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Hydrometeorological monitoring network of Java Island and hydrologic characteristics of the major river basins

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Abstract Java Island had been known as the most populated island in the world. The population had been doubled in the last four decades to about 128 million people with average population density of about 1, 000 people per sq. km. This high population density accompanied with rapid physical developments in the past decades have created extensive land and forest destructions and causing intensified man-induced natural disasters, such as floods, droughts, forest fires and landslides. The availability of integrated hydrological and meteorological data for the whole territory of Java Island is an opportunity through which research can take advantage in many fields, including development of water management and disaster monitoring. For this reason, we reviewed the hydrometeorological monitoring network of Java Island and the characteristics of the major river basins in this paper.

Key words hydrology, monitoring, characteristic, Java Island

INTRODUCTION

Java Island could be divided into 14 major watersheds i.e. Ciujung-Ciliman, Ciliwung-Cisadane, Cisadea-Cikuningan, Citarum, Cimanuk, Ciwulan, Citanduy, Pemali Comal, Serayu, Jratun Seluna, Progo-Opak-Oyo, Bengawan Solo, K. Brantas, and Pekalen Sampean. Those watersheds are really essential to fill up the requirement for agriculture, industries, electricity power, and domestics of Java citizens. Unfortunately, the water yield of those watersheds decreased in recent years because of climate change impact and population pressure (Amien and Runtunuwu, 2008).

Climate change has already caused the change in rainfall pattern resulting in the shift of the onset of the seasons. The dry season will become longer causing water deficit and possibly drought that reduce planted areas and crop yield. On the other hand the rainy season will become shorter with higher intensity inducing landslide and flood (Meiviana et al., 2004). Dutta and Herath (2004) reported that Indonesia is the third most frequently affected by floods in Asia. Based on data from CRED (2007) in period of 1980-2007, about 34% of all natural disasters is flood that occurred almost in all provinces of Indonesia with direct economic losses about US $ 1.638.050. The worst flood occurred in 2007, when 454.8 km2 of Jakarta were flooded and 590.000 people were evacuated (National Planning Board, 2007). In this last two years alone landslides on island of Java has taken hundreds of life and loss US $ 109.745 of property worth. The major change also was caused by human activities with land cover and land use conversions from vegetated area into non vegetated area, as reported by Isa (2006) that paddy field area in Java Island decreased 50,100 ha per year.

To improve the role of watershed as main water supplier for irrigation, industries, and domestics' requirement, the water resources database system of each watershed with their circumstances are imperative. Based on this system, the water sharing management of each watershed could rearrange in order to minimize the water insecirity impacts.

HYDROMETEOROLOGICAL MONITORING NETWORK OF JAVA ISLAND

Figure 1 shows the present network of hydrometeorological stations of Java Island which managed by IAHRI (Runtunuwu and Las, 2007). There are 74 automatic weather station (AWS) and 23 automatic water level recorder (AWLR) in seven provinces i.e. Lampung, West Java, Centre of Java, DI Yogyakarta, East Nusa Tenggara, East Kalimantan and South-east Sulawesi. In addition, IAHRI has collaboration with other institutions such as BMG, and Ministry of Public Works to collect the meteorological data, as shown in Table 1. It is available upon request to Numeric and Spatial Information System for Agroclimate and Hydrology Laboratory (NSISAH), IAHRI. The data from those stations is at present used in hydrometeorological studies, such as climate forecasting and water yield prediction.

Fig. 1 The location of hydrometeorological stations of Java Island managed by IAHRI.

The main problem in collecting data from other institutions was the variability of kind of data. Each institution designed their observed instrument based on their purposes and budget; therefore, the data were dissimilar in variable, unity, observed period, and structure form. These problems were handled by standardising the climate and hydrology variables as well their unity before put into database system. The availability of the latest data is essential; therefore, online networking for collecting data from other institutions to database system has to develop.

IAHRI develops the water resources information system based on three important aspects; Firstly, one watershed with one database system for one management, in order to accommodate the specific characteristics of each watershed. Secondly, by integrating both tabular and spatial data in one database system due to the variability of input data type; and finally was user friendly.

An example of water resources information system which developed by IAHRI

Table 1 The number of hydrometeorological stations of Java Island recorded by IAHRI.

No	Province	Number of stations
1	DKI Jakarta	4
2	West Java	408
3	Central of Java	636
4	East Java	406
5	D.I. Yogyakarta	77
Total		1 531

was Citarum Water Resources Information System (Kartiwa, et al. 2005) in collaborating with Perum Jasa Tirta II (PJT II). The project was started with characterized the whole input data, such as tabular, vector and image data. The types of those data were awfully varied in observed period and size scale; therefore, reorganizing the data in one database system was imperative. In general, tabular data were watershed characteristics, climate/rainfall, and discharge data that could put into database system by using worksheet form. The spatial data such as administrative boundary, watershed/sub watershed boundary, contour, river, road, and irrigation network that put into the system by digitations technique. The other spatial data was image data such as land cover type distribution that obtained from image satellite processing.

The next step was hydrology modelling development by using programming technology. They were several discharge prediction models could be used, however in Citarum watershed purpose the H2U and GR4J models has been selected. The Hydrogramme Unitaire Universel (H2U) model predicted instantaneous discharges of watershed (Duchesne et al., 1997) with automatic rainfall station while GR4J model (Perrin, 2000) predicted daily discharge of watershed with manual rainfall station only. By running the discharge prediction model, the yield water of Citarum watershed could be calculated. This information was very important for PJT II in order to determine the amount of water supply for irrigated paddy field, industries, and domestics.

Opening Menu of Citarum Water Resources Information System consists of Main Menu, Daily Simulated Discharge, Instantaneous Simulated Discharge, and Observed Data Presentation, Figure 2. Observed presentation menu consists of two windows choice i.e. watershed and reservoir information. Watershed information presented discharge data visualization at outlet, rainfall data, and discharge data debit at weir and climate data. Map based on GIS presented on main menu is interactive, showed position of observed discharge station, rainfall, climate and dam; reservoir; administrative boundary; watershed/sub watershed boundary; contour, river, road, irrigation network, and information of land use change, as shown in Figure 3.

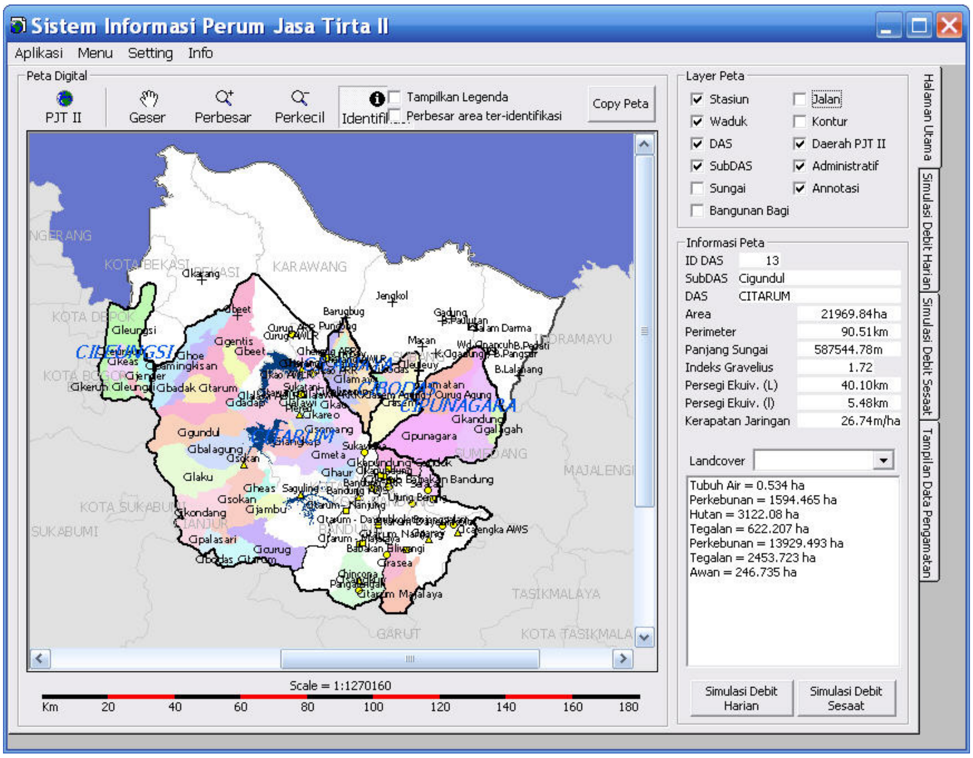

Fig. 2 The opening menu of the Citarum Water Resources Information System.

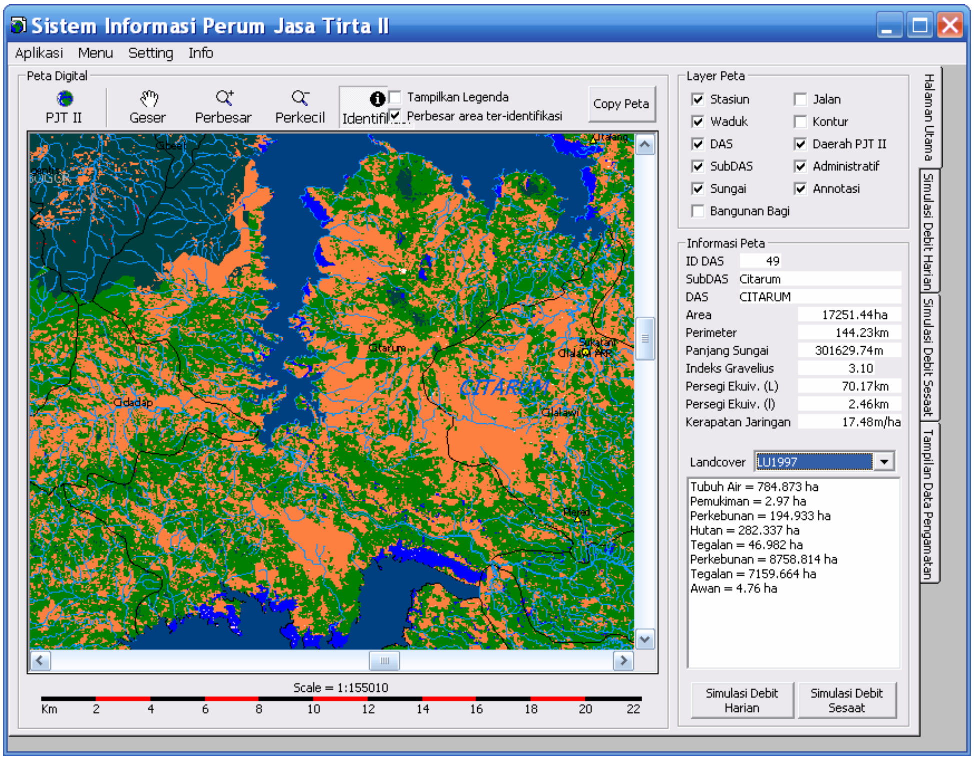

Fig. 3 Kinds of spatial data.

(a)

(b)

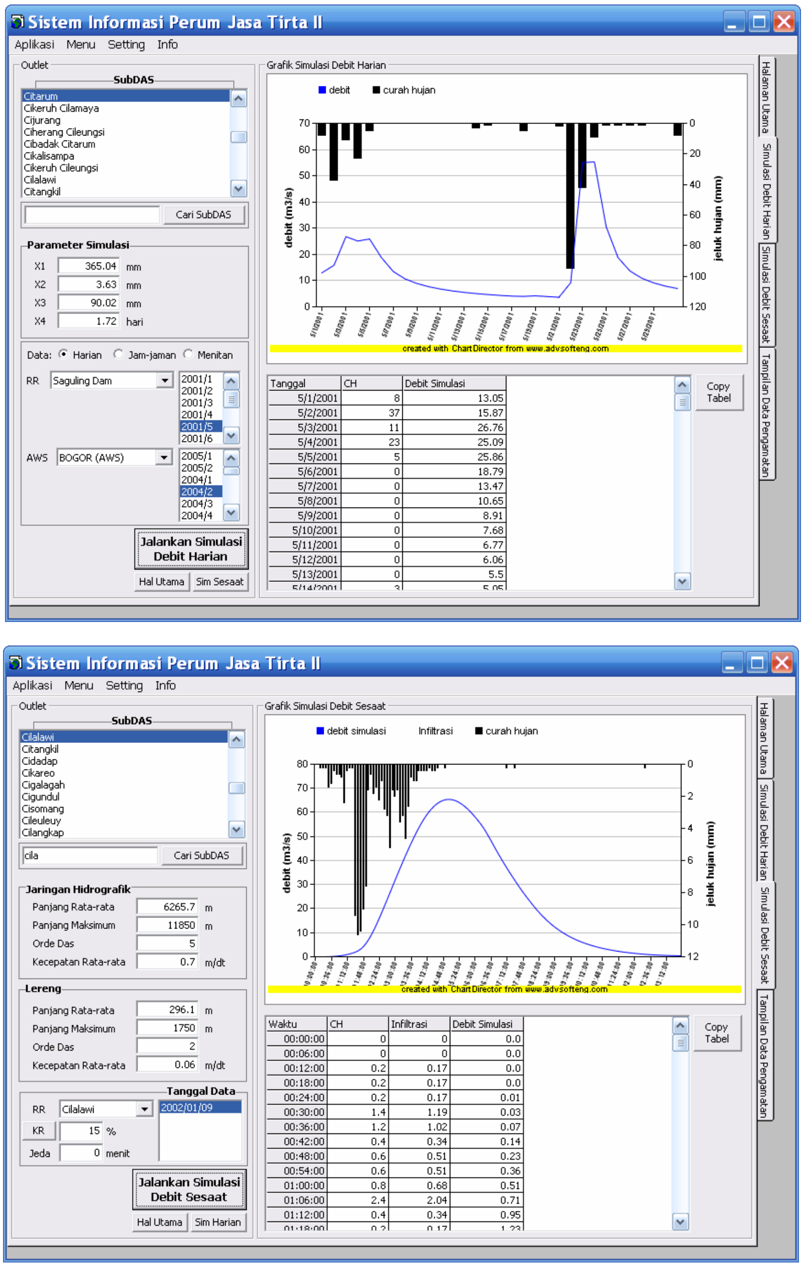

Fig. 4 The capture of (a) the daily discharge and (b) instantaneous discharge by using prediction model that integrated to database system.

Daily simulated discharge menu is developed based on GR4J model application. This menu facilitates the discharge simulation for a watershed/sub watershed based on rainfall and evapotranspiration data as well the parameter model that recorded in database system. The minimum requirement data were watershed information, area, production function method (runoff coeficient or infiltration index/ Φ index) with tranfer function parameter which consists of hydrolic length, velocity of flow, number of order of each drainage network and hillslope. Nash dan Sutcliffe (1970) in Estiningtyas et al. (2005) noted that the correlation coeficient between observed and simulation result using this model was around 0.80.

Instantaneous simulated discharge menu is developed based on the modified H2U model (Kartiwa et al. 2005). The original version of the H2U model ignored the hillslope component. This assumption does not give any problem on a grand watershed application because mean hydraulic length in the hillslope is very short than mean hydraulic length in the channel network so the hillslope effect is not significant. In the modified H2U model, we proposed the modeling of the basin pdf of the travel time through the convolution between the pdf channel network and the pdf hillslope. The model was determined by topographical and drainage network map analysis as well as the calculation module available in instantaneous simulated discharge menu. The requirement data to calcultae the debit were maximum capacity of the production store, water exchange coefficient, maximum capacity of the routing store, and time base of unit hydrograf. Estiningtyas et al. (2005) noted that the correlation coeficient between observed and simulation result using this model was around 0.73.

Recently, PJT II needs information about the water availability in the future, therefore, water status estimation is imperative. Analog with the rainfall we could calculate the water level of the dam for one month, three or six months later. In this case, the water high level bacame as resultant of water balance of the dam, there were rainfall and inlet discharge estimated using H2U or GR4J models as the input and outlet discharge, evaporation, infiltration, and seepage as the output.

In order to disseminate this product to the end user, the user interface has been developed based on LAN and WEB technologies. The LAN interface was developed for internal purposes. The staf could access the whole data as well update the data by using entry data facilities. The WEB interface WEB could accessed by outsider who wants obtain water resources information from PJT II.

CHARACTEISTICS OF THE JAVA MAJOR RIVER BASINS

The hydrology of Java major rivers can be recognized from the seasonal river discharge data that strongly influenced by the biophysical characteristics of the river basins. Seven major river basins representing 35% of the area of Java island were selected that spread from west to east, so that can be considered as representative of the island hydrologic condition. Portions of the developed parts of the basins, as indicated by agricultural, paddy fields and urban areas, already dominated the island with more than 50% as indicated on Table 2.

It is interesting to note that paddy field areas for Citarum and Cimanuk already passed over 30% of basin area, while the others are already between 20 to 24%, while it is understood that 20% is considered as a threshold of carrying capacity for paddy sawah. Therefore, it is understandable that the hydrologic conditions of Java Island have been in critical state for some time now. Another point to make is the proportion of urban areas, especially for Bengawan Solo basin that already passed 30%, while for forest covers all basins consistently have less than 30% as mandated in the Forestry Law (1999) as well as of National Spatial Plan Law (2007). Natural forest cover has been decreasing in the last century from 90% in late 1800s, to only about 4% in 2005 (Baplan-Dephut RI, 2007), and with plantation forest (including private forest) at about 18%, another critical situation.

Table 2 Biophysical and land use characteristics of river basins.

No.	Names of Rivers	Length [km] Catchment area [km^2]	Highest peak [m] Lowest point [m]	Cities Population (1995, 2000)	Land Use [%] (1977, 2000)
1	Ciujung*	147.5 1934.7	Mt.Halimun 1764 ---	Serang --	A(20); F(40); L(1.0); P(20); U(10); O(9.0)
2	Cisadane	137.6 1 266.6	Mt. Pangrango 3 002 River mouth, 0	Bogor 4 018 000 (2000) Tangerang 1 502 000 (2000)	A(48.52); F(16.34); L(1.15); P(22.77); U(11.22)
3	Citarum	269 6 080	Mt.Wayang 1 700 ---	Bandung 2 513 000	A(18); F(20); L(2.5); P(30); U(29.5)
4	Cimanuk River (Main River)	230 3 600	Mt. Ciremai, 3 078 River mouth, 0	Cirebon 256 134 Indramayu 89 182 Garut 104 319	A (29.76); F (22.76); P(35.99); L (0.01); U (6.55); O(4.93)
5	Citanduy	170 4 460	Mt.Cakrabuana 1 750 0	Tasikmalaya 187 609 Ciamis 145 406 Banjar 130 197	A(48.05); F(9.32); L(0.08); P(23.64); U(16.56); O(2.35)
6	Serayu (Main River)	158.4 3 383	Mt. Prahu 2 565 0	Purwekerto 209 005 Cilacap 212 119	F(17.00); P(24.62); A(35.64); U(22.74)
7	Bengawan Solo	600 16 100	Mt.Lawu 3 265 ---	Solo 525 371 Ngawi 829 726	A(25.3); F(19.5); L(0.9); P(21.9); U(32.4)

Source: Catalog of Rivers. A: Agricultural; F: Forest; L: Lake, river, marsh, P: Paddy field, U: Urban, O: Others, * different source.

Hydrologic characteristics of these major rivers, as presented on Table 3, show strong seasonal variations with ratios of maximum discharge to minimum discharge 20 to well over 100, and it is recognized that these ratios are increasing almost for all rivers in Java. The decreasing trends in flow patterns are characterized by increased maximum discharges and lowered minimum discharges. Therefore, indicate the deterioration of water storage capacity of the basins, naturally on the natural water bodies, as well as on reservoirs and dams.

Nugroho (2006) studied the characteristics of river flows in Java, considering the upstream, middle, and downstream sections, and concluded that significant changes had occurred dominated with decreasing trends in the downstream sections as given on Table 3. These flow patterns are also characterized by amplifying flow regimes, with increasing maximum discharges from intense rainfalls and lower low flows from prolonged droughts. The influenced of ENSO (El Nino Southern Oscillation) and Indian Ocean Dipole Mode were believed (Aldrian, 2006), though decreasing regional rainfall in Java island is very much attributed to the disappearing of Java forest cover

Tabel 3 Summary of trends of river flow patterns according to basin sections.

No.	River Name	Trends of Flow patterns		
		Upstream	Middle	Downstream
1	Ciujung	Very decreasing	decreasing	Decreasing
2	Cisadane	Moderately decreasing	Highly increasing	-
3	Citanduy	Moderately increasing	Increasing	Decreasing
4	Citarum	Normal	-	Decerately decreasing
5	Cimanuk	Very decreasing	Moderately decreasing	Normal
6	Serayu	Decreasing	Moderately decreasing	Decreasing
7	Bengawan Solo	Highly increasing	Moderately decreasing	Moderately decreasing

Source: Analyzed from avail. discharge data, 1973-2003.

in the last century.

Regional characteristics of Java water resources can be shown from values of specific discharge of the rivers, ranging from 15 m3/s/100km2 to 80 m3/s/100km2, but mostly under 30 m3/s/100km2 except for Serayu and Ciujung. It is believed that at present conditions, these specific discharges of Java's rivers are somewhat lower than those historical conditions, as summarized in the study of Nugroho (2006) and shown on Table 4.

CONCLUSION

Hydrometeorological monitoring network of Java Island and characteristics of the major river basins have been reviewed on this paper. There were many developments and improvements in this topics however there are still remaining tasks that we have to carry out such as: improving the distribution of ground based observation, applying the system to other watershed, improving the output of analysis and prediction, coordinating the different water authorities, contribution to JSPS activity is to develop database system for Ciliwung basin and other experimental basins, integrating analysis results to the database, and developing interface of the database to the hydrologic modeling parts for simulation possible changes.

Table 4 Hydrologic characteristics of Java major rivers.

No.	Station	Location	Catchment area (A) [km^2]	Observation period	Observation items[1)] [frequency]	$\bar{Q}$[2)] [m^3/s]	Qmax[3)] [m^3/s]	$\bar{Q}max$[4)] [m^3/s]	$\bar{Q}min$[5)] [m^3/s]	$\bar{Q}/A$ [$m^3/s/100km^2$]	Qmax/A [$m^3/s/100km^2$]	Period of statistics
1	Ciujung-Kragilan	S: 06°08'11.2" E: 106o18'01.0"	1 857	1969-2003	Q(d)	99.7	1200	700	20	5.11	60.0	1969-2003
2	Cisadane-Batubeulah	S 06° 29' 00" E 106° 41' 00"	819.60	1968 - 2000	Q (d)	134.7	438.4	305.6	19.95	4.48	14.59	1970~1997
3	Citarum-Tanjungpura	S: 06° 20' 00" E:107° 19' 00"	5 970	1969-1977	Q(d)	171	1250	851	15.74	2.86	20.9	1969-1977
4	Citanduy	S: 07° 24' 00" E:108° 42' 00"	2 515	1969-1984	Q(d)	204.0	987	710.6	16.27	8.11	39.24	1969-1984
5	Cimanuk-Rentang	S 06 ° 43' 00" E 108 ° 10' 00"	3 003	1970-1997	Q(d)	273.4	2 020	1 497	58.80	10.39	76.78	1971~1995
6	Serayu-Rawalo	S 07°30'34" E 109° 17' 14"	2 631	1971-1995	Q(d)	95.1	254	111.7	61.041	11.60	30.991	1970- 2001
7	B.Solo-Babat	S: 07° 07' 12" E:112° 09' 36"	14 247	1982-1991	Q(d)	404.3	2207	1731	26.2	2.84	15.9	1982-1991

Source: Catalog of Rivers

[1]Q: Discharge; [2)] Mean annual discharge; [3)] Maximum monthly discharge; [4)] Mean maximum monthly discharge; [5)] Mean minimum monthly discharge

d: daily (Source: Cat. Rivers)

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