Impact of Climate Change on Floods in Bengawan Solo and Brantas River Basins, Indonesia

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Abstract

It is believed that due to a warmer climate, with its increased climate variability, flood magnitude and frequency are likely to increase in most regions, and volumes of low flows are likely to decrease in other regions in the world. With higher temperatures, the water-holding capacity of the atmosphere and evaporation into the atmosphere increase, and this favors increased climate variability, with more intense precipitation and more droughts. While temperatures are expected to increase everywhere over land and during all seasons of the year, although by different increments, precipitation is expected to increase globally and especially in many river basins in Indonesia, but to decrease in many others. In late December 2007 and early January 2008, persistent heavy rains led to overflowing rivers, flooding and landslides throughout Indonesia, resulting in numerous fatalities and crop losses. The two largest river basins in Java Island i.e. Bengawan Solo and Brantas River basins, were the hardest hit on the basins from flooding and landslides. More than 100 people have been killed and hundreds of thousands have been affected in East and Central Java Provinces by the flooding and landslides, which began on December 25, 2007. Based on Multi-satellite Precipitation Analysis (MPA) produced at NASA's Goddard Space Flight Center for December 24, 2007 to January 2, 2008, the highest rainfall totals for the period were over 250 millimeters (about 10 inches). Although the highest amounts were over water, parts of Java received in excess of 6 to 8 inches. Deforestation in the region may have contributed to the devastating mudslides. This paper will discuss the impact of climate change on increasing flood magnitude and frequency, taking into account flood occurrences in the Bengawan Solo and Brantas River basins, Indonesia. The flood magnitude and frequency in the basins have increased significantly and become significant issue in the basins' water resources management. The recent flood occurred in the basins last year has caused economic disturbances in the region.

Climate Change

Climate change refers to a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to internal processes and/or external forcings. Some external influences, such as changes in solar radiation and volcanism, occur naturally and contribute to the total natural variability of the climate system. Other external changes, such as the change in composition of the atmosphere that began with the industrial revolution, are the result of human activities.

Global warming is the increase of the Earth's surface median temperature over time. Since the late 1950s, the global average surface temperature has increased by 0.6 degree Celsius. Projections by the Intergovernmental Panel on Climate Change (IPCC) show temperatures rising during this century by 1.4–5.8 degrees Celsius. For the next two decades, a warming of about 0.2 degree Celsius is projected for a range of emissions scenarios done in the Working Group I of the Fourth Assessment Report of IPCC. Even if the concentrations of greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1 degree Celsius per decade would be expected. The accelerating rise in temperature in recent years appears to have the world headed toward the upper end of the projected range of increase (IPCC, 2007).

Climate change is expected to have a major impact on water resources. According to a report of Working Group I of the IPCC, phenomenon and direction of trend on heavy precipitation events frequency (or proportion of total rainfall from heavy falls) increases over most areas is likely for likelihood that trend occurred in the late 20th century (typically post 1960), is more likely than not for likelihood of a human contribution to observed trend and is very likely for likelihood of future trends based on projections for 20th century using emission scenarios. In some regions increases in magnitude and frequency of extreme events are already being observed, and some experts are attributing this to a changing climate although there remain large uncertainties. Global increases in temperature will have profound effects on evaporation, which in turn affects atmospheric water storage and hence magnitudes, frequencies and intensities of rainfall events as well as the seasonal and geographical distribution of rainfall and its inter-annual variability. That condition will lead to the increase both floods and droughts' risks. But for floods, it do not only depend on precipitation intensity but also volume, timing, antecedent conditions of rivers and their drainage basins (e.g. existence of dikes, dams, or reservoirs). Human encroachment into flood plains and lack of flood response plans increase the damage potential. Frequent floods will cause damage to crops; soil erosion; inability to cultivate land due to water logging of soils; increased risk of deaths; disruption of settlement, commerce, transportation; loss of property etc.

Condition in Indonesia

According to Baumert et al (2005), by the year 2003, Indonesia had become the 16th largest greenhouse gas (GHG) emitter in the world, with 346.8 Mega tonnes (Mt) of CO_2/ year, contributing to 1.34% of world total emissions in the same year. In 2000, Indonesia emitted 504.6 Mt CO_2 of all the six Kyoto gases, placing Indonesia at the 15th rank among the world's GHG polluters. If the emissions from land use, land use change and forestry (LULUCF) sector are taken into account, Indonesia jumped straight among the big three polluters, by generating 3,067.7 Mt CO_2/year or about 6 times as high as its emissions from energy sector only.

The annual mean temperature in Indonesia has increased by around 0.3 degree Celsius since 1990. The 90s was the warmest decade and an increase of almost 1 degree Celsius above the 1961-1990 average in 1998 has made it the warmest year in the century. The rise of temperature has occurred in all seasons of the year (Climatic Research Unit, May 2006). Several figures below forecast the change of mean temperature in Indonesia from the period of 2000 to 2020 (Susandi, 2007). The figures show the mean temperature in different parts in Indonesia that will increase about 0.11 to 0.14 degree Celsius from 2000 to 2010 and 0.13 to 0.165 degree Celsius from 2010 to 2020.

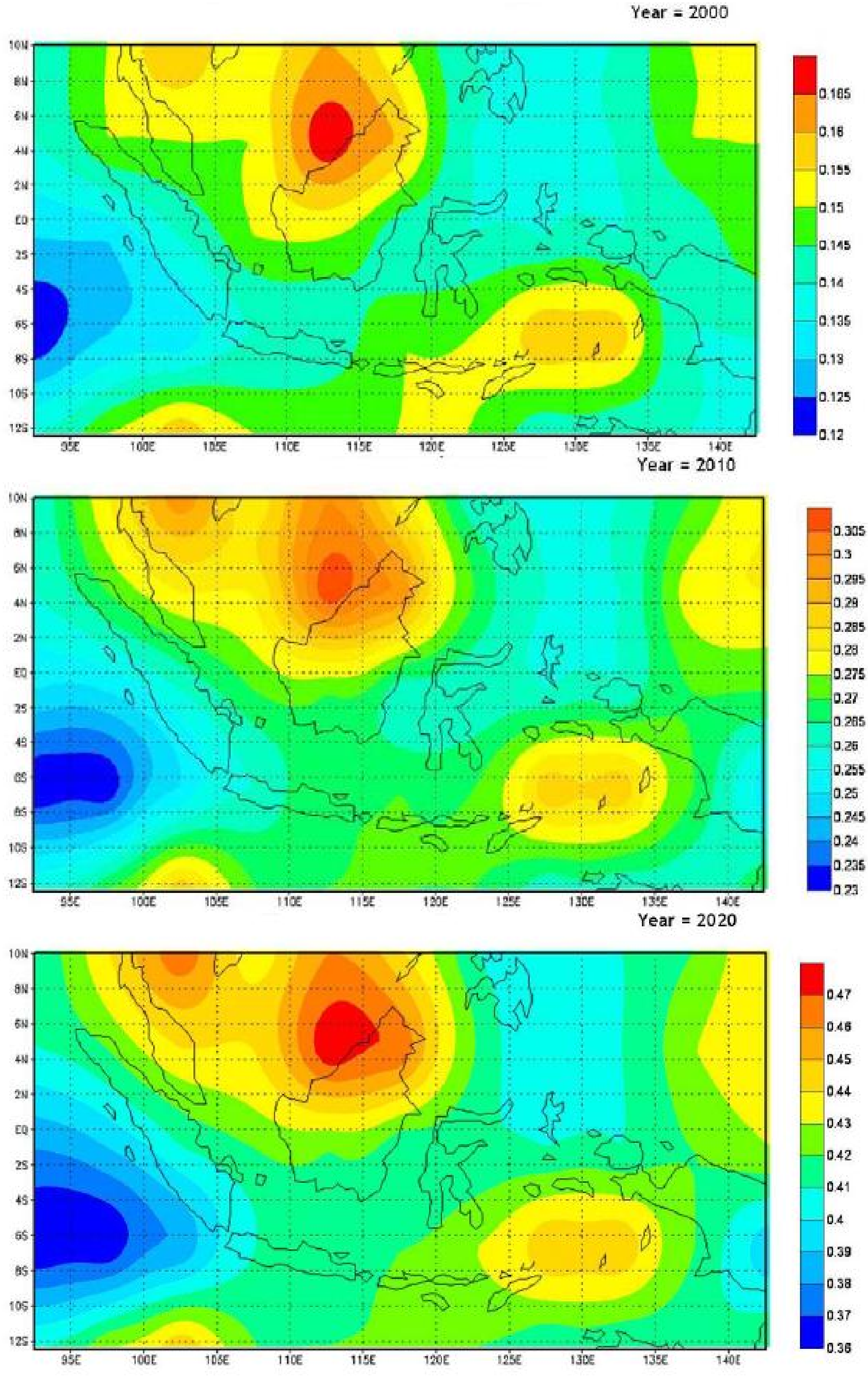
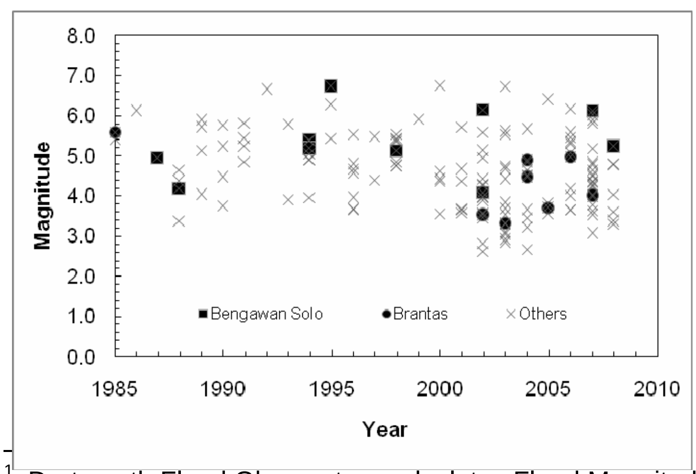


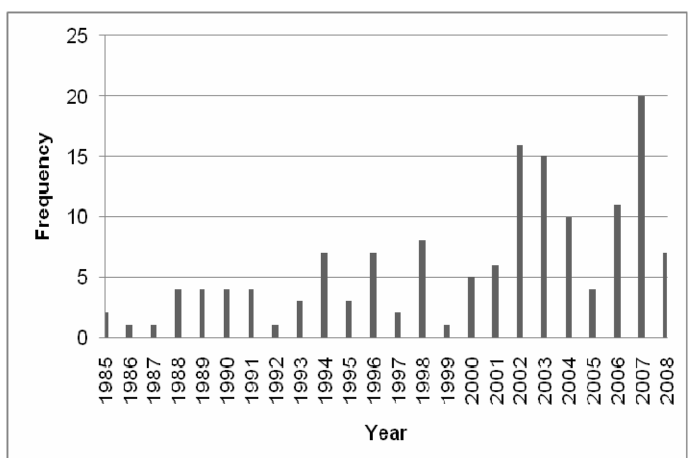
Figure 1 Prediction of Mean Temperature Change in Indonesia Year 2000 (above), 2010 (center) and 2020 (below) (Source: Susandi 2007)

According to Ratag (2001) in Susandi (2007), Indonesia is predicted to have 2 to 3% more rainfall each year. Syahbuddin, et.al (unknown) carried out a study that used rainfall data from 1950-1979 to simulate rainfall zone anomaly especially in the rainy season (October-March) and 2010-2039 period. Rainfall zone anomaly is the rainfall difference between rainy season (mm) in the initial period of 1950-1979 and the next period of 2010-2039. The quantity of rainfall is presented by monthly average of rainfall condition in both periods. The data were collected from Tanahbogo station, Central Lampung and Genteng, East Java. Between 2010 and 2039, the study predicted an increasing amount of rainfall, that is indicated by positive anomaly of rainfall zonation change, increase of the temperature and evaporation especially on the Malaka and Karimata Strait, Banda and Arafura Oceans. Change in quantity of rainfall, particularly rainfall of 100-150 mm/day are significant (59% and 100%) at Tamanbogo and Genteng stations from 1991 to 2000.

In Indonesia, there have been a number of extreme weather events in the past few years. These include heavy rain on southern part of Sulawesi Island causing at least 216 deaths in June 2006, rainfall and accompanying mudslide killing at least 207 people in north shore of Java Island in January 2006. Furthermore, the last extreme events in the beginning and end of 2007, the big flood in Jakarta and Bengawan Solo basin respectively, which were triggered by extreme rainfall are indicating more occurrences of extreme weather events in Indonesia. Being an archipelagic country, Indonesia is very vulnerable to the impacts of climate change. Prolonged droughts, increased frequency in extreme weather events, heavy rainfall leading to big floods, are only a few examples of what climate change has brought about.

Dartmouth Flood Observatory Global Archive of Large Flood Events records more than 140 flood events have occurred in Indonesia from 1985 to the beginning of 2008 caused by heavy rains, out of them, fifty flood events have magnitude (M)[1] of above 5. From the records, it can be identified that more than sixty flood events have occurred in Java Island, most of them occurred in the Bengawan Solo and Brantas River basins, both the two largest river system in the island. The frequency of flood events in Indonesia are likely to increase significantly in the last twenty years.





[1] Dartmouth Flood Observatory calculates Flood Magnitude = Log(duration x severity x affected area). Severity Class - Assessment is on 1-2 scale. The floods are divided into three classes. Class 1: large flood events: significant damage to structures or agriculture; fatalities; and/or 1-2 decades-long reported interval since the last similar event. Class 1.5: very large events: with a greater than 2 decades but less than 100 year estimated recurrence interval, and/or a local recurrence interval of at 1-2 decades and affecting a large geographic region (> 5,000 sq. km). Class 2: Extreme events: with an estimated recurrence interval greater than 100 years.

Figure 2 Magnitudes (left) and Frequency (right) of Flood Events in Indonesia From 1985 to the Beginning of 2008 (Source of data: Dartmouth Flood Observatory)

The Bengawan Solo and Brantas River Basins

The Bengawan Solo River basin is the largest river basin on the island of Java, between $110^0$18' and $112^0$45' East Longitude and $6^0$49' and $8^0$08' South Latitude. The basin belongs administratively to two provinces, Central Java and East Java. The majority of the Upper Solo River basin belongs to Central Java Province while the majority of the Madiun and Lower Solo River basins belongs to East Java Province. The basin covers 17 regencies: Boyolali, Klaten, Sukoharjo, Wonogiri, Karanganyar, Sragen, Blora, Rembang, Ponorogo, Madiun, Magetan, Ngawi, Bojonegoro, Tuban. Lamongan, Gresik, Pacitan; and 2 municipalities: Surakarta and Madiun.

The Bengawan Solo River basin drains a watershed area of around 19,778 km^2 in total, discharging into the Java Sea at Ujung Pangkah, Gresik, in the north of Surabaya City after travelling about 600 km from its spring in the Sewu Mountain Ranges. The Bengawan Solo River basin is geographically divided into an upstream basin (9,827 km^2) and downstream basin (6,273 km^2) with a boundary at the confluence of the Solo and Madiun Rivers near Ngawi, Girindulu and Lorog Rivers basin in Pacitan (1,517 km^2), Lamong River basin (720 km2) and small river basins in the north coastal area (1,441 km^2). Mt. Lawu (3,265 m), located in the center of the upstream basin, further divides the upstream basin into two sub-basins, namely the Upper Solo River basin of 6,072 km^2 in the west and the Madiun River basin of 3,755 km^2 in the east. The downstream basin is called the Lower Solo River basin with a river length of 300 km from Ngawi to its outfall.

The population in the Bengawan Solo River basin is estimated at 16.03 million in 2005. Population in the basin part of Central Java counts for 26.06% of Central Java population, while population in the basin part of East Java counts for 27.46% of East Java population.

The Brantas River basin, the second largest river basin on the island of Java, is located in the eastern part of the Java Island, Indonesia, between $110^0$30' and $112^0$55' East Longitude and $7^0$01' and $8^0$15' South Latitude. It covers catchment area of about 11,800 km^2 in total (covers 9 regencies: Trenggalek, Tulungagung, Blitar, Kediri, Malang, Sidoarjo, Mojokerto, Jombang, Nganjuk; 6 municipalities: Kediri, Blitar, Malang, Mojokerto, Surabaya, Batu) and its main stream, the Brantas River, runs about 320 km long. The geological formation of the Brantas River basin is characterized mostly by Pleistocene and Neogene Tertiary with numerous volcanic materials and partly with coral limestone. The plains and delta consist of alluvial soils (silt, clay loams) well suited to paddy cultivation. The basin contains two active volcanoes: Mt. Semeru (3,676 m) to the East, and Mt. Kelud (1,724) near the basin center. Volcanic ash is both a major source of soil fertility and a primary cause of reservoir sedimentation within the basin.

The Brantas River itself originates in Mt. Anjasmoro, located northwest of Malang City and takes its way around the alluvial cone of extinct volcanoes such as Mt. Kawi, Mt. Butak etc. Gathering together many tributaries above the delta include the Lesti (Southeast), Ngrowo (Southwest), Konto (Central) and Widas (Northwest) Rivers along its traveling. At the confluence with the Ngrowo River in the South-western portion of the basin, the Brantas turns north through the agriculturally productive plains region and finally east through the delta, also an important paddy growing area. Then, it finally bifurcates at Mojokerto City to Porong River and Surabaya River, both of which pour into the Madura Strait.

Population in the basin is quite dense, closing to 15.50 million people in the year 2003. This counts for 43% of East Java population. Population is concentrated in the lower basin, in the major metropolis of Surabaya and surrounding communities; and in the upstream communities of Malang, Kediri and Blitar. Industry is also concentrated in the downstream and delta regions.

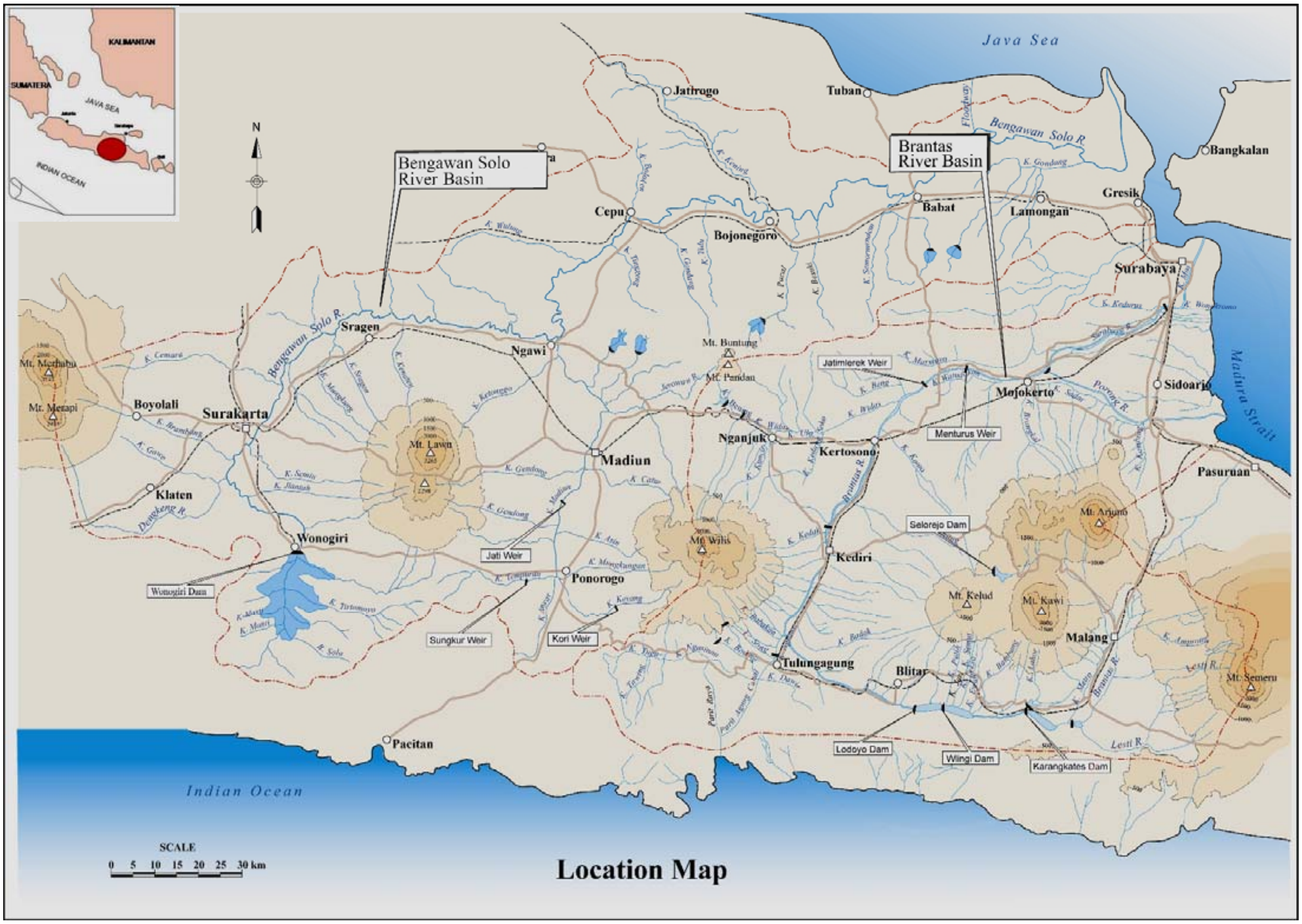


Figure 3 Map of Bengawan Solo and Brantas River Basins

Recent Big Flood in the Bengawan Solo and Brantas River Basins

In the late December 2007 until early January 2008, persistent heavy rains took place throughout Indonesia and led to flooding and landslides. The two largest river basins in Java Island i.e. Bengawan Solo and Brantas River basins, were the hardest hit on the basins from flooding and landslides. Figure 4 shows rainfall totals from the Tropical Rainfall Measuring Mission (TRMM) based[2], near-real-time, multi-satellite Precipitation Analysis (MPA) produced at NASA's Goddard Space Flight Center for December 24, 2007 to January 2, 2008. The highest rainfall totals for the period (shown in dark red) were over 250 millimeters (about 10 inches). Although the highest amounts were over water, parts of Java received in excess of 6 to 8 inches (orange and red areas).

[2] Tropical Rainfall Measuring Mission (TRMM) satellite was launched into service with the primary mission of measuring rainfall from space as a joint mission between NASA and the Japanese space agency, JAXA. It can also be used to calibrate rainfall estimates from other sources.

The rainfall during that period revealed anomalies, or deviations from the average rainfall observed during the same period from 1998 through 2007. As can be seen in Figure 5, regions that received more rain than average are blue and green. Average rainfall is white, and below-average rainfall is yellow, orange, and red. The rainfall pattern revealed by this image is typical of La Niña. A classic horseshoe pattern of above-average rainfall covers parts of the West Pacific, Indonesia and southern Southeast Asia, and northern Australia. A smaller horseshoe-shaped area of below-normal rainfall enfolds the region where ocean temperatures were cooler than average.

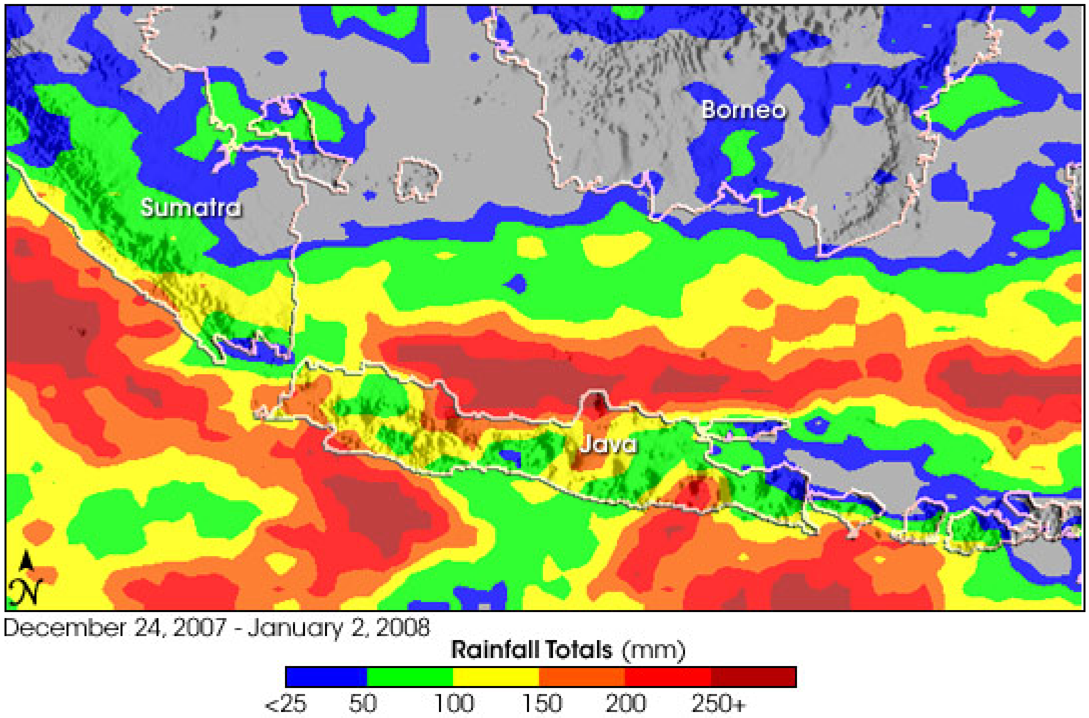


Figure 4 Rainfall Totals in Some Parts of Indonesia from the TRMM-based for December 24, 2007 to January 2, 2008 (Source: NASA's Goddard Space Flight Center)

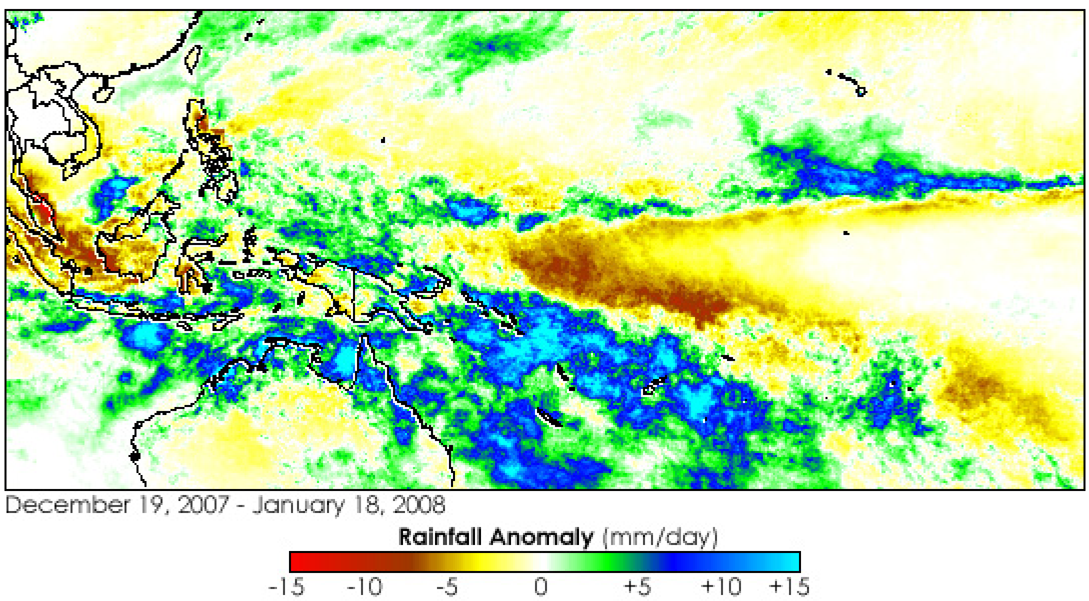


Figure 5 Rainfall Anomaly (mm/day) in the West Pacific, Indonesia, Parts of Southeast Asia, and Northern Australia from the TRMM-based for December 19, 2007 to January 18, 2008 (Source: NASA's Goddard Space Flight Center)

The flood in Bengawan Solo River basin at that time was mainly characterized by the reason that heavy rainfall with 136 mm/day on an average was taken place simultaneously and intensively in both the river basins of Madiun and Upper Solo rivers in December 25, 2007, although small rainfall was recorded in the Lower Solo River basin. Especially, 1-day rainfall in Madiun River basin on December 25, 2007 was quite big to be 141 mm/day on an average which is equivalent to more than 500-year probable rainfall intensity. In the other area, 1-day rainfall at Upper Solo River basin on December 25, 2007 was 124 mm/day on an average which is equivalent to 55-year probable rain fall intensity (Nippon Koei, 2008).

From the water level record, the flood run-off discharge scales were estimated at 40-year probability level against the existing flood protection level of 5-year probability for the Madiun River, 30-year probability scale against the existing protection level of 10-year probability for the Upper Solo River and 50-year probability against the existing protection level of 10-year for Bojonegoro City in the Lower Solo basin, respectively. Probability of Bengawan Solo River Basin mean rainfall and discharge during flood in the Late December 2007 until early January 2008 are summarized in Table 1 and 2.

Table 1 Probability of Bengawan Solo River Basin Mean Rainfall During Flood in the Late December 2007 Until Early January 2008

Duration	Item	Upper Solo Basin (6.072 km')	Madiun Basin (3,755 km^2)	Upper Solo & Madiun Basin (9 ,827 km^2)	Wonogiri Dam (1,350 km^2)
1 – Day	Amount	134 mm	141 mm	137 mm	128 mm
	Return Period	55 years	> 100 years	> 100 years	40 years
3 – Day	Amount	186 mm	178 mm	183 mm	158 mm
	Return Period	60 years	> 100 years	> 100 years	> 10 years
6 – Day	Amount	247 mm	201 mm	230 mm	207 mm
	Return Period	70 years	50 years	80 years	6 years

Source: Nippon Koei, Co. Ltd, Lower Solo River Improvement Project Phase II

Table 2 Probability of Bengawan Solo River Basin Mean Discharge During Flood in the Late December 2007 Until Early January 2008

Water Level Gauge	River	Date	Time	Gauge Reading (m)	Water Level (m. above sea level)	Discharge (m^3/sec)	Return Period (Years)	Design Discharge [m^3/sec]
Jurug	Upper Solo	Dec. 26, 2007	12:00	11.75	89.07	1,986	30	1,550 (10-year Flood)
A. Yani	Madiun	Dec. 26, 2007	06:00	9.60	63.30	1,421	40	1,460 (5-year Flood)
Bojonegoro	Lower Solo	Dec. 29, 2007	23:00	16.09	15.97	2,431	50	2,530 (10-year Flood)

Source: Nippon Koei, Co. Ltd, Lower Solo River Improvement Project Phase II

Flood in Bengawan Solo River basin in the late December 2007 was not only caused by persistent heavy rains, but also due to watershed degradation, lack of flood control structures, incompleted river improvement projects, lack of drainage system, and flood forecasting and warning systems are yet to be established in the basin. The primary flood control facility in the basin is the Wonogiri Multipurpose Dam located at about 55 km upstream of Surakarta. The dam was completed in 1982 and controls flood runoff from the uppermost 1,350 km^2 of the basin. The reservoir provides 232 million m^3 of flood control capacity regulating the peak discharge of 4,000 m^3/s to 400 m^3/s.

At the same period, heavy rainfall took place simultaneously and intensively in whole Brantas River basin started on December 24, 2007 at 09.00 AM until December 26, 2007 having duration of about 64 hours. In upper reach of Brantas River basin and Sutami Lahor sub basin, cumulative rainfalls of about 192 mm for 23 hours was recorded at Poncokusumo Station, about 196 mm in 38 hours at Pujon Station, about 578 mm in 32 hours at Dampit Station, and 372 mm in 24 hours at Sengguruh Station, and the highest discharge of about 1,582 m^3/s and 750 m^3/s were recorded at Gadang Station and Tawangrejeni Station, respectively. Maximum inflow discharge to Sengguruh reservoir was recorded of about 1,422 m^3/s at that time.

Recorded maximum inflow discharge in Sutami Reservoir, the largest reservoir in Brantas River basin, located in the downstream of Sengguruh Reservoir, was about 1,434.5 m^3/s that could be controlled by the reservoir. Accordingly, water level of Sutami Reservoir increased 7.97 m in 24 hours, from elevation + 263.22 m on December 26, 2007 at 00:00 to elevation +271.19 m on December 27, 2007 at 00:00, with total volume of water was about 81 milion m^3. It was considered that the function of Sutami Reservoir to control flood could work well at that time.

Heavy rainfalls also occurred in other parts of Brantas River basin e.g. Wlingi – Lodoyo sub basin, middle reach of Brantas, Konto sub basin, Tulungagung – Trenggalek sub basin, Widas sub basin and lower reach of Brantas at that time. Due to existence of flood control structures e.g. reservoirs, levee etc., river improvement projects in the mainstream of Brantas River and some major rivers in the basin, as well as Flood Forecasting and Warning System, flood in these area could be controlled. But, in some small tributaries e.g. Amrong, Bogel, Sadar, Batan, Gunting Rivers, flood occurrence couldn't be avoided due to lack of flood control structures.

Damages Due to Recent Big Flood and Landslides

More than 100 people have been killed and hundreds of thousands have been affected in Bengawan Solo River basin in East and Central Java by the flooding and landslides, which began on Dec 25 2007. The overflowing Bengawan Solo River causing widespread flooding in heavily-populated Java inundated at least 6,491 households in the Municipality of Surakarta on 26 December. The majority of houses in flooded areas have suffered only moderate visible structural damage, but possessions within the houses have often been swept away or destroyed. The worst damage from flooding has occurred in the poorest areas, where houses are often constructed from cheap materials such as corrugated iron or wood paneling. The worst cases of damage overall have been in connection with the landslides (also responsible for the majority of the fatalities). 71 people died in the landslide in Karanganyar, which means this incident accounts for over half of the fatalities. The road connecting Surakarta and the East Java Province through the Karanganyar District was cut off, preventing access to many landslide affected areas.

As of 31 December, reports indicated that the majority of the floods in the Provinces of Central Java and East Java had receded. However, floods continued to inundate 14 sub-districts (117 villages) in the Bojonegoro District, East Java, blocking roads and the railway. East Java Coordination Unit for Disaster Management (SATKORLAK PB) indicated 36,764 houses and 9,324 hectares of crops were affected by the floods in this district. As of 2 January, 32 people had been admitted to hospitals and 24,893 outpatients were treated due to floods and landslides in the

Central Java Province. In the East Java Province, 15 people were admitted to hospitals and there were 361,098 outpatients, according to the Department of Health, Government of Indonesia.

Based on estimation made by Agriculture Department, Government of Indonesia, losses from agriculture sector due to flood in Bengawan Solo River basin was about Rp. 93.3 billion consist of the damage of 20,762 ha of paddy field, 723 ha of corn field and 22 ha of palawija (plants including soybeans and peanuts) fields. Bengawan Solo River Basin Development unit borne losses of about Rp. 85 billion consist of damage of many levees, dyke and gates along the river from upstream to downstream. Total losses due to the flood was estimated by State Ministry of National Planning and Development of about Rp. 2,000 billion covers all damages consist of roads, irrigation facilities, bridges, dams, etc including potential loss such as harvest failure due to inundation of paddy fields.

At the same period, flood in Brantas River basin mainly occurred in the tributaries. On 26 December, floods and landslides cut off roads and isolated hundreds of houses in the Mojowarno Sub-District, Jombang District, in the Province of East Java. No casualties were reported. From 25 December, seasonal torrential rains caused the Amprong River in Poncokusumo Sub-District, Malang Municipality, to inundate at least 111 houses and caused two deaths. Flood waters, reaching as high as two metres, increased rapidly preventing the community from saving any personal belongings. The flood affected population were accommodated in several emergency shelter sites, managed by the Malang District Coordination Unit for Disaster Management. Hundreds of houses in the Trenggalek District were inundated by flood waters from 26 December. There were no reports on casualties, but search and rescue teams from Surabaya are assisting in the evacuation of the affected people, mostly located in Tugu Sub-District.

Table 2 Casualties and Damages Due to Flood in Each Regency/Municipality in Bengawan Solo River Basin in the Late December 2007 Until Early January 2008

No.	Regency/ Municipality	Damages/Impacts
Bengawan Solo River Basin		
1	Wonogiri	- Total damage cost amounted Rp 42 billion - 9 people died - House damage cost amounted Rp 9.3 billion - Water supply facilities damage cost amounted Rp 18.6 billion (Damages in 104 points) - 10,289 ha of paddy field were inundated - Urgent road and bridge rehabilitation works amounted Rp 7.2 billion
2	Sukoharjo	- Total damage cost amounted Rp 31.29 billion - 1 person died, 9,662 people displaced - 10 districts were inundated e.g. Polokerto, Majalaban, Nguter - Road of Solo-Wonogiri inundated (50 cm) in 5 points at Nguter
3	Karanganyar	- 71 people died due to landslide, 6 people died due to flood - Road of Solo-Tawangmangu disconnect
4	Solo	- Total damage cost amounted Rp 11.258 billion - 12 villages in 5 district were inundated, e.g. Kampung Sewu, Jagalan, in Jebres District, 6,491 houses were damaged
5	Sragen	- Total damage cost amounted Rp 192 billion - 94 villages in 18 districts were inundated - 5 people died, 33 people injured - 153 houses were damaged, 4,220 ha of paddy field in Sidoharjo and Tanon Districts were inundated - Left bank of Colo Barat Canal collapsed (11 m length)

		- Road of Sragen-Solo was inundated in Sidoharjo district (1.20 m depth)

Table 2 (continued) - Casualties and Damages Due to Flood in Each Regency/Municipality in Bengawan Solo River Basin in the Late December 2007 Until Early January 2008

No.	Regency/ Municipality	Damages/Impacts
6	Ngawi	- Total damage cost amounted Rp 40 billion - 5 people died - Road of Ngawi-Sragen was inundated in Mantingan District
7	Blora	- Damage of agriculture sector amounted Rp 3.6 billion - Damage of infrastructures amounted Rp 6.5 billion - 8,251 houses were damaged - 2 people died
8	Bojonegoro	- Total damage cost amounted Rp 598.3 billion - 36,764 houses were damaged - Road and railway Bojonegoro-Cepu disconnect, Road damage cost amounted Rp 28 billion - 147 villages in 17 districts were inundated (Kanor, Trucuk, Baureno, Kalitidu, Balen, Padangan), 669 school buildings were damaged - 283,945 people affected and 192,531 people displaced
9	Tuban	- Total damage cost amounted Rp 25.6 billion - 22 villages in 5 districts (Widang, Rengel, Plumpang, Soko, Parengan) were inundated - 6,500 houses were damaged
10	Lamongan	- Total damage cost amounted Rp 10.1 billion - 37 villages in 9 districts were inundated, 8,619 houses were damaged - Loss of small industries amounted Rp 3,1 billion - 2,352 ha of paddy field and 471 ha of fishpond were inundated
11	Gresik	- Total damage cost amounted Rp 30 billion - 46 villages in 4 districts (Bungah, Dukun, Manyar, Sedayu) were inundated (1-1.5 m depth) - 1 person died - 832 ha of paddy field and 2,214 ha of fishpond were inundated
Brantas River Basin		
12	Malang	- Many houses were damaged in Lesanpuro, Madyopuro and Kedungkandang villages due to inundation from Amrong River - Damage of Mantung and Kwayangan Check dam in Konto River.
13	Blitar	- 5 hectares of settlement and 8 hectares of paddy fields were inundated due to flood water from Bogel River.
14	Mojokerto	- 4 hectares of settlement and 8 hectares of paddy fields in Gebang Malang Village, 100 hectares of paddy fields in Damarsi Village and 4 hectares of paddy fields in Kweden Kembar Village were inundated due to flood water from Sadar River.
15	Kediri	- Right Levee of Batan River was collapsed (Up Stream Purwoasri Bridge)
16	Jombang	- 55 hectares of settlement and 190 hectares of paddy fields were inundated due to flood water from Gunting River.
17	Trenggalek	- Dykes in Krandekan, Bendorejo, Tamanan and Kelutan Villages were collapsed due to flood water from Ngasinan River.

Source: Ministry of Public Works, Government of Indonesia and Jasa Tirta I Public Corporation (2007)

Watershed Degradation and Sedimentation Problem in Bengawan Solo and Brantas River Basins

Due to population pressure at the present moment, in Wonogiri Reservoir catchment in upper part of Bengawan Solo River Basin, about 90% of the total land has been cultivated with dry-land farming that is categorized as highly fragile to surface soil erosion. While forests covers only 10% of the catchment. As the impact, Wonogiri Reservoir is rapidly filled with sediments transported from the catchment. Poor land use of its catchment and intensive farming of annual crops using poor practices on the highly erosive and steep-sloped uplands as well as highly populated and intensely farmed areas are the main causes of the sedimentation of the Wonogiri Reservoir which is the only one multipurpose dam and reservoir in Bengawan Solo River Basin which has function to control flood in the basin. A preliminary assessment of the current state of sedimentation indicated that the effective reservoir capacity has decreased to nearly 60% of the original one.

Similar condition occurs in the Brantas River basin. The Brantas basin has eight reservoirs with a total gross storage capacity of 647 million m^3 and effective storage capacity of 479 million m^3. Because of sedimentation the gross and effective storage are now down to 405 million m^3 (62.6%) and 343 million m^3 (71.6%) respectively. Other 60 basins in Indonesia also encounter watershed degradation. To cope with this problem, Government of Indonesia intends to restore dozens of devastated river basins started this year in efforts to prevent flood-related disasters which expected to occur more frequently in Indonesia due to the vast land changes in watershed areas and increase of frequencies and intensities of rainfall events.

Table 3 Loss of Reservoirs Storages in Bengawan Solo and Brantas River Basins Due to Sedimentation

No.	Reservoir	Initial Storage (mill m^3)			Current Storage (mill m^3)			Sediment Rate (mill m^3/year)
		Year	Effective	Total	Year	Effective	Total	
	Bengawan Solo River Basin							
1	Wonogiri	1980	433.0	735.0	2005	375.0	621	4.56
	Brantas River Basin							
2	Sengguruh	1988	19.0	21.5	2005	0.9	1.5	1.18
3	Sutami	1972	253.0	343.0	2006	146.7	174.7	4.95
4	Lahor	1977	29.4	36.1	2006	25.2	30.6	0.20
5	Wlingi	1977	5.2	24.0	2006	2.1	4.4	0.68
6	Lodoyo	1980	4.2	5.8	2006	2.7	2.7	0.12
7	Selorejo	1970	50.1	62.3	2006	40.8	42.9	0.54
8	Bening	1981	28.4	32.9	2004	26.2	28.7	0.18
9	Wonorejo	2000	99.4	111.0	2005	99.6	110.3	0.14

Source: Jasa Tirta I Public Corporation (2007)

Measures Had Been Done and Need to be Done

To cope with flood hazards that happen frequently in the Bengawan Solo and Brantas River basins, some measures consist of both structural and non structural measures had been done and still need to be done in the basins, involving Central Government, Provincial Government, Regency/Municipality Government, communities, NGOs, etc. The measures that had been done are re-forestation, reducing sheet erosion by terracing and constructing sediment control structures, sediment removal in the reservoirs to secure flood control capacity by dredging and flushing, promoting public initiatives on re-greening and establishment of early warning systems, etc.

Some measures that need to done are constructing flood control structures (dam, reservoir, flood way, etc), developing river improvement projects to increase flood capacity of the rivers, watershed conservation by reviewing catchments management plan, continuing sheet erosion control (terracing, re-greening, re-forestation and construction of sabo works) and promoting intensive public awareness and initiative in environment issues, establishing advance flood forecasting and warning system, flood hazard map etc.

Conclusion

Climate change will have wide-ranging impacts on the environment, socio-economic and related sectors including water resources, especially in developing countries because they have fewer resources to adapt socially, technologically and financially. As happened in late December 2007 and early January 2008 in Bengawan Solo and Brantas River basins, both are the two largest river basins in Java Island, where severe flooding and landslides occurred due to extreme event of intensive heavy rains. Watershed degradation, lack of flood control structures, incompleted river improvement projects, lack of drainage system and flood forecasting and warning systems have worsen the situation. Total losses due to the flood was estimated by State Ministry of National Planning and Development of about Rp. 2,000 billion covers all damages consist of roads, irrigation facilities, bridges, dams, etc including potential loss such as harvest failure due to inundation of paddy fields.

To cope with hazards due to floods that expected to take place more frequently in Bengawan Solo and Brantas River basins in the future, assistances from international parties in forms of capacity-building, transfer of technology and funds to support monitoring and forecast of weather and climate, as well as advance flood forecasting and warning system in the basins are needed as measures to adapt climate change impacts on floods in the basins. In addition, systematic planning and capacity-building are also needed to reduce the risk of disasters and raise the resilience of communities to increasing floods.

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