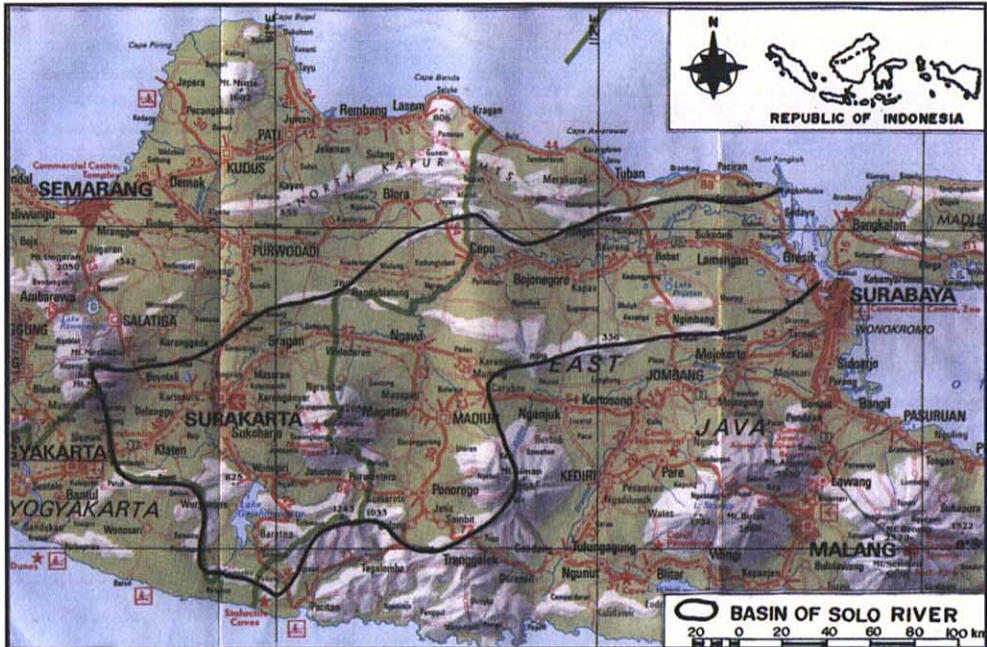


# Bengawan Solo

## Map of River



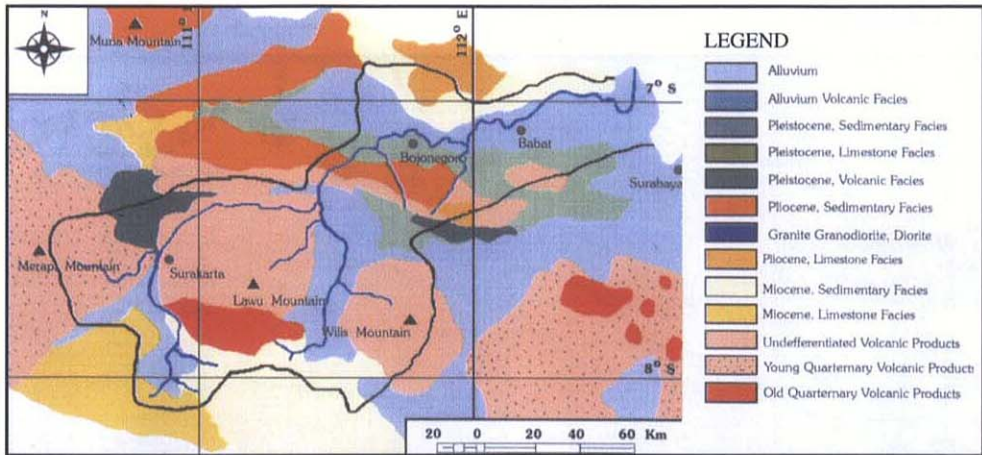
Atlas Indonesia dan Dunia , P. T Karya Pembina Swajaya, 1992

## Table of Basic Data

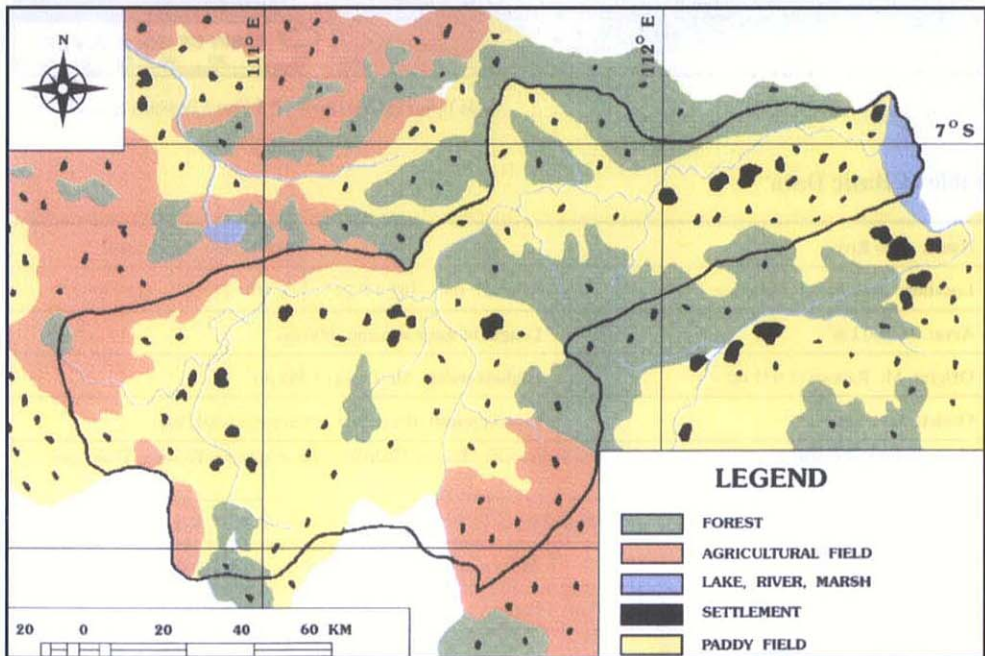
Name: Solo River		Serial No.: Indonesia-2
Location: Java Island, Indonesia	S 06° 37' 05" ~ 08° 17' 27"	E 110° 27' 16" ~ 112° 39' 27"
Area: 16 100 km <sup>2</sup>	Length of main stream: 600 km	
Origin: Mt. Ratawu (1 035 m)	Highest point: Mt. Lawu (3 265 m)	
Outlet: Java Sea	Lowest point: River Bed at Sembayat (-8.02 m)	
Main geological features: Pleistocene & Pliocene Sedimentary Facies, Undifferentiated Volcanic Product, Young and Old Quaternary Volcanic Product		
Main tributaries: Dengkeng River (830 km <sup>2</sup> ), Madiun River (3 755 km <sup>2</sup> ), Pacal River (358 km <sup>2</sup> ), Kening River (823 km <sup>2</sup> )		
Main lakes: Sarangan (1 ha)	Main marshes: Jabung (7000 ha), Jero (20 000 ha)	
Main reservoirs: Wonggiri Reservoir (730 x 10 <sup>6</sup> m <sup>3</sup> , 1981)		
Mean annual precipitation: 2 100 mm		
Mean annual runoff: 363 m <sup>3</sup> /s at Bojonegoro (12 804 km <sup>2</sup> ) (1983-1991)		
Population: 13 500 000 (1993)	Main cities: Solo, Ngawi, Madiun, Bojonegoro, Gresik	
Land use: Forest (19.5%), Paddy field (21.9%). Other agriculture (25.3%), Settlement (32.4%), Lake (0.9%) (1992)		

## 2. Geographical Information

### 2.1 Geological Map



### 2.2 Land Use Map



## 1. General Description

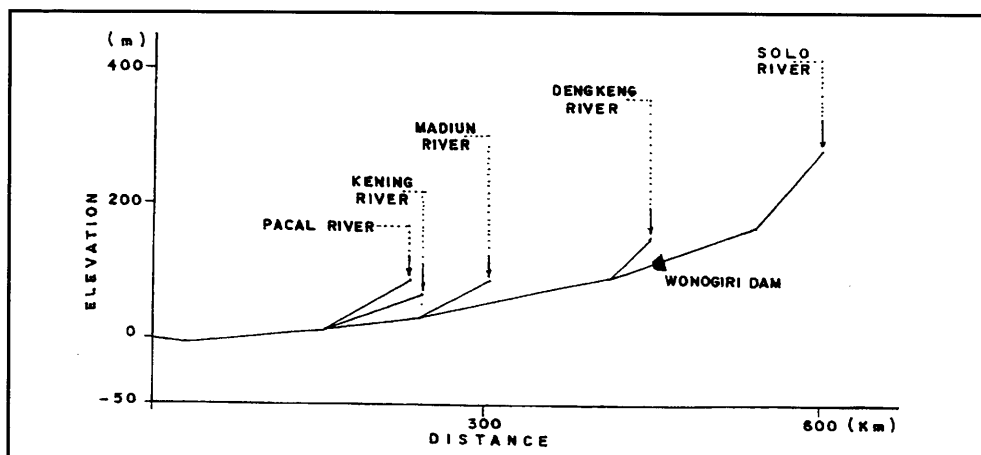
The Solo River - the largest in Java Island - is 600 km long and has a catchment area of 16 100 km<sup>2</sup>. It runs through the Central and East Java Provinces, and through several mountain ranges such as Kapur, Kendeng, Merapi, Merbabu, Lawu, and Wilis. The main stream valleys of upper Solo (6 072 km<sup>2</sup>) and Madiun (a tributary with catchment area 3 755 km<sup>2</sup>) are wide and extend over the flat alluvial plain. The lower Solo crosses the low hills of tertiary and quaternary Kendeng ridge. The tertiary hills consist of tuffaceous sandstone, siltstone, mudstone and limestone of Miocene. Tropical monsoon climate characterised by distinct wet and dry seasons is predominant in the basin. The average annual rainfall in the basin is 2 100 mm. The Wonogiri multipurpose dam with a capacity to store 730 x 10<sup>6</sup> m<sup>3</sup> of water was built in 1981. Approximately 47.2% of the basin area is utilized for agricultural production, tobacco in particular. The basin population in 1993 has been 13.5 million. The Solo basin is identified as one of the main grain producing areas of Indonesia.

### 2.3 Characteristics of River and Main Tributaries

No.	Name of river	Length [km] Catchment area [km <sup>2</sup> ]	Highest peak [m] Lowest point [m]	Cities Population [1993]	Land use [%] (1992)				
					A	F	L	P	S
1	Solo (Main River)	600 16 100	Mt. Lawu, 3 265 -----	Solo 525 371 Ngawi D. 829 726	25.3	19.5	0.9	21.9	32.4
2	Dengkeng (Tributary)	60 830	Mt. Merapi, 2 911 -----	Sukoharjo District 711 580	24.5	3.0	0.5	66.0	6.0
3	Madfiun (Tributary)	63 3 755	Mt. Lawu, 3 265 -----	Madiun 643 109	8.4	19.6	0.3	67.6	3.4
4	Kening (Tributary)	79.9 823	Mt. Jurang Buntung, 92 -----	Bojonegoro District 1 117 601	6.8	54.2	0.2	33.7	5.1
5	Pacal (Tributary)	75.2 358	Mt. Pandan, 897 -----	Bojonegoro District 1 117 601	5.6	49.9	1.9	27.8	14.8

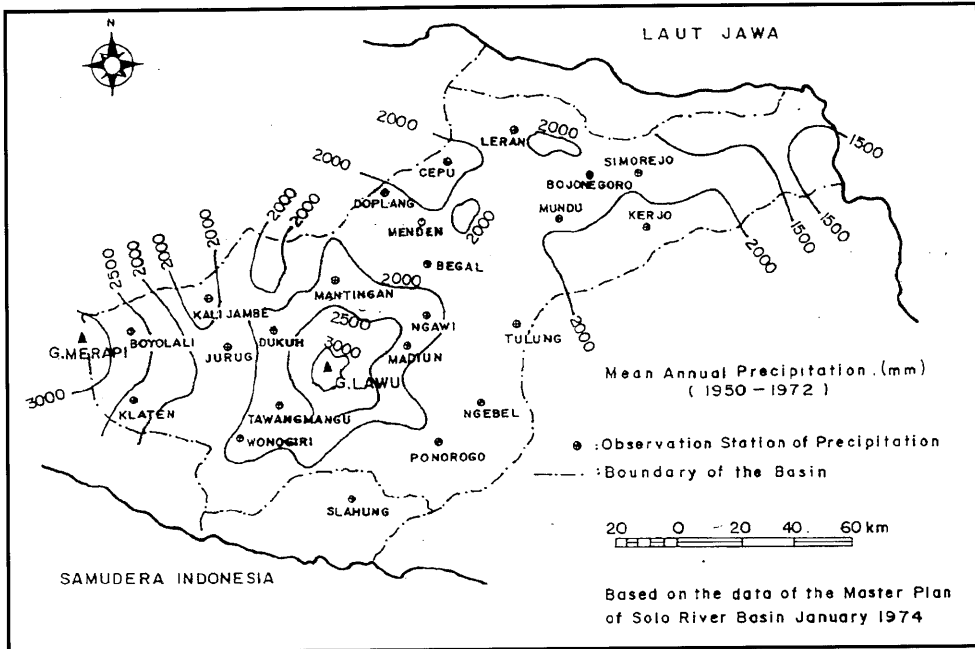
A: Other agricultural field F: Forest L: Lake, River, Marsh P: Paddy field S: Settlements

### 2.4 Longitudinal Profiles



### 3. Climatological Information

#### 3.1 Annual Isohyetal Map and Observation Stations



#### 3.2 List of Meteorological Observation Stations

No.	Station	Elevation [m]	Location	Observation period	Mean annual precipitation [mm]	Mean annual evaporation [mm]	Observation items <sup>1)</sup>
	Panasan	104	S 07° 33' E 110° 45'	1973~1983	-	855	E, RH, T, WV
125	Pabelan	100	S 07° 34' E 110° 45'	1983~1993	2 221	1 626	E, P, RH, T, WV
	Jiwan	110	S 07° 37' E 111° 29'	1983~1993	1 837	1 423	E, P, RH, T, WV
37	Iswahyudi	110	S 07° 37' E 111° 31'	1976~1979	-	1 862	E, RH, T, WV
28	Padangan	25	S 07° 10' E 111° 37'	1977~1982 1952~1991	- 1 717	2 117 -	E, P, RH, T, WV
	Kejuron	42	S 07° 05' E 111° 44'	1955~1991	1 770	-	P, RH, T, WV
30	Bojonegoro	20	S 07° 11' E 111° 53'	1952~1991	1 628	1 416	E, P, RH, T, WV

1) E: Evaporation P: Precipitation RH: Relative humidity T: Temperature WV: Wind velocity

### 3.3 Monthly Climate Data

Station: Bojonegoro

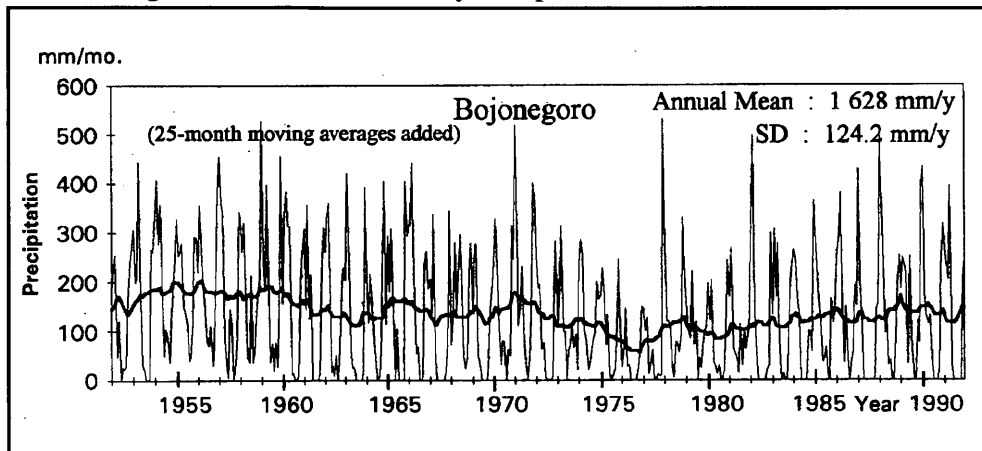
Observation item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Period for the mean
Temperature [°C]	27.3	27.8	28.1	28.1	27.8	27.2	26.8	27.0	27.5	27.8	28.4	28.1	27.7	1977~1991
Precipitation [mm]	263	247	233	151	86	47	42	21	22	70	183	256	1 628	1952~1991
Evaporation* [mm]	81.1	78.5	99.5	101.7	117.1	118.8	124.6	142.9	156.8	164.6	127.5	103.0	1 180	1979~1991
Solar radiation** [MJ/m <sup>2</sup> /d]	5.1	5.4	5.9	5.5	5.8	5.7	5.9	6.3	6.7	7.1	6.3	5.6	5.93	1981~1987
Duration of sunshine*** [hr]	223	209	198	328	380	456	670	539	540	242	351	251	4387	1973~1983

\* Average using Class A Pan

\*\* At Iswahyudi

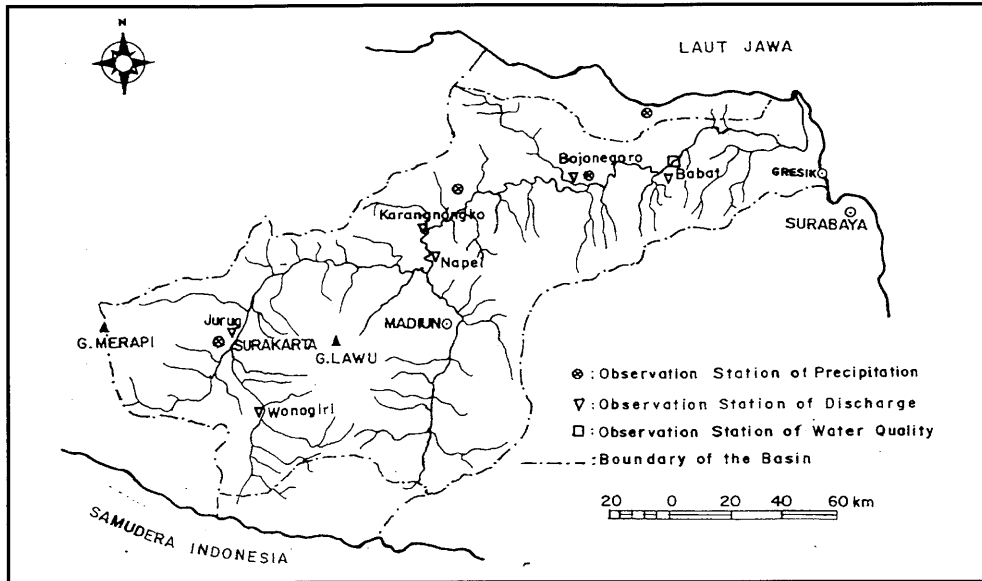
\*\*\* At Panasan

### 3.4 Long-term Variation of Monthly Precipitation



## 4. Hydrological Information

### 4.1 Map of Streamflow Observation Stations



### 4.2 List of Hydrological Observation Stations

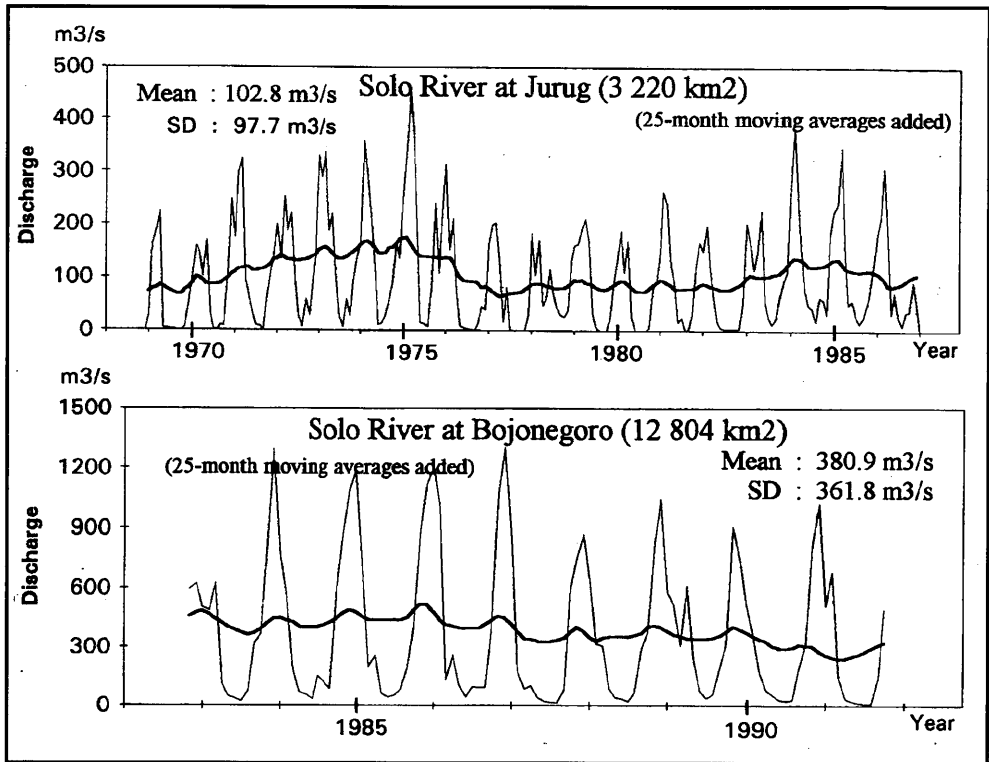
No.	Station	Location	Catchment area (A) [km <sup>2</sup> ]	Observation period	Observation items <sup>1)</sup> (frequency)
1	Jurug	S 07° 33' 08" E 111° 19' 54"	3 220	1969~1992	Q(d)
2	Napel	S 07° 30' 43" E 107° 36' 00"	9 880	1983~1991	Q(d)
3	Karangnongko	S 07° 15' 50" E 111° 29' 42"	10 078	1983~1991	Q(d)
4	Bojonegoro	S 07° 08' 24" E 111° 52' 36"	12 804	1983~1991	Q(d)
5	Babat	S 07° 07' 12" E 112° 09' 36"	14 247	1982~1991	Q(d)

No.	$\bar{Q}$ <sup>2)</sup> [m <sup>3</sup> /s]	Q max <sup>3)</sup> [m <sup>3</sup> /s]	$\bar{Q}$ max <sup>4)</sup> [m <sup>3</sup> /s]	$\bar{Q}$ min <sup>5)</sup> [m <sup>3</sup> /s]	$\bar{Q} / A$ [m <sup>3</sup> /s/100km <sup>2</sup> ]	Q max / A [m <sup>3</sup> /s/100km <sup>2</sup> ]	Period of statistics
1	110.0	1 152	762	10.8	3.42	35	1969~1992
2	273.8	2 010	1 809	14.1	2.77	20	1983~1991
3	212.0	1 587	1 421	12.6	2.10	16	1983~1991
4	362.9	2 127	1 879	19.0	2.83	17	1983~1991
5	404.3	2 207	1 731	26.2	2.84	15.9	1982~1991

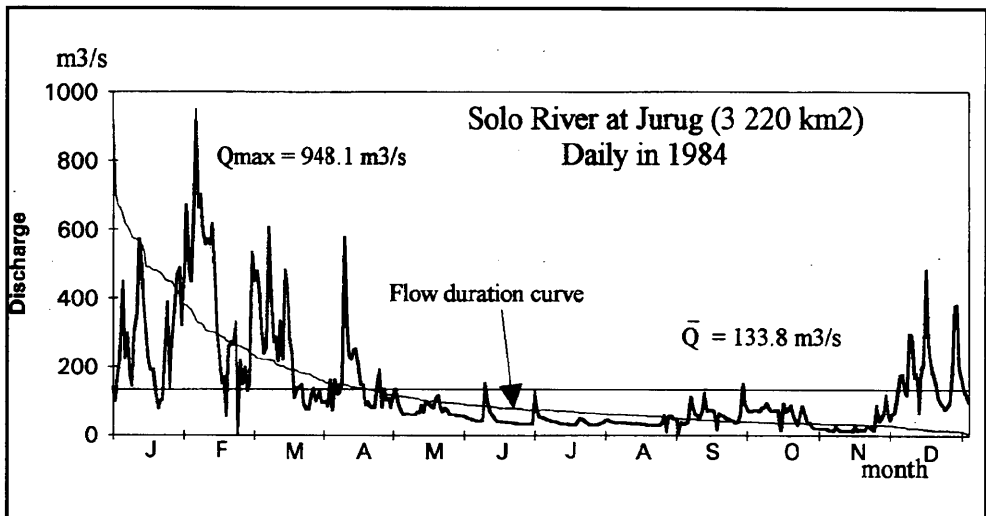
1): d: Daily  
Q: Discharge

2) Mean annual discharge  
3) Maximum discharge  
4) Mean maximum discharge  
5) Mean minimum discharge

4.3 Long-term Variation of Monthly Discharge

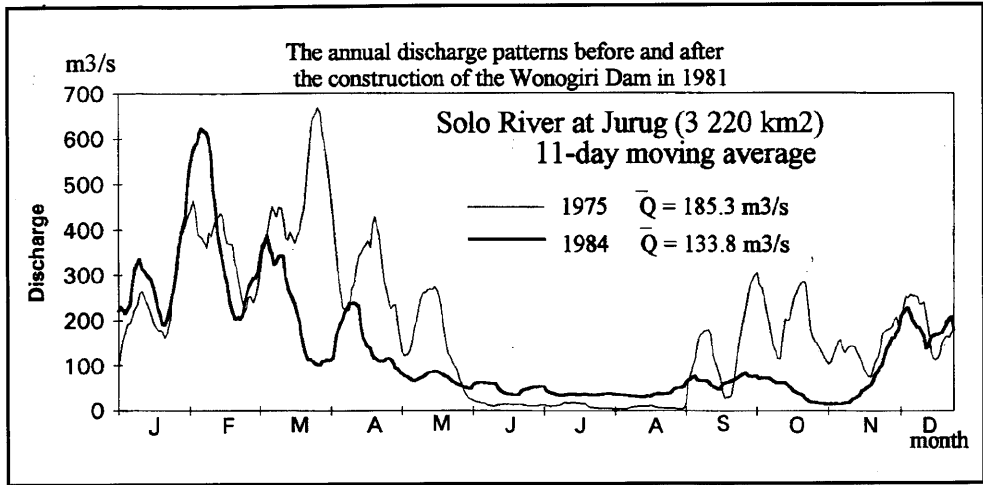


4.4 Annual Pattern of Discharge





4.5 Unique Hydrological Features



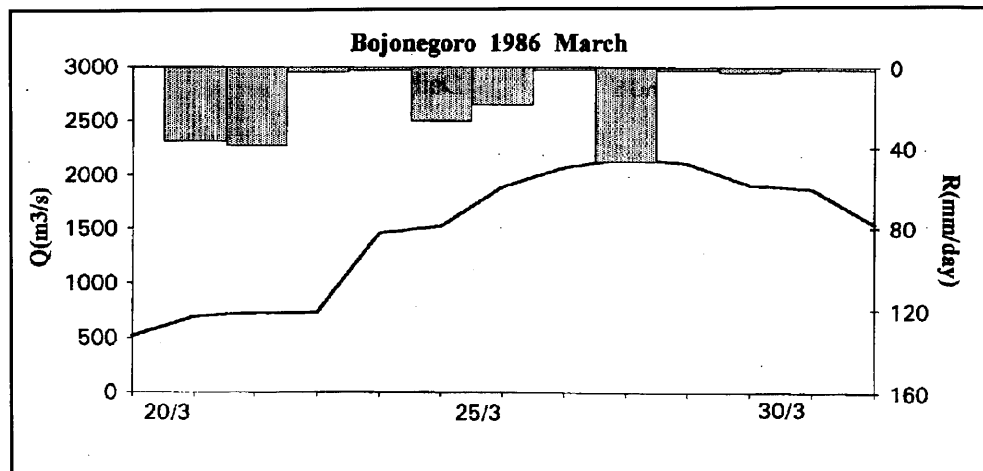
4.6 Annual Maximum and Minimum Discharges

At Bojonegoro [12 804 km<sup>2</sup>]

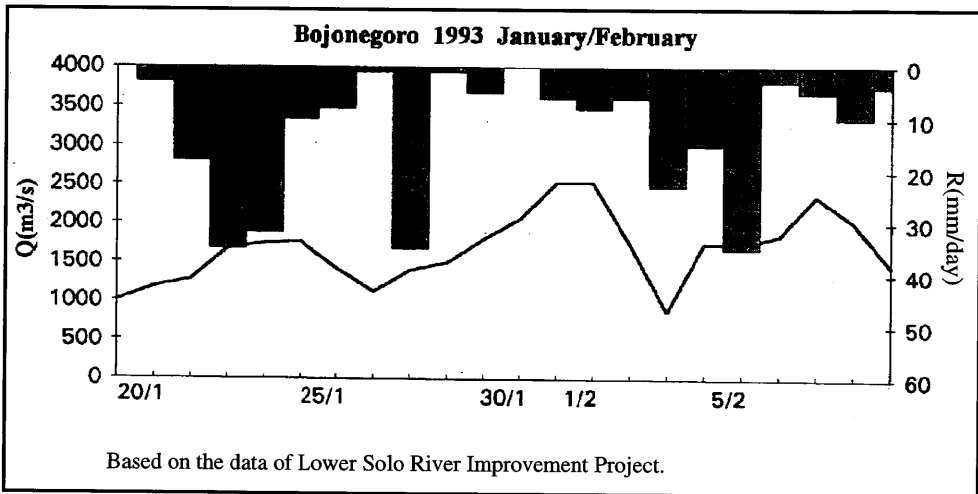
Year	Maximum <sup>1)</sup>		Minimum <sup>2)</sup>		Year	Maximum <sup>1)</sup>		Minimum <sup>2)</sup>	
	Date	[m <sup>3</sup> /s]	Month	[m <sup>3</sup> /s]		Date	[m <sup>3</sup> /s]	Month	[m <sup>3</sup> /s]
1983	12.26	1 359	9	20.3	1988	1.29	1 988	10	14.8
1984	2.13	1 764	8	22.0	1989	2.16	1 890	9	27.2
1985	3.06	1 962	10	26.9	1990	2.02	1 844	9	14.8
1986	3.27	2 127	8	28.2	1991	2.17	1 926	9	7.6
1987	2.19	2 055	11	7.9					

1), 2) Instantaneous observation by recording chart

4.7 Hyetographs and Hydrographs of Major Floods



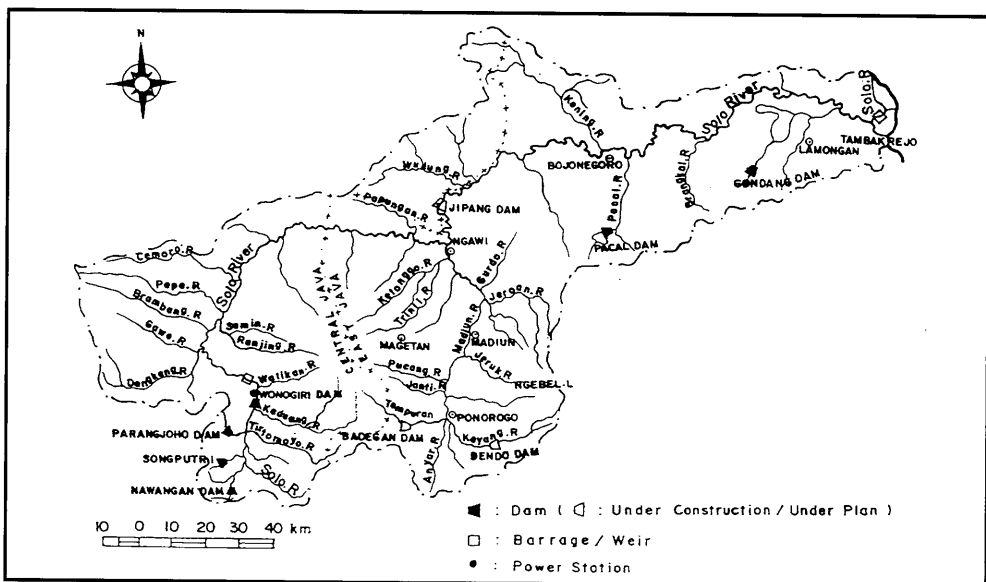




**5. Water Resources**  
**5.1 General Description**

The Bengawan Solo has about 16 100 km<sup>2</sup> catchment area or about 12.31% of the extent of Java Island (130 777 km<sup>2</sup>). The river flows through the provinces of central and eastern Java. The lower reach which is on the northern side and along the coast of Java sea is a plain area. There are seven dams built across the river with various storage capacities. The largest one is the Wonogiri Multipurpose Dam completed in 1981 with a storage capacity of 730 x 10<sup>6</sup> m<sup>3</sup>. Other dams are just for irrigation. Some dams have been constructed before the second world war. In the wet season, floods with discharges in excess of 2 000 m<sup>3</sup>/s are frequent in this area. The mild slope of the river bed, its narrow cross section, meandering, and generally low river bank levels have caused the maximum flooding area to reach 152 000 ha or about 10% of the catchment area.

**5.2 Map of Water Resources Systems**



### 5.3 List of Major Water Resources Facilities

#### Major Reservoirs

Name of river	Name of dam	Catchment area [km <sup>2</sup> ]	Gross capacity [10 <sup>6</sup> m <sup>3</sup> ]	Effective capacity [10 <sup>6</sup> m <sup>3</sup> ]	Purpose <sup>1)</sup>	Year of completion
Solo	Wonogiri	1 350	730	440	A,F,N,P	1981
Tempuran	Parangjoho	21.75	1.30	1.19	A	1983
Kedung Wanglu	Nawangan	2.67	0.80	0.77	A	1978
Melati	Song Putri	2.95	0.80	0.66	A	1984
Gondang	Gondang	68.1	25.9	23.0	A	1986
Pacal	Pacal	89.0	48.0	-	A	1933
Prijetan	Prijetan	23.2	22.0	-	A	1930

#### Floodways

Name of transfer line	Names of rivers and places connected		Length [km]	Maximum capacity [m <sup>3</sup> /s]	Purpose <sup>1)</sup>	Year of completion
	From	To				
Pelangwot	Solo River	Java Sea	12.5	500	F	*

#### Retarding Basins

Name of river	Name of retarding basin	Area [km <sup>2</sup> ]	Volume [10 <sup>6</sup> m <sup>3</sup> ]	Purposes <sup>1)</sup>
Solo	Jabung	70	147	A, F
-	Jero	200	-	A

\* Under construction

1) A: Agricultural use F: Flood control N: Maintenance of normal flows P: Hydropower

### 5.4 Major Floods and Droughts

#### Major Floods at Ngawi [6 072 km<sup>2</sup>]

Date	Peak discharge [m <sup>3</sup> /s]	Rainfall [mm] Duration	Meteorological cause	Dead and missing	Major damages (Districts affected)
1966	2 200	317 -----	Long duration rainfall	158	Surakarta, Wonogiri, Sragen
1968	850	120 -----	Long duration rainfall	*	Surakarta, Wonogiri, Sragen
1975	900	98 -----	Long duration rainfall	-	Surakarta, Wonogiri, Sragen

Major Floods at Bojonegoro [12 804 km<sup>2</sup>]

Date	Peak discharge [m <sup>3</sup> /s]	Rainfall [mm] Duration	Meteorological cause	Dead and missing	Major damages (Districts affected)
1966	2 200	127 3.14~3.15	Long duration rainfall	10	Bojonegoro, Babat, Lamongan
1968	2 065	77 3.26~3.28	Long duration rainfall	16	Bojonegoro, Babat, Lamongan
1975	2 300	137 3.21~3.23	Long duration rainfall	-	Bojonegoro, Babat, Lamongan
1992	953	103 3.16~3.18	Long duration rainfall	-	Bojonegoro, Babat, Tuban, Lamongan
1993	2 537	130 1.30~2.01	Long duration rainfall	5	Bojonegoro, Babat, Tuban, Lamongan
1994	2 496	133 3.24~3.25	Long duration rainfall	20	Bojonegoro, Babat, Tuban, Lamongan

\* No data

## 5.5 Groundwater and Water Quality

River Water Quality at Jurug<sup>1)</sup> in 1991

Date	Feb 28	Mar 17	May 12	Jul 1	Aug 20	Oct 25
pH	7.7	7.7	7.9	6.1	8.3	7.2
DO [mg/l]	-	-	5.7	6.0	0.0	1.1
COD [mg/l]	16	37	26	31	18	33
SS [mg/l]	1 822	666	92	-	-	54
F.Coli x 10 <sup>5</sup> *)	0.9	1.1	18	0.2	0.5	11
Discharge [m <sup>3</sup> /sec] **)	362.7	98.1	25.4	12.4	8.1	16.5

1) Located at Jurug

\*) Membrane filter method, colonies/100 ml

\*\*) Discharge on the water quality observation date

## 5.6 Other Notable Water Resources Features

## Water Uses at Major Reservoirs

Name of dam	Hydropower capacity [MW]	Agricultural use [km <sup>2</sup> ]	Industrial use [10 <sup>6</sup> m <sup>3</sup> ]	Fisheries use [10 <sup>6</sup> m <sup>3</sup> ]	Municipal water supply [10 <sup>6</sup> m <sup>3</sup> ]
Wonogiri	12.4	232	-	560	-
Parangjoho	-	7.5	-	-	-
Nawangan	-	3.45	-	-	-
Song Putri	-	5	-	-	-
Gondang	-	60	-	-	-
Pacal	-	175	-	-	-
Prijetan	-	46.03	-	-	-

## 6. Socio-cultural Characteristics

The Upper Bengawan Solo catchment area covers Ponorogo and Surakarta regions. Ponorogo is very famous for its "Reog Ponorogo" as a specific traditional art which is a combination of dancing and art. Many visitors - both domestic and foreign - come intentionally to see this performance. Surakarta has been well known since the 17th century as a large kingdom. The King's palace is more familiarly called "Kraton". The heirlooms and the kraton architecture have been well maintained and have attracted the research interests of tourists and the historians. The river's name Bengawan Solo is also immortalized in a song by Mr. Gesang, the composer and the singer. Some fossils of the olden humans have been found at several locations in the middle part of the Bengawan Solo catchment area including that of *Pithecanthropus Erectus* which is estimated about 2 million years old. It was found in 1936 at Sangiran village and the *Homo Soloensis* was found in 1934 at the Bengawan Solo valley in Trinil.

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