Integrated Watershed Management to Prevent Floods and Sustain Water Resources In Jakarta, Indonesia

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Abstract

*There are nine major rivers flowing through Jakarta, the capital city of Indonesia. Total extent of the nine watersheds in Jakarta and its vicinity is about 106 000 ha . Average annual rainfall of 17 stations (1972-1999) throughout the watersheds is **2 973** mm. These make the total water resources throughout Jakarta is about **3.151** billion cubic meters per year (cmy).*
*Average water demand for agricultural uses is about 4.0 mm perday or **1 460** mm per year or **1.548** billion cmy throughout the watersheds. Therefore, the total annual retained water as storage in the soils, ponds, lakes, reservoirs, ground water,vegetations, rivers, and for municipal use will be only 1 513 mm or 1.296 billion cmy.*
*Water demand (municipal use) for 11 million people in the nine watersheds is about **1.288** billion cmy or **360** liter per capita per day in urban area and 180 liter in rural area. Water demand for industries uses is about 16 million cmy.*
Water loss through floods during rainy seasons is about 1.020 billion cmy due to the increasing runoff coefficient of the watersheds Changing land use and improper agricultural management are likely the main cause of the increasing runoff coefficient.
The losses of water have caused inevitable lacking of water for municipal uses during dry seasons.
It is clear from this analysis that the water problems in Jakarta is not only frequent and high floods in rainy seasons but also lacking of water for municipal use in dry seasons. These situations seem to be worse in the future. Therefore, the water problems in Jakarta need an extremely great attention. The key to undertake these problems is a set of activities in an integrated and holistic watershed management programs which may called Jakarta Megapolitan Water Management System.

Key Words : Water resources,Floods, Watershed, Rainfall.

Introduction

Jakarta as capital city of Indonesia has become a metropolitan city like any other capital city in the world. Total population of Jakarta has reached 8.6 million in 2003 with population density about 12 960 people per square kilometer (BPS,2003).
This city has also become the center of business activity; it contributes about 34 % of the total economic activities of Indonesia.
The growing population and business activities have caused a tremendous conversion of agricultural land for houses, shopping centers, schools, offices industrial parks, parking area, highways, and airports. These changing land use is likely become the source of much erosion/sediment, runoff and garbage that fill and pollutes rivers, drainage channels and reservoirs (ponds, lakes) which in turn causing floods in rainy seasons. On the other side, the changing land use is the main cause of decreasing infiltration and ground water table and in turn causing drought in dry seasons.
The rate of runoff in rainy seasons is increasing due to the decreasing of infiltration rate. Runoff coefficient increased from 0.38 in 1990 to 0.54 in 1996. The increasing runoff coefficient has caused floods more frequently with higher intensity and broader damaged areas. Floods in 2002 inundated 85 locations in Jakarta which covered 16 041 ha (17% of total area), the depth of water logging ranged from 0.2 m to 3.0 m and length of inundation ranged from two hours to 10 days. In the following dry season some areas in Jakarta suffering from extreme lacking of water. There are nine major rivers flowing throughout Jakarta and Ciliwung river is the biggest (Figure 1 and Table 1). Total extent of the nine watersheds about 106 000 ha. Watershed that has a complete hydrological data records is

Ciliwung watershed. Therefore, the total water resources and demands of Jakarta will be calculated based on recorded data in Ciliwung watershed.

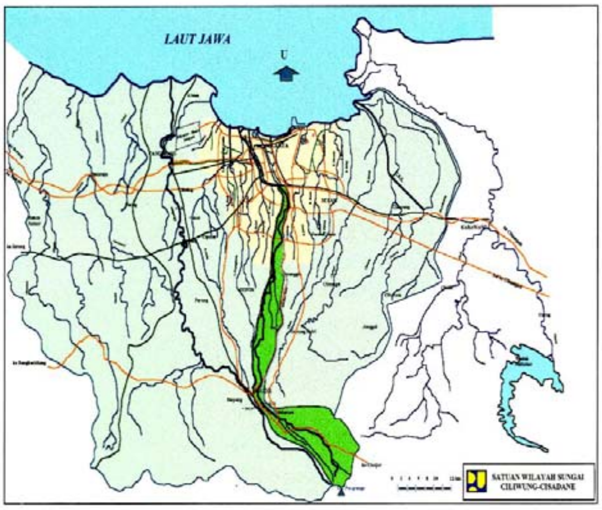

Figure 1. Jakarta and the nine major watersheds.

Table 1. Major Rivers (Watersheds) in Jakarta (NEDECO, 1973)

Rivers/watershed	Area (Sq km)	Length (km)	Lowest elevation (m)	Highest elevation (m)
Cakung	55	33	6	90
Buaran	30	23	9	45
Sunter	73	40	12	122
Cipinang	48	36	12	107
Ciliwung	347	117	8	2908
Krukut	98	37	7	117
Grogol	33	27	29	100
Pesanggrahan	110	83	3	205
Angke	263	100	3	220
Total	**105.7**			

Water Resources

The total water resources for Jakarta is predicted using rainfall and stream discharge analysis. Rainfall analysis showed that average annual rainfall of 17 stations throughout the nine watersheds is 2973 mm (Table 2). These make the total water resources for Jakarta is about 3.151 billion cubic meter per year (cmy). However, the total water resources in Ciliwung watershed alone will be 951.36 million cmy. Stream discharge analysis showed that monthly water discharge of Ciliwung river is ranged from 16.0 cubic meter per second (cms) in dry seasons to 33.4 cms in rainy seasons with the average of 23.2 cms throughout the year (Figure 2). These make the total water resources in Ciliwung watershed is about 560 million cmy. The ratio of stream discharge to total rainfall, therefore, is 0.59. Using this ratio to the other eight watersheds make the total stream discharge or water resources for Jakarta and its vicinity is about 1750 mm or 1.855 billion cmy. This make the total retained water in the watersheds as water storage in the soils, ponds, lakes, reservoirs, ground water and vegetation is 1.296 billion cmy.

Table 2. Daily and annual rainfall (mm) of Ciliwung Watershed (Fakhrudin, 2003)

Stations	Average daily rainfall	Maximum daily rainfall	Annual rainfall
Upper reach	**122.2**		**3832 7**
Tugu Selatan	101	162	3541
Citeko	102	151	3303
Cibeureum	102	150	3480
Ciawi	135	227	3925
Katulampa	114	150	3834
Empang	128	210	4210
Hambalang	136	200	4116
KBR-Bogor	138	262	4124
Cimanggu	132	160	4130
Atang Sanjaya	134	316	3736
Middle reach	**111.7**		**2594**
Cibinong	110	180	3153
Citayam	109	155	2579
Depok	95	126	2562
Psr Minggu	133	170	2082
Lower reach	**102.6**		**1828**
HP. Kusuma	105	162	1901
Rawamangun	108	181	1771
BMG	94	148	1812
Average	**110.7**		**2 973**

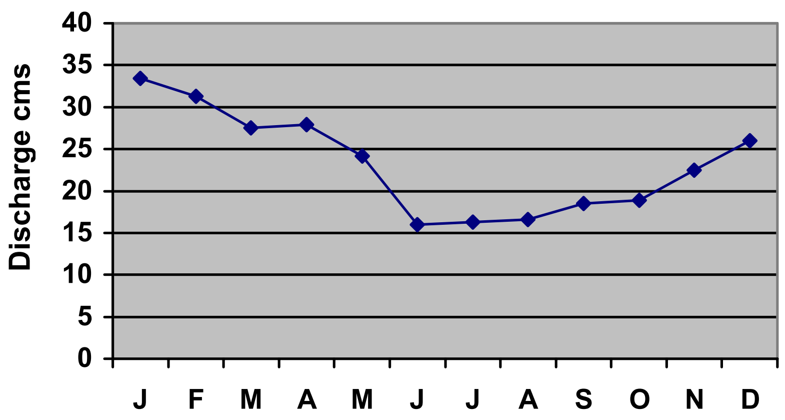

Figure 2. Monthly stream discharge of Ciliwung

Water Demands

Water demands for societal uses is divided into three major uses: municipal uses, industrial uses, and agricultural uses.
Municipal demand included water for domestic purposes, commercial use, fire protection, street washing, and lawn and garden irrigation. In Jakarta, the municipal uses is provided through municipal water system with the rate of 360 ℓ/capita/day in urban area and 180 ℓ/capita/day in rural area. The capacity of the municipal water system is only 13.93 cms or 439.296 million cmy make the system can serve only 3.343 million people or 38.8% of the population.
Since the total population of Jakarta and its vicinity in the watershed is about 11 million, which consists of 8.6 million in urban area and 2.4 million in rural area the total demand for municipal uses is about 1.305 billion cmy. Water demand for industrial uses is ranged from 125-1000 cubic meter per day (cmd) for about 88 industries in Jakarta; this make the total water demand for industries uses is about 16 million cmy.
Water demand for agricultural (forest, upland agriculture, paddy rice, garden, etc) is calculated with the assumption of evapotranspiration about 4.0 mm per day; this make the total water demand for agricultural is 1460 mm per year or 1.548 billion cmy. Societal demand for water in Jakarta and its vicinity, therefore, is about 2.852 billion cmy (Table 3).

Table 3. Water Balance in Jakarta and its vicinity

Water Resources (billion cmy)		**Water demands (billion cmy)**	
Stream discharges Water loss through floods	0.538 1.317	Municipal uses	1.288
Retained in lake, soil, groundwater, vegetation, reservoirs.	1.296	Industrial uses	0.016
		Agricultural (forest, upland agriculture and paddy rice)	1.548
Available water	**1.824**	**Total demands**	**2.852**
Defisit	**1.028**		

Watershed Problems

Floods and water losses

During rainy seasons (Des, Jan, Feb, March, and April) Ciliwung river always causes floods. In recent years, peak discharges of Ciliwung river is increasing (Table 4 and 5). The increasing flood or peak discharge is likely because the increasing runoff coefficient of the watershed. Runoff coefficient is increasing from 0.36 to 0.54 (Table 4) due to the changing land use particularly from forest and agriculture to non agriculture uses and the inadequate soil and and water conservation practices in agricultural areas.
The floods not only detrimental to the environment and damage properties but also causing tremendous loss of water. During five months of rainy seasons, water discharge in Ciliwung is about 400 million cubic meter or 71 % of the total annual discharge. Most of this water cannot be used to meet the societal needs because it flows directly to the sea. Using the same proportion to the other eight rivers, make the total loss of water during rainy seasons in Jakarta and its vicinity is about 1.317 billion cmy.

Table 4. River Discharge as affected by land use changes (by simulation technique)

Land use changes	Katulampa				Ratu Jaya				Manggarai/Jakarta			
	Qp (m^3/s)	Tp (hr)	Vo (m^3)	Pe/P (%)	Qp (m^3/s)	Tp (hr)	Vo (m^3)	Pe/P (%)	Qp (m^3/s)	Tp (hr)	Vo (m^3)	Pe/P (%)
1990	100.33	6	3058264	23	167.67	7	6504960	30	191.29	9	10321 344	36
1996	205.37	5	5052784	38	320.81	6.5	10407936	48	383.11	8.5	15482 016	54
Projected 2012	280.1	5.5	6382464	48	487.00	6	13009920	60	576.50	8.5	18635 760	65

Table 5. Maximum Discharge of Ciliwung during floods

Year	Maximum Discharge (cms)
1990	191
1996	383
2002	482
2012 (predicted for return period of 2 year)	578

Drought and Water deficit

Because the failure to keep the loss of water during rainy seasons, many people had been suffering from the lacking of fresh water particularly in dry seasons. Since the total demand for water is much higher that the total supply through the municipal water system, most people take the needed water from the retained water in ponds, lakes, reservoirs, groundwater and rivers. The retained water in those reservoirs is only 1.296 billion cmy but the needed for municipal uses, industries, and agricultural is 2.852 billion cmy (Table.3). Table 3 also indicates that Jakarta and its vicinity have been lacking of water particularly in dry seasons. Because it is impossible to balance the deficit from those reservoirs the Government has tried to transfer some water from Citarum river to Jakarta. The amount of water transfered through West Tarum canal to Jakarta approximately 16.0 cms or 504.6 million cmy. This additional water canot balance the deficit of water completely. Beside this effort, the Government should also set a holistic water resources program in the nine watersheds to prevent the water lost during rainy seasons through integrated watershed management.

Integrated Watershed Management

It is clear from this analysis that the water problems in Jakarta is not only frequent and high floods in rainy seasons but also lacking of water for municipal use in dry seasons. These situations seem to be worse in the future. Therefore, the water problem in Jakarta needs an extremely great attention. The key to undertake these problems is a set of activities in an integrated and holistic watershed management programs. The integrated watershed management program should be identically with sustainable development program in the watersheds. Therefore, the programs should overcome the problem of frequent and high floods, the problem of lacking fresh water for municipal use, as well as to increase farmers/community welfare simultaneously.

Focus of the integrated watershed management programs will be to reduce runoff in the whole watershed by increasing infiltration rate and to accommodate the water discharge in a safe manner without flooding. Activities to increase infiltration rate can be carried out through the

following activities: integrated and proper land use planning; implementation of conservation farming systems (strip cropping, multiple crops farming systems including fish and/or livestock); implementation of appropriate conservation techniques (mulching, terracing, contour planting, ridge and furrow planting); practicing appropriate soil management techniques (minimum or no tillage, contour tillage, contour planting); spring development; building of grass waterways, diversion ditch, drainage ditch, efficient irrigation systems and building of check dams/water retardance structures or situ (s) in appropriate site.
All of these activities should be planned carefully using appropriate models to determine what to build where and implemented accordingly in the whole nine major watersheds. These programs will be more effective when the nine watersheds is integrated into one management system which may called Jakarta Megapolitan Water Management System

Conclusions

Based on the results and discussions the following conclusions can be drawn;

1. Potential water resources of Jakarta is about 3.151 billion cmy.
2. Water demand for municipal uses, industries uses and agricultural uses is 2.852 billion cmy.
3. Retained water as water storage in the soils, ponds, lakes, reservoirs, ground water and vegetation is 1.296 billion cmy.
4. Lost of water through floods during rainy season is 1.317 billion cmy due to changing land use and inadequate soil and water conservation practices.
5. Jakarta has been deficit of water particularly during dry seasons.
6. Water problems in Jakarta need an extremely great attention. The key to undertake the problems is a set of activities in an integrated and holistic watershed management programs, transfer of water from Citarum and Cisadane watersheds, and Jakarta Megapolitan based water resources management.

References

Biro Pusat Statistik, 2003: *Statistik Lingkungan Hidup Indonesia 2003. Jakarta Indonesia.*

Biro Pusat Statistik, 2003: *Jakarta dalam angka 2004. Biro Pusat Statistik, Jakarta Indonesia.*

Fakhrudin, 2003: *Kajian Respon Hidrologi akibat perubahan penggunaan lahan DAS Ciliwung dengan model Sedimot II. Bogor Agricultural University. Indonesia*

Muslim Munaf, 1992*: Kajian Sifat Aliran Sungai Ciliwung, Bogor Agricultural University*

Nedeco, 1973: *Masterplan for Drainage and Flood Control of Jakarta, Jakarta Indonesia.*

Proyek Induk Ciliwung-Cisadane, 2003: *Data aliran Sungai Ciliwung. Jakarta Indonesia.*

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