発表要旨

First International Workshop

on

Water and
Sediment Management
in Brantas River Basin

July 28-29, 2005

Klub Bunga Butik Resort, Batu, E. Java, Indonesia

Background and objectives

The increase of the world's population has brought an increase in water usage for greater food production, flood damage by urbanization and increase of water demand. Especially, the population in Asia is already 60 % of the world's population and is forecasted to increase further to 1.7 billion. Thus, we must promote comprehensive water resources management with the aim of a sustainable evolution of the basin in Asia.

In Brantas River Basin, East Java of Indonesia, there is a long history of cooperation between Indonesian and Japan. This cooperation contributed to the economical evolution in Brantas River Basin. Also, a number of joint scientific projects between Indonesia and Japan were conducted to study the sediment dynamics and water cycle in Brantas River Basin. Some of these projects, such as Takara CREST, Prof. Fujita's Project and Sunada CREST, are still running. It can be thought that there are a number of useful/important information, knowledge and data for the development of comprehensive water resources management techniques in the rapidly population increasing area. So, we considered that the exchange information and result of investigations are important for clarifying current issues, potential future problems and direction of our researches. Based on these exchanges, scientific aspects of comprehensive watershed management plan for Brantas River Basin can be discussed. We hope that people who work for watershed management of Brantas Rivers and study for sediment dynamics in Brantas River Basin will attend the workshop.

Workshop Topics

We will argue the scientific aspects of following issues

- Comprehensive sediment management of Brantas River Basin
- Land use change in Mountainous area and its relation to sediment yield
- Sustainable management of reservoirs in upper and middle reaches
- Mt. Kelud eruption and its relation to sediment dynamic in middle and lower reaches
- Riverbed degradation and role of sand mining in lower reach

Program

Wednesday July 27, 2005

Arrival through the afternoon and evening

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Thursday July 28, 2005 ***Anggrek Hall Hotel Klub Bunga***

Session 1 General Discussion about Brantas River Basin and Integrated River Basin Management

Session Chair Dr. Eng. Satoru OISHI (University of Yamanashi)

9:00-9:05 Opening remarks 1
Mr. Socheh (Jasa Tirta I Public Corporation)

9:05-9:10 Opening remarks 2
Prof. Kengo SUNADA (University of Yamanashi)

9:10-9:20 Opening remarks 3
Mr. Siswoko (Director General of Water Resources, Ministry of Public Works, GOI)

9:20-10:00 Erosion and Sedimentation Problems in the Upper Reach of Brantas River Basin and its Countermeasures
Mr. Soekistijono (Jasa Tirta 1 Public Corporation)

10:00-10:40 Integrated River Basin Management in Humid Asia
Prof. Katumi Musiake (Fukushima University)

Coffee Break (location: lobby lounge)

11:00-11:40 Assessment of Water Quality Status for the Brantas and Citarum Rivers Approaching by the Water Quality Index Evaluation System
Dr. Mohd Ali Fulazzaky
(Directorate General of Water Resources, Ministry of Public Works, GOI)

11:40-12:20 Observation and Modeling of Sediment Transport for Comprehensive Sediment Management in Japan
Dr. Ryosuke Tsunaki
(National Institute for Land and Infrastructure Management)

12:20-13:30 ***Lunch (location: Teratai coffee shop)***

Session 2 Sediment Dynamics in Brantas River Basin

Session Chair *Dr. Mohd. Ali Fulazzaky (Directorate General of Water Resources, Ministry of Public Works, GOI)*

13:30-14:10 Sediment Runoff in the Brantas River Basin after the Eruption of Mt. Kelud 1990

Dr. Eng. Masaharu FUJITA, Dr. Eng. Yoshifumi SATOFUKA and Prof. Shinji EGASHIRA (*Kyoto University and Rittsumeikan University)*

14:10-14:50 Handling of Critical Land in Brantas River Basin

Mr. Eddy Hertanto (Brantas Catchment Rehabilitation and Conservation Office, Ministry of Forestry)

Coffee Break (location: lobby lounge)

15:10-15:50 Comprehensive Basin-wide Sediment Management Study in the Brantas River Basin

Mr. Masaki ITO

(Consultant Team for Water Resources Existing Facilities Rehabilitation and Capacity Improvement Project)

15:50-16:30 Brantas River Basin Development Programs for Present and Future

Mr. Joko Yudi (Brantas River Development Project Office)

16:30-17:00 *Discussion of first day's presentations and second day workshop discussion points*

Moderator: Mr. Soekistijono (Jasa Tirta I Public Corporation)

Welcome dinner (Hotel Klub Bunga)
Location: Pool side

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Friday July 29, 2005 Anggrek Hall Hotel Klub Bunga

Session 3 Sediment Yield and Sedimentation in Reservoirs
Session Chair Dr. Taro UCHIDA (NILIM)

9:00-9:40 On Sediment Yield and Transport in the Lesti River Basin
- Experiences from Field Observations and Remotely Sensed data-
Prof. Hajime NAKAGAWA, Dr. Eng. Yoshifumi SATOFUKA, Yasunori MUTO, Ph.D., Dr. Eng. Satoru OISHI, Mr. Takahiro SAYAMA, and Prof. Kaoru TAKARA (Kyoto University and University of Yamanashi)

9:40-10:20 Effect of Land-use Change on Sedimentation Rate at Upper Citarum River Basin, West Java Province
Mr. Eddy Djajadiredja, Dr. Agung Bagiawan Ibrahim and Rachmat Suria (Research Institute for Water Resources, Agency for Research and Development, Ministry of Public Works)

Coffee Break (location: lobby lounge)

10:50-11:30 The Quantitative and Qualitative Analysis of Erosion and Sedimentation in Upper Brantas Basin
Mr. Dian Sisinggih, Prof. Kengo SUNADA, Dr. Eng. Satoru OISHI (University of Yamanashi)

11:30-13.30 ***Lunch and Friday Praying for Moslems***

Session 4
Session Chair Mr. Dian Sisinggih (Yamanashi University)

13:30-14:10 Reservoir Sedimentation Prediction
-Based on Pollutant Characteristic in Watershed
Mr. Tri Budi Prayogo, Ms. Aniek Masrevaniah and Dr. Ery Suhartanto (Brawijaya University)

14:10-14:50 Assessing the Sediment Sources of Deposited Sediment in Reservoirs Using Sediment Tracer Techniques
Dr. Nobutomo OSANAI, Mr. Tomoyuki NORO and Dr. Taro UCHIDA (National Institute for Land and Infrastructure Management)

Coffee Break (location: lobby lounge)

15:20-16:00 Management of Brantas River in the Aspect of Exploitation and Controlling
Mr. Mashuri (East Java Water Resources)

16:00-16:40 Application of Remote Sensing and GIS for Flood and Sediment Runoff Prediction
Prof. Kaoru TAKARA (Kyoto University)

16:40-17:30 *Closing Discussions*
Moderator: Prof. Hajime NAKAGAWA (Kyoto University)

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Saturday, July 30, 2005	***Site visit (Brantas Origin, Sengguruh, Sutami, Lahor, Wlingi etc.)***
Sunday, July 31, 2005	***Site visit (Mrican, Brantas Middle Reach, Surabaya River etc.)***

Expected Participants

(Japan)

1. Prof. Katumi Musiake	Fukushima University, Japan Science Technology Agency (JST)
2. Prof. Kengo Sunada	Yamanashi University (Sunada CREST)
3. Dr. Satoru Oishi	Yamanashi University (Sunada CREST/Takara CREST)
4. Mr. Dian Sisinggih	Yamanashi University (Sunada CREST)
5. Prof. Kaoru Takara	Kyoto University (Takara CREST)
6. Prof. Hajime Nakagawa	Kyoto University (Takara CREST)
7. Dr. Masaharu Fujita	Kyoto University
8. Mr. Takahiro Sayama	Kyoto University (Takara CREST)
9. Mr. Masaki Ito	Consultant Team for WREFR and CIP
10. Dr. Ryosuke Tsunaki	NILIM (Sunada CREST)
11. Mr. Tomoyuki Noro	NILIM (Sunada CREST)
12. Dr. Taro Uchida	NILIM (Sunada CREST)
13. Mr. Fumito Takahashi	Tsukuba University

(Indonesia)

1. Mr. Eddy Djajadiredja	Research Institute for Water Resources
2. Dr. Agung B. Ibrahim	Research Institute for Water Resources
3. Mr. Joesron Loebis	Research Institute for Water Resources
4. Dr. Mohd. Ali Fulazzaky	DGWR
5. Mr. Joko Yudi	Brantas Project
6. Mr. Mashuri	East Java Water Resources Service Office
7. Mr. Kukuh Satoto	Brantas Catchment Rehabilitation and Conservation Office, Ministry of Forestry
8. Ms. Aniek Masrevaniah	Brawijaya University
9. Mr. Tri Budi Prayogo	Brawijaya University
10. Dr. Erry Suhartanto	Brawijaya University
11. Dr. Agus Suharyanto	Brawijaya University
12. Mr. Soekistijono	Jasa Tirta I Public Corporation
13. Mr. Widyo Parwanto	Jasa Tirta I Public Corporation
14. Mr. Erwando Rachmadi	Jasa Tirta I Public Corporation
15. Dr. M. Mukhlisin	Politeknik Negeri Semarang

EROSION AND SEDIMENTATION PROBLEMS IN THE UPPER REACH OF BRANTAS RIVER BASIN AND ITS COUNTERMEASURES

by

Soekistijono

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The Brantas River basin, one of the largest river systems in Indonesia, 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 11,800 km^2 in total and its main stream, the Brantas River, runs about 320 km long. Population in the basin is quite dense, closing to 15.50 million people in the year 2003 which counts for 43% of East Java population.

Development in the basin commenced in 1960s, has resulted into 8 (eight) reservoirs, four river-improvement-schemes, four barrages, and three rubber dams, etc. Total investment in water resources infrastructure is priced Rp 7.63 trillion based on the year 2003 price level (US$ 0.097 billion, Yen 78.8 billion, Rp. 258.9 billion).

Evidently, as benefit of the development, about 60.000 ha of area are secured from annual inundation as flood control in the mainstream is established with a designated capability to control 50-years return period flood. Hydroelectric power generation in the basin also increases from a small amount of 170 kWh that is generated by two hydroelectric generation units from the Dutch-period, to a lump amount of 1 billion kWh annually. Also, related to that, as of 2004, development of water resources infrastructures has secured water supply for irrigation of about 121,000 ha from mainstream, for domestic of about 144 MCM and industrial of about 243 MCM. The benefits of development has been considered in supporting economic development of East Java Province as well as National development since GRDP of the basin was Rp. 150,630 billion – approx. US$ 17.66 billion which counts for 59% GRDP of East Java and 8% of GRDP National (as of 2003).

One of main issues identified as the most likely to have significant impacts on future water management in the Brantas Basin is erosion and sedimentation problem mainly in the upper reach which is higher than the expected. Severe erosion which is related to land use and spatial management, and natural forces in form of volcanic debris enhances sedimentation that shortens economic life of major dams in the basin and natural base flow degradation during dry spells.

Jasa Tirta I Public Corporation as Brantas River Basin Management Agency has conducted measures to cope with erosion and sedimentation problem. In preparing and implementing the appropriate actions, we rely on some result of research conducted by many agencies, which sometimes are having significant differences e.g., erosion and sedimentation rates; sources of sediment etc. subsequently may cause in-effective countermeasures.

Integrated River Basin Management in Humid Asia

Katumi Musiake

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Water problems are too diverse to be solved from a single perspective. Whether in Japan, Western countries, or developing countries, there have been tendencies from ancient times in each region to deal in an integrated manner with water problems arising in each era. However, as the socio-economy has changed rapidly due to population increase, urbanization, industrialization, and extensive agricultural development since the second half of the 20th century, water problems have become more complex and serious. To solve these problems, water management in more integrated manner, enlarged and more effective, is required.

The purpose of my presentation is to make clear the meaning of "integrated river basin management (IRBM)" and then to discuss water management issues in relation to regional characteristics of hydrology and water resources in humid monsoon Asia.

First, in order to recognize the serious background of water problems in Asia, the present situations and future trends of population, water demand and water-related disasters are outlined compared to those in other regions of the world.
Secondly, the concept of IRBM is tried to be clarified, by being examined from the following three view-points:

- Functional view-point: Whether relevant functions and measures are involved adequately to achieve the objectives of the water management.
- Geographical view-point: The "river basin" is an important geographical unit in the humid region to analyze hydrological processes / water balance as well as to consider water supply, water-related disaster mitigation and aquatic eco-system conservation.
- Administrative view-point: Whether relevant agencies and stakeholders are involved adequately in the administrative structure established to achieve the objective of the management, and whether the structure provides centripetal force, collaborative leadership and executive ability.

Thirdly, regional characteristics of water management issues in humid monsoon Asia are discussed, taking into consideration climatic, geomorphologic and human activity factors as the three major factors governing the regional characteristics of the hydrology-water resources system. It is insisted that land conditions of the tectonic zone is very important to express regional characteristics of hydrology-water resources system particular in the monsoon Asia.

Finally, water issues particular to IRBM in humid Asia are described in the following items:

- High potential of hydro-power generation
- Mountain slope cultivation
- Heavy sediment yield and water-related disasters in mountain areas due to seismic and volcanic activities
- Paddy cultivation and its special water management requirement
- Urban area development in the low-lying alluvial plain and flood plain management
- "Too little water" problems due to imbalance between water supply and increasing water demand

ASSESSMENT OF WATER QUALITY STATUS FOR THE BRANTAS AND CITARUM RIVERS APPROACHING BY THE WATER QUALITY INDEX EVALUATION SYSTEM

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Abstract

The assessment of river water pollution is usually conducted by a comparison between the effective water quality and the standards regulated by law. The water quality standards are fixed both on water utilization purposes and on consideration of water quality degradation. The water quality index is usually assigned through an evaluation of the water condition by classification into several categories. This paper elaborates a tool for water quality evaluation and completed by the application of a software system to define the water quality index. The assignment of the index is fixed from index-1 to index-5 according the water degradation taking account of an indicated value of water quality parameter concentrations. Index-1 means a category of the excellent quality of unpolluted water and index-5 is a category of the very polluted water.

Around 150 water quality parameters of comparable nature and impact on environment are grouped into 15 *alterations* that are: temperature, color, suspended particles, oxidized organic matters, nitrogen matters, nitrate, phosphorous matters, mineralization, acidification, inorganic micro-pollutant for raw water, inorganic micro-pollutant for bryophytes, pesticide for raw water, organic micro-pollutant non-pesticides for raw water, micro-organisms, and phytoplankton. The index determination consists of 3 stages: - starting with a selection of the biggest limit value of parameter in each alteration according the index classification, - following by a selection of the highest index of alteration, and finally, terminating by fixation of the water quality index.

The application of the index system has been conducted to 2 rivers, the Citarum River in West Java and the Brantas River in East Java. The assessment of the water quality for the Citarum River was based on data from 10 sampling point locations and by evaluating 33 parameters, which were monitored in the dry season period in 2003. The result indicates the index-5 for the upstream region of the Citarum River due to high concentration of suspended particles and phosphorous. The index-5 always was still present along the middle stream, due to receiving the effluents coming from domestic and industrial wastes, indicated by high concentrations of organic matters and bacteria indicators. After the water passed the 3 cascade reservoirs (Saguling, Cirata and Jatiluhur), the index-3 was found, and in the downstream region of the Citarum River close to the sea the index-5 was observed again, due to contamination by industrial and domestic wastes. The assessment of the water quality for the Brantas River was done for 5 sampling points selected from 51 monthly monitoring locations of data collection in 2003 and by evaluating 22 to 28 parameters. The data were selected by application of the rule of 90% and the result shows the index-5 for water quality along of the Brantas River due to high concentration of suspended particles, phosphorous and inorganic micro-pollutants.

By applying the system could be easily identified the real problems related to the point sources of pollution loads and be effectively defined the best action plan for solving the problem related in managing water resources and improving water governance concerning the water quality management and pollution control in related river basin.

Key words: evaluation, index, pollution, water quality.

1. Introduction

Water resources management entails the development of appropriate quantities of water with an adequate quality. The deterioration of water quality reduces the usability of the resources for down-stream stakeholders. The government of the Republic of Indonesia, in the year of 2001, under the water resources sector reformation framework has been issued the government regulation number 82 on water quality management and pollution control, as a reference especially for the water managers who working in the several related institutions of the national, provincial and river basin levels. This regulation consists the role of the institutions for the central as well the regional governments, the technical arrangement for water quality management and pollution control as well as the classification of national water quality criteria, and for supporting the real operational in field of this government regulation needs to be more detail translated by each provincial governments through their regional regulations. The water quality index system is developed to answer the desire of all regions in Indonesia on the classification of in-stream water quality degradation degree by using a national standard mechanism and than of course can be followed up by each provincial government taking account as a tool for assessment of the status of water quality regarding the process of preparation the priority of action plan on water quality management and pollution control as well as the formulation of the regional regulation on water quality standards for each river segment areas located in their administrative regions.

According to the results of field inventory for some cases indicating that the high water pollution in the rivers and lakes due to the high increasing of social and economic activities and industrial developments. Although the impact of economic development in the regions produces some unusable materials such as waste solids and wastewater as well as industrial waste gazes. The industrial and domestic wastewaters are really, after or before passing in a wastewater treatment plant, ejected to the river and lakes. Actually, the sources and types of pollutant are not correctly monitored yet and of course regarding for this reason it really needs to be developed a comprehensive method for evaluation of the water pollution degree. Ahead, this method could be considered to following up by the regional government maybe in issuing the regional government regulation or the governor decree. A new method of water quality assessment system have been developed in 1999 by the Agence de l'eau Loire- Bretagne, Oudin *at. al* (1999) and, after an evaluating to the method on considering of the specific country climate and of the habitually water quality parameters monitoring, it can be appropriate widely implemented in Indonesia taking account of some modifications needed, Fulazzaky (2000). Because the system consists a comprehensive classification of the water quality parameters, including the complex and rigorous alterations such as the pesticides and inorganic micro-pollutant matters as well as the organic micro-pollutant non-pesticides that it really has not been considered under the assessment framework mechanism of water quality in Indonesia. This method will be predictable adapted for advances in space science and technology. And, by using the similar method, in 2003 the Directorate General of Water Resources have been developed the water quality assessment system and implemented for two in-stream water rivers in Indonesia, Rapport of internal study (2003).

2. Methodology and Architecture of the Water Quality Index System

Several steps on assessment of the water quality index system

The several steps are commonly used to assess the classification of water quality degradation degree, called the evaluation system of water quality index, as follows:

- classifying the water quality parameters into 15 alterations which have a comparable nature and impact on environment;
- evaluating the appropriate limit value for each water quality parameters into 5 index classes respectively representing by blue, green, yellow, orange, and red for excellent quality of unpolluted water, good water quality, moderate water quality, bad water quality, and unusable water quality of very polluted water;
- formulating the water quality index classes for all parameters of each alterations with mentioning the range of 0 to 20 for index-1, of > 20 to 40 for index-2, of > 40 to 60 for index-3, of > 60 to 80 for index-4, and of > 80 to 100 for index-5;
- fixing the water quality index by evaluating of all parameters in each alterations and choice of the very bad value of the water quality parameter as the representative for the index of alteration and following by choice of the very bad alteration as the representative for the water quality index.

Classification of the water quality parameters into 15 alterations

The in-stream water quality of a river segment area is designated by the monitored value of the water quality parameters, although for generalizing the water quality status in the common sense it is necessary classified around of the 150 parameters of comparable nature and impact on environment into 15 alterations, as following: 1. temperature; 2. color; 3. suspended particles; 4. oxidized organic matters; 5. nitrogen matters; 6. nitrate; 7. phosphorous matters; 8. mineralization; 9. acidification; 10. inorganic micro-pollutant for raw water; 11. inorganic micro-pollutant for bryophytes; 12. pesticides for raw water; 13. organic micro-pollutant non-pesticides for raw water; 14. micro-organisms; and 15. phytoplankton.

Table 1. Example, the oxidized organic matter parameters of water quality index classification

Alteration	Parameter	Unity	Limit value of parameter for index classification				
			Index-1	Index-2	Index-3	Index-4	Index- 5
Oxidized organic matters	Dissolved oxygen	mg/l O_2	8	6	4	3	< 3
	Oxygen saturation	% O_2	90	70	50	30	< 30
	COD	mg/l O_2	20	30	40	80	> 80
	BOD	mg/l O_2	3	6	10	25	> 25
	DOC	mg/l C	5	7	10	12	> 12
	NH_4^+	mg/l NH_4	0.5	1.5	2.8	4	> 4
	NTK	mg/l N	1	2	4	6	> 6

Note: COD as chemical oxygen demands; BOD as biochemical oxygen demands; DOC as dissolved organic carbons, NH_4^+ as ammonium, and NTK as nitrogen total Kjeldahl.

Category of water quality index according the water quality degradation degree

The assignment of the index of water quality is fixed by 5 categories, as showing in Table 1 for oxidized organic matters for instance, according to the water quality degradation degree taking account of an indicated limit value of the water quality parameters selected from 15 alterations, as following: the index-1 means a category of excellent quality of unpolluted in-stream water and representing by blue color; the index-2 assigns a category of good quality of in-stream water and representing by green; the index-3 indicates a category of moderate quality of in-stream water and representing by yellow; the index-4 assigns a category of bad quality of in-stream water and representing by orange; and the index-5 means a category of unusable quality of very polluted in-stream water and representing by red.

Method for determination of the water quality index

Every parameter around of 150 water quality parameters that including in the 15 alterations has a limit value for each index category, for evaluating the result of water quality monitoring can be started by selecting one of the water quality parameter of each alterations that having the highest index category as the representative of the parameters and than to be continued by comparing the index among of the alterations and selecting one of the alteration that having the highest index category as the representative of the alterations and finally fixing the highest index as the water quality index for the selected location of sampling point of the in-stream water of rivers or lakes.

3. Study on temperature as a sensitive parameter to assess the water quality index for the tropical country

In the literature, Oudin *at. al* (1999), indicated that for the temperature parameter categories, if the value of temperature is below of 21.5 ^{o}C the water quality of in-stream water categorized by index-1, and than successively following by limit values of the temperature of > 21.5 to 23.5 ^{o}C for index-2; of > 23.5 to 25 ^{o}C for index-3; of > 25 to 28 ^{o}C for index-4; and finally for the value of temperature over of 28 ^{o}C categorized by index-5. This category is not suitable applied to the tropical country like Indonesia regarding the risk of classification the natural water quality in several regions into a very bad category of the index-5 and the reality in field showed that the in-stream water indicated by the temperature over than 28 ^{o}C is also appropriate for several uses as well for irrigation and also for natural biology functions. According to the same literature, it seems that the deviation of temperature monitored at the down-stream of an ejected pollutant location is resulted by deducting the effective temperature measured at the down-stream to the temperature at the up-stream, and the value of temperature's deviation can be used to representing the temperature parameter. Although it needs for a sampling point location to be compared by the historical temperature data indicating that it is more applicable used for the tropical climate country such as for Indonesia. The water quality index category indicated by the temperature's deviation is for the value of temperature's deviation bellow of 1.5 ^{o}C indicated by index-1 and successively following by the limit value of temperature's deviation of > 1.5 to 2 ^{o}C indicated for index-2; of > 2 to 2.5 ^{o}C for index-3; of > 2.5 to 3 ^{o}C for index-4; and for the deviation value of temperature over of 3 ^{o}C is categorized by index-5. Of course, in the case of this study the application of temperature's deviation is more realistic and adaptable to be selected.

4. Implementation of the water quality index system for two selected rivers in Indonesia

Data selection from two important rivers

In implementation of the water quality index system for assessment of the in-stream water has been selected for two important rivers, due to the reason of the economic development purposes in Indonesia, located in Java island, that is the Citarum River in West Java and the Brantas River in East Java, where in both the water resources is managed by the Jasa Tirta Public Corporation and the water quality monitoring has been routinely programmed on their annual budget activities. Among the data collection of the two rivers 10 locations of sampling point of the Citarum River monitored on August 2003 and 5 locations selected from 51 sampling point locations of the Brantas River monitored along the period of time series of 9 months of the year of 2003 were applied for running the system.

Determination of water quality index for the Citarum River

The 10 sampling point locations for the Citarum river is applied for running the model by using the data monitored on August 2003, where 3 sampling points (Curug, Walahar and Tanjungpura) located in the down-stream and 7 other locations (Wangisagara, Majalaya, Sapan, Cijeruk, Dayeuhkolot, Brujul, and Nanjung) located in the up-stream of the 3 cascade reservoirs (Saguling, Cirata and Jatiluhur) as showed in Figure 1.

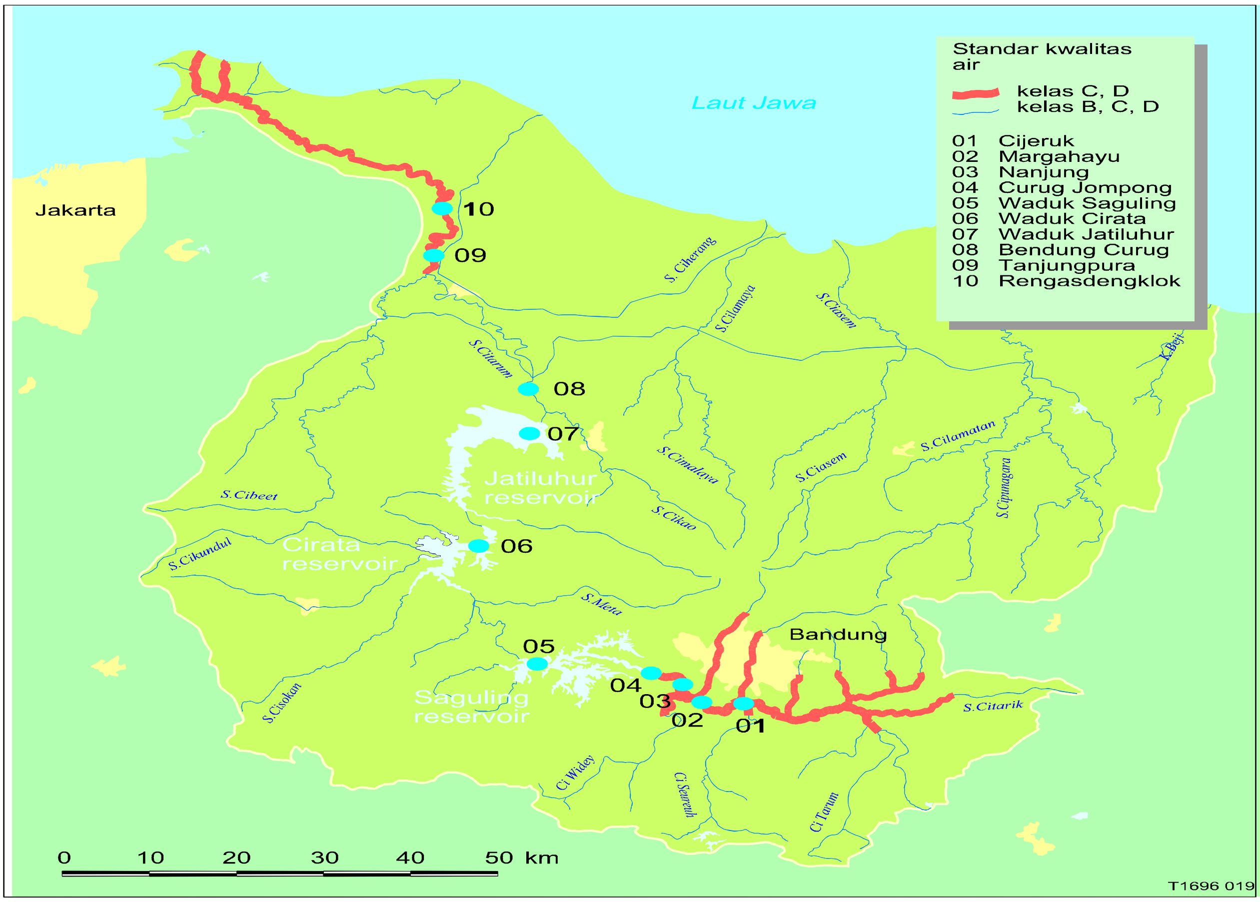

Figure 1. Sampling point locations along the Citarum River

The application of model test, for instance, to be selected for the Nanjung sampling point located at the up-stream region of the Citarum river taking account of the river segment received a very high pollutant coming from industrial and domestic wastewaters of the Bandung city and Bandung district areas, and the result of evaluation just for oxidized organic matters as showing in Table 2 indicated the index-5 of water quality status. The result of evaluation for the 33 water quality parameters which classified into 13 alterations, where two alterations: pesticides and micro-pollutant organic non-pesticides were not be evaluated due to absent of data, showed that the index-5 was founded for suspended particles, oxidized organic matters, and phosphorous alterations indicated by high values of suspended solids, dissolved oxygen, biochemical oxygen demands, total phosphorous, and soluble phosphorous as well as for inorganic micro-pollutant for raw water and micro-organisms. The impact of pollution is really mentioned in field by appearing the eutrophicated phenomena in the Saguling reservoir located in the down-stream of the Nanjung station in where has been installed a biggest hydropower in Indonesia.

Table 2. Example, water quality index evaluation for the oxidized organic matters

Water quality parameter of oxidized organic matters	**Unity**	**Value**	**Class of parameter index**	**Water quality index**
Dissolved oxygen	mg/l O_2	0	5	**5**
COD	mg/l O_2	75	4	
BOD	mg/l O_2	30	5	
NH_4^+	mg/l O_2	0.955	2	

Remarks : location Nanjung; date of monitoring August 21, 2003

The analysis of 10 sampling point locations along the Citarum River by evaluating the 33 water quality parameters showed in Table 3, with application of the similar method such as for evaluation of the water quality index at the Nanjung location given the values of all index of 13 alterations for each locations as well as the water quality index of the in-stream water quality. All locations have the excellent quality of temperature and nitrate but it was very polluted phosphorous matters except at the Bendung Curug, Bendung Walahar and Tanjungpura sampling points where located at the down-stream of the 3 cascade reservoirs.

Table 3. Result of water quality index evaluation for the Citarum River

Types of alteration	**Index of alteration**									
	01a	01b	01c	01	03a	03b	03	08	09a	09
Temperature	1	1	1	1	1	1	1	1	1	1
Color	2	2	4	3	3	3	4	2	3	2
Suspended particles	5	4	5	5	3	4	5	2	2	3
Oxidized organic matters	2	5	5	5	4	5	5	2	2	2
Nitrogen matters	3	1	3	3	3	3	3	3	1	3
Nitrate	1	1	1	1	1	1	1	1	1	1
Phosphorous matters	5	5	5	5	5	5	5	2	2	3
Mineralization	3	1	3	2	1	1	2	1	1	2
Asidification	1	1	4	1	1	1	3	1	1	1
Inorganic micro-pollutant for raw water	3	3	4	3	4	4	5	1	1	1
Inorganic micro-pollutant for bryophytes	1	1	1	1	1	2	3	1	1	1
Pesticides for raw water										
Organic micro-pollutant non-pesticides for raw water										
Micro-organisms	3	5	5	5	5	5	5	3	3	5
Phytoplankton	1	1	4	1	1	1	3	1	1	1
Water quality index	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**3**	**3**	**5**
Number of parameter analysis	33	33	33	33	33	33	33	33	33	33

Remarks: 01a Wangisagara, 01b Majalaya, 01c Sapan, 01 Cijeruk, 03a Dayeuhkolot, 03b Brujul, 03 Nanjung, 08 Bendung Curug, 09a Bendung Walahar, 09 Tanjungpura.

According the result of analysis for water quality degradation status as showing in Table 3, the in-stream water of the Citarum River from up-stream to down-stream is very polluted water that indicated by the index-5 except the Bendung Curug and Bendung Walahar locations which indicated by the index-3. The moderate water quality for some segments of the Citarum River as mentioned by the index-3 at the two locations, although a lot of industries and urban areas founded at the up-stream region, it is probably indicated the presenting of the self-purification phenomena for in-stream water of the Citarum due to the presence of the 3 cascade reservoirs: the Saguling, Cirata and Jatiluhur, where located in the up-stream of the sampling locations. The polluted parameters of the Citarum River were exactly dominated by the phosphorous matters, oxidized organic matters, micro-organisms as well as by the suspended particles.

Determination of water quality index for the Brantas river

The implementation of the water quality index system for in-stream water of the Brantas River to be done after passed the process of selection of the data via the rule of 90%, Oudin *at. al* (1999), F = (i-0.5)/N or i = 0.9 x N + 0.5, where: i is the number of applicable monitored water sample; N is the number of monitored water sample; and F = 0.9 is percentile of applied data. It can be really used this rule, of course, by considering one of the major activities for the water resources management in the Brantas River basin that the Jasa Tirta 1 Public Corporation has been frequently monitored water quality along the Brantas River both by manual collected water sample for the 51 stations and by automatic real time monitoring system for the 23 stations as showed in Figure 2.

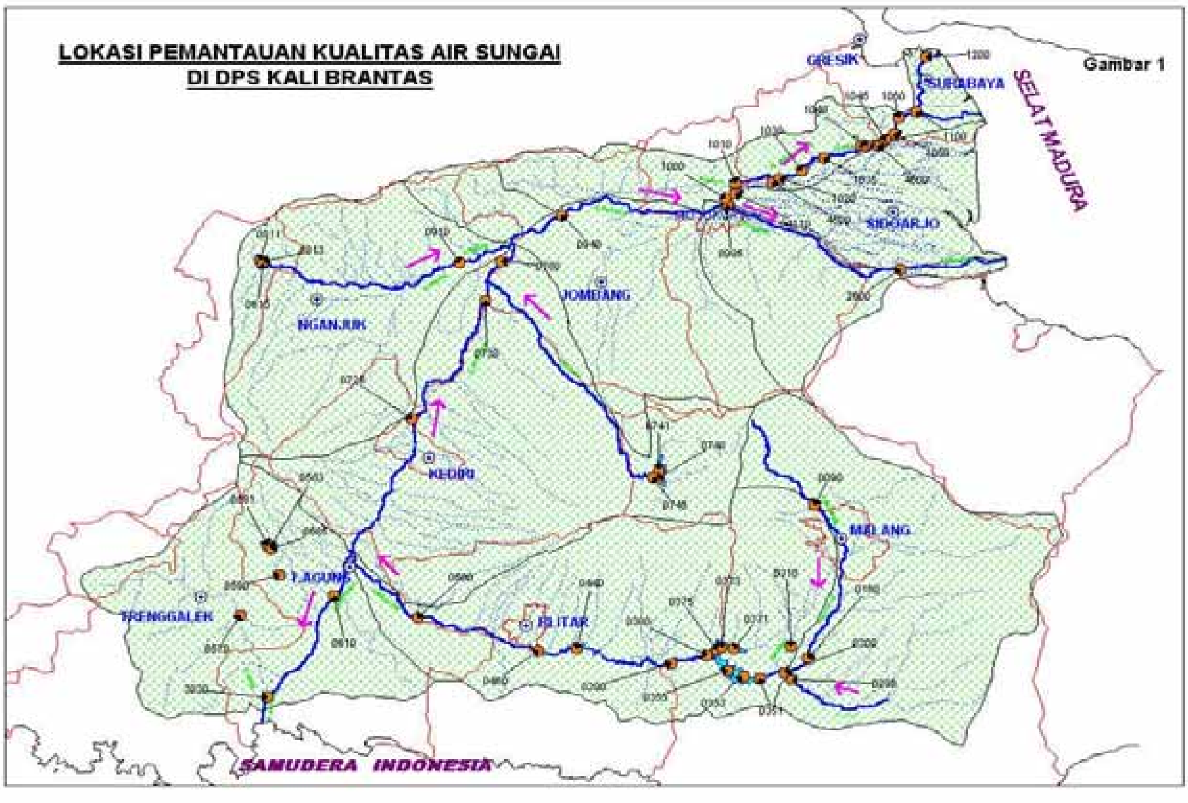

Figure 2. Sampling point locations along the Brantas River

The evaluation of the 22 to 28 parameters is classified into 11 alterations due to the absence of three alterations: color, pesticides for raw water and organic micro-pollutant non-pesticides for raw water as well as the micro-organisms under the annual water quality monitoring program as showed in Table 4. According to the result of the data analysis by implementing the water quality index system showing that the index-5 representing by suspended particles and inorganic micro-pollutant on raw water was founded for all selected locations along the Brantas River, at: the Kedung Paderingan, Ploso, Perning, Ngagel and Porong. The high concentration of suspended solids showing the progressively increasing of the rate of sediment transport in the river as a cumulative impact of land erosion due to deforestation and degradation of the watershed catchment area, since 1998, in the upper of the Brantas basin. The high concentration of copper and mercury in the stream of the Brantas River may be either coming from industrial wastewater or from mountainous eruption sludge and so, of course, it is necessary to be followed up by a detail research program.

The index-4 of oxidized organic matters as well the phosphorous matters in the up-stream and middle stream of the Brantas River and also the index-5 in the down-stream indicating of polluted and very polluted water quality along the river due to high amount of direct or indirect ejected of the industrial wastewater and also stimulated by charging the direct ejected domestic wastewater coming from some households of several cities close the river.

Table 4. Result of water quality index evaluation for the Brantas River

Types of alteration	**Number of applicable result and index of alteration**									
	0160		**0940**		**1020**		**1100**		**2600**	
	i	**index**	**N**	**index**	**N**	**index**	**N**	**index**	**N**	**index**
Temperature	9	1	8	1	9	1	10	1	9	1
Color										
Suspended particles	9	5	3	5	9	5	10	5	9	5
Oxidized organic matters	9	4	8	4	9	4	10	5	9	5
Nitrogen matters	9	3	8	3	9	5	10	3	9	3
Nitrate	9	3	7	2	9	2	10	2	8	2
Phosphorous matters	9	4	8	5	9	4	10	5	9	5
Mineralization	9	1	8	1	9	1	10	1	9	2
Asidification	9	1	8	1	9	1	10	1	9	1
Inorganic micro-pollutant for raw water	9	5	1	5	7	5	8	5	7	5
Inorganic micro-pollutant for bryophytes	9	4	5	1	7	3	10	1	7	3
Pesticides for raw water										
Organic micro-pollutant non-pesticides for raw water										
Micro-organisms										
Phytoplankton	9	2	8	3	9	3	10	2	9	4
Water quality index	**5**		**5**		**5**		**5**		**5**	
Number of parameter analysis	28		22		25		26		25	

Location remarks: 0160 Kedung Pedaringan; 0940 Jembatan Ploso; 1020 Jembatan Perning; 1100 Ngagel; 2600 Jembatan Porong

5. Conclusion

The water quality index system as an indicator of water pollution can be widely used to assess the in-stream river water in Indonesia although the application of the system on the in-stream lake water must be evaluated more detail by studying the quality of water of each different depths. The system needs to be modified according to the local climate of the country especially the sensitive parameters such as temperature.

The result of the water quality index system by implementing for 2 rivers: the Citarum and Brantas showing that in both the in-stream river water has been very high polluted. The result of this study is really supported by the other results of previous studies, of course, due to many cases of water pollution and land degradation in the river basin catchment areas. The parameters indicated a high and specific pollutant to be used as an indicator for selecting the priority of program for the water quality management and pollution control.

In considering the role of the Brantas River is very important to develop the social economic activities of the peoples in East Java province and also Indonesia such as raw water for drinking water of Surabaya, the second biggest city in Indonesia, it seems that it is necessary to be continued forward by studying on verification of the sources of inorganic micro-pollutant in order to chose the priority of the appropriate solution to be implemented in the pollution control program.

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Observation and modeling of sediment transport for Comprehensive sediment control

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Sediment moves down from mountain through the phenomena of landslide and erosion, and enters a river. The sediment in the river is transported downstream with the current and pours into the sea. During this course, various problems occur such as overflow from the river due to the raised riverbed and eroded sand beach of the sea.

Until now, these problems are addressed individually for each control area, Sabo, dam, river, and coastal range in Japan. For example, coastal erosion is caused by various entangled factors such as a decrease in sediment transport from the mountain into the sea and a blockage of sediment transport by structures such as a jetty. In order to address these problem effectively, cooperation among the personnel responsible for mountain, river, and fishing port management is required in addition to the actions taken by those responsible for coastal management. This type of cooperative activity is called "comprehensive sediment control" in Japan. In this case, a series of regions is called a "natural sediment transport systems" because the movement of sediment from the mountain to the sea must be considered.

To take appropriate action for "comprehensive sediment control", NILIM conducted (1) measurements of spatial change in the amount of sediment discharge and (2) development of numerical model for estimating topographic change in natural sediment transport system.

Measurements of sediment discharge

Measurements were conducted in Abe River Basin in Japan. A variety of sediment discharge observation devices have been proposed, but the measurement precision of each of these measurement devices has not been systematically clarified. Thus, first, channel experiments were conducted to clarify the measurement precision of sediment flow volume observation devices systematically.

Development of numerical model

The model to estimate topographic change throughout a natural sediment transport system consists of a riverbed variation calculation model and a seashore change model. The riverbed variation calculation model estimates topographic change from the mountainous stream to the flat land and to the river mouth by applying a sediment runoff model from the river basin mountains to the flat land and a riverbed variation model from the flat land to the river mouth. This model was applied to observation results in Abe river basin. Generally, the numerical model fitted with the observation data.

Sediment runoff in the Brantas River Basin after the eruption of Mt. Kelude 1990

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1. INTRODUCTION

So far huge sediment production due to the eruption of Mt.Kelud has given serious damage to the Brantas river basin. On the other hand the eruption has provided soil and sand for agricultural land and construction material. As Mt.Kelud erupts once fifteen years on average, the sediment related disaster and the blessing have repeatedly given to the basin in a short cycle. With regard to the sediment management in the Brantas basin, therefore, an advanced control system both of sediment runoff and the sediment utilization should be developed for the conservation of the preferable river basin. So, as a first step for developing such a system, we made an attempt to clarify the actual situation of sediment runoff after the eruption of Mt.Kelud in 1990. This attempt could provide important information to the sediment management. Hereinafter, we describe the results obtained up to now.

2. RIVERBED VARIATION

Figure 1 shows the Brantas river basin. The reach of our interest is from Tulungagung to Mojokerto. Some tributaries, such as Badak River, Ngobo River and Konto River, flow into this reach. Figure 2(a) and (b) show the bed variation of this reach from 1978 to 1996. Before the eruption 1990 bed degradation had taken place, particularly the bed level was locally lowered near Ploso. According to a survey by JASA TIRTA, the volume of sand mining at several points along the main river is distributed as shown in Figure 3. The sand is taken in the whole reach, but the volume near Ploso is comparatively large because there is a big plant of sand mining. Thus, the bed degradation is probably caused by the sand mining. Immediately after the eruption 1990, the situation changed from bed degradation to bed aggradation, but the condition returned to the bed degradation in one year. Figure 4 shows the grain size distributions of the bed material collected near Kediri in 1994, 1999 and 2004. This figure shows armor coat is developing in the main river with the bed degradation.

3. WASH LOAD

Generally, wash load transport rate is expressed by $Q_w = \alpha Q^2$. The coefficient α reflects the activity of sediment erosion in the basin. Therefore, the erosion activity could be monitored by means of the observation of wash load. We carried out field observations on wash load from 1998 to 2004. Figure 5 shows the change of the coefficient α. From 1998 to 2003 the value was remarkably decreasing because of the stabilization of gullies in the mountain area. Against our expectation, the latest data indicates the increase of α. Recently the sand mining site has extended to the more upstream region especially in Lesti River. Also, the illegal deforestation is not regulated yet. The increase of α seems to be caused by these impacts.

4. SEDIMENT SUPPLY FROM THE TRIBUTARIES

Shortly after the eruption 1990, the lower reach of the Badak River was filled up with sediment, but according to our field surveys in 1994, 1995 and 1996 little sediment had been transported by floods in the river. This fact shows that immediately after the eruption a large amount of sediment was supplied to the main river through the tributaries, but after that no sediment supply condition is maintained. So, we carried out the numerical simulation of the riverbed variation for several sets of sediment supply condition and estimated the possibly supplied sediment volume. Consequently, if the sediment discharges from the tributaries are given as shown in Figure 7(a), the simulation result agrees with the actual bed variation immediately after the eruption. This sediment discharge from Badak River was calculated using the grain size distribution shown in Figure 6 and the local topographical feature near the confluence. Thus we infer that immediately after the eruption the produced sediment is discharged to the main river by the local flow near the confluence. Figure 7(b) shows the simulation result for no sediment supply. Even if we employ such a condition, the topographical change after 1991 cannot be explained. This means the sand mining is a first factor of the bed degradation. Figure 4 shows the change in the grain size distribution of bed material near Kediri. The agreement between the simulation result and the observation result is not so bad.

5. CONCLUSION

We analyzed the topographical change in the Brantas River before and after the eruption of Mt.Kelud in 1990 and discussed the change in the situation of sediment runoff. As a result, it is found that the sediment supply from the tributaries causes the bed aggradation immediately after the eruption, but the active sand mining changes the situation to degradation almost in one year. The sediment supply immediately after the eruption can be estimated with the grain size of the sediment produced by the eruption and the local flow condition near the confluence.

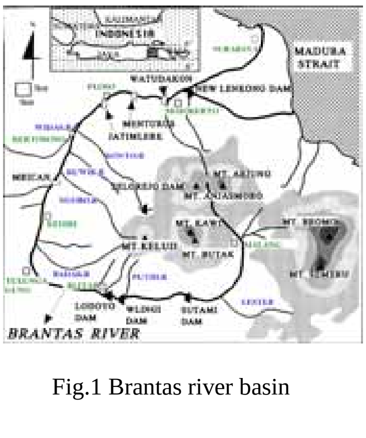

Fig.1 Brantas river basin

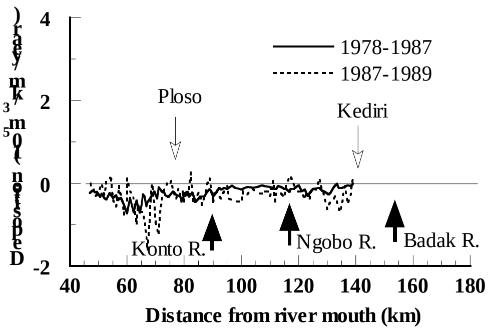

Fig.2 a）Bed variation before the eruption of Mt.Kelud 1990

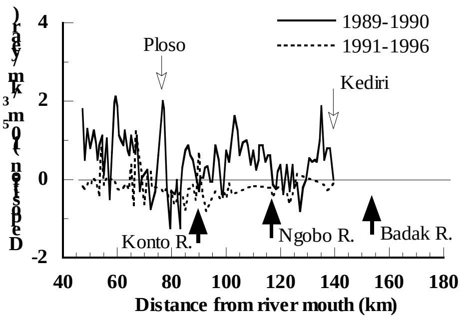

Fig.2 (b） Bed variation after the eruption of Mt.Kelud 1990

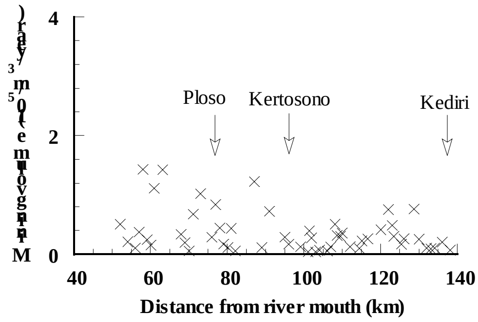

Fig.3 The estimated sand mining volume

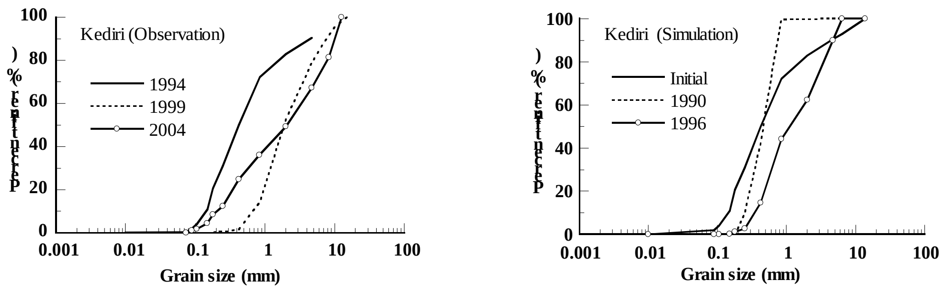

Fig.4 Change of grain size distribution of the bed material in Kediri

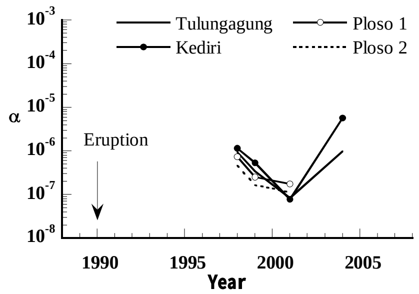

Fig.5 Change of the coefficient α after the eruption 1990

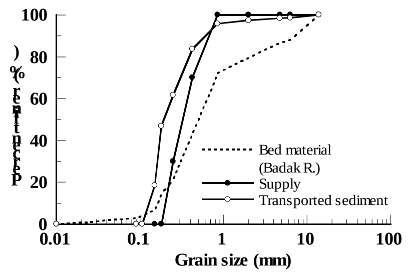

Fig.6 Grain size distribution of supplied sediment and transported sediment

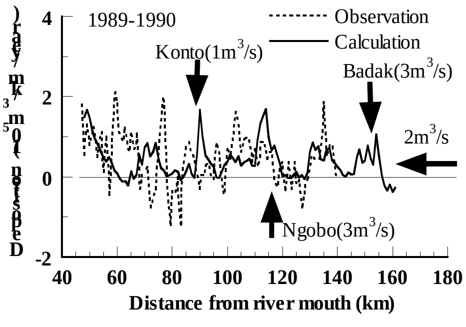

Fig.7 (a) Simulation result of bed variation from 1989 to 1990

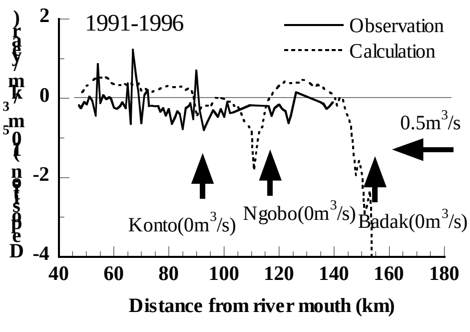

Fig.7 (b) Simulation result of bed variation after 1991

Form Abstract
First International Workshop
on
Water and Sediment Management in Brantas River Basin
Batu, July 28-29, 2005

Title	Handling of Critical Land of Watershed Brantas
Abstraction	Balai Pengelolaan DAS Brantas (BPDAS Brantas) covering 10 Sub-Province and 7 town, there are : Malang Sub Province, Blitar, Trenggalek, Tulungagung, Kediri, Nganjuk, Jombang, Mojokerto, Pasuruan and also Sidoarjo, and Batu Town, Malang, Blitar, Kediri, Mojokerto, Pasuruan and also Surabaya. Critical land in and outside forest area in this time for the width of 280.258 Ha, and pursuant to data of PT. Jasa Tirta I year 2003, that happened sedimentation in all Dams which there are alongside River of Brantas and highest sedimentation in Dam of Sutami that is 145.200.000 m3. For the agenda of handling critical land, year 2003 Government have formed Team Co-Ordinate repair of environment through the National Reforestation an Rehabilitation, as the implementation of is Gerakan Nasional Rehabilitasi Hutan dan Lahan (GERHAN). GERHAN planned to be executed by during 5 year start year 2003 up to 2007. In region work BP DAS Brantas have realized by activity for the width of 29.197,8 Ha (year 2003) and year 2004 for the width of 35.495 Ha. While for year 2005 up to year 2007 have been planned by for the width of 206.285,2 Ha. With GERHAN expected critical land in DAS Brantas can lessen, erosion in control and sedimentation can be minimized, the mentioned earn form with participation / contribution from all good sides of Central Government, Local Government and the parties which is have importances to and also society.
Guest Speaker	C. KUKUH SUTOTO
Institution	BPDAS Brantas
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Form Abstrak
First International Workshop
on
Water and Sediment Management in Brantas River Basin
Batu, July 28-29, 2005

Judul	Penanganan Lahan Kritis DAS Brantas
Isi Abstrak	Wilayah kerja Balai Pengelolaan DAS Brantas (BPDAS Brantas) meliputi 10 Kabupaten dan 7 kota, yaitu : Kabupaten Malang, Blitar, Trenggalek, Tulungagung, Kediri, Nganjuk, Jombang, Mojokerto, Sidoarjo serta Pasuruan dan Kota Batu, Malang, Blitar, Kediri, Mojokerto, Pasuruan serta Surabaya Luas lahan ritis di dalam dan diluar kawasan hutan saat ini seluas 280.258 Ha, dan berdasarkan data dari PT. Jasa Tirta I tahun 2003, bahwa terjadi sedimentasi di semua Bendungan / Waduk yang ada di sepanjang Sungai Brantas dan sedimentasi tertinggi di Bendungan Sutami yaitu 145.200.000 m3. Dalam rangka menangani lahan kritis, tahun 2003 Pemerintah telah membentuk Tim Koordinasi perbaikan lingkungan melalui Rehabilitasi dan Reboisasi Nasional, sebagai implementasinya adalah Gerakan Nasional Rehabilitasi Hutan dan Lahan (GERHAN). GERHAN direncanakan dilaksanakan selama 5 tahun mulai tahun 2003 sampai dengan 2007. Di wilayah kerja BP DAS Brantas telah direalisasi kegiatan seluas 29.197,8 Ha (tahun 2003) dan tahun 2004 seluas 35.495 Ha. Sedangkan untuk tahun 2005 sampai dengan tahun 2007 telah direncanakan seluas 206.285,2 Ha. Dengan GERHAN diharapkan lahan kritis di DAS Brantas dapat dikurangi, erosi terkendali dan sedimentasi dapat diperkecil, hal tersebut dapat terwujud dengan partisipasi / kontribusi dari semua pihak baik Pemerintah Pusat, Pemerintah Daerah dan para pihak yang berkepentingan serta masyarakat.
Nama Penyaji	C. KUKUH SUTOTO
Instansi	BPDAS Brantas
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COMPREHENSIVE BASIN-WIDE SEDIMENT MANAGEMENT STUDY IN THE BRANTAS RIVER BASIN

- Water Resources Existing Facilities Rehabilitation and Capacity Improvement Project (WREFR&CIP) -

Masaki ITO

Team Leader, Consultant Team for WREFR&CIP

One of the main objectives of the project (WREFR&CIP) is to restore the capacity and function of existing damaged facilities that were built with the financial assistance of OECF/JBIC. In the Brantas River, the Upper Bengawan Solo River, and the Madiun River basins, there are many damaged river facilities due to the riverbed degradation. Further, in the Brantas River basin, there are many sediment related issues in the Brantas River such as eruption of Mt. Kelud, pyroclastic flows and debris flows from Mt. Kelud, sedimentation problems in the reservoirs, and estuary deposit of the Porong River.

Engineering studies were conducted on the comprehensive basin-wide sediment management study for the Brantas River basin to solve the sediment related issues in the basin and to manage the sediment in the basin. In addition, the engineering studies comprise the following objectives:

(1) Formulation of a riverbed management plan for the Upper Bengawan Solo River and the Madiun River basins,

(2) Formulation of a watershed conservation master plan for the four (4) target areas to reduce and control sediment yield and discharge into the Brantas River system,

(3) Survey on solid waste disposal into the Upper Brantas River, and

(4) Other structure improvement study.

To solve the various sediment related issues and to manage the sediment in the Brantas River basin, the concept of Sediment Flow System which covers all the sediment flow from the watershed to the river mouth was introduced into the study, since the sediment related issues in the Brantas River are ranging from the watershed to the estuary and some of the issues have been induced by the unbalanced sediment flow between the upper reach and the lower reach due to the erupted materials of Mt. Kelud, blocking of sediment flow by the sabo facilities and dams, and sand mining in the river.

On sediment yield and transport in the Lesti River Basin - Experiences from field observations and remotely sensed data -

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Integrated sediment management is crucial for water resources and river environment, especially when dam reservoirs are located at downstream of erodible volcanic area, such as the Lesti River Basin (Upper Brantas River Basin), Indonesia. The large amount of yielded sediment brings severe sedimentation problems affecting the reservoir capacity. Intensive erosion control is necessary with the understanding of dominant sediment sources and their trends based on the inter and inner annual variability of land cover condition.

The continuous observations of rainfall and soil erosion have been conducted in the Lesti River Basin since October 2003. We implemented also some intensive field observations on discharge and sediment conductivity inside the river channel for some days in February 2003, December 2003, and February 2005. We measured discharge and sediment conductivity at several locations along the river for the sake of identifying how sediment yielded from catchment flows into river channel. The observation results showed that sediment conductivity increased up to about 15,000 ppm within a few hours after rainfall at a location whose catchment area is vastly cultivated, while sediment conductivity did not increase more than 30 ppm at a location whose catchment area is covered by forest. These results indicate that the dominant sediment source in the Lesti River basin is cultivated area.

Currently, we investigate the relationship between rainfall, land cover and soil erosion by utilizing micro rain radar and remotely sensed data (ADEOS/AVNIR, July 1997, 16m; LANDSAT7/ETM+, May 2002, 30m; and the multi temporal TERRA/MODIS from January 2002 to September 2003, 250m). NDVI series from the multi temporal TERRA/MODIS indicates high seasonal variability of the vegetation activity. The NDVI trend indicates rapid vegetation growth in the beginning of rainy season. At the same period the installed erosion measurement has observed higher rate of sediment load, which suggests the erosion rate may be higher at the beginning of the rainy season.

EFFECT OF LAND-USE CHANGE ON SEDIMENTATION RATE AT UPPER CITARUM RIVER BASIN, WEST JAVA PROVINCE

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ABSTRACT: *A weak management in land-use planning can result in disasters and great losses to the people. Citarum river basin is an example of the miss management practice. Deforestation caused by urbanization of upper Citarum watershed has lead to an increasing sedimentation rate. It quickly affects Saguling Reservoir's capacity lying in the main stream of Citarum. Eventually, people who usually get benefit from the reservoir may suffer losses due to its ineffectiveness. To overcome this problem, not only a forestation action should be done but also some anticipating actions such as continual monitoring at Citarum stream and periodical sounding of the reservoir.*
Keywords*: land-use change, sedimentation rate, reservoir's capacity, monitoring, sounding*

INTRODUCTION

Background

The more increasing population rate and economic growth in Indonesia results in the more changing land-use of urban area. Unfortunately, it is often found that the land-use management practice does not comprise water balance aspect. The practice can effect in many disasters such as floods, drought and high-rate sedimentation.

Those disasters have all been found to occur in main watersheds of West Java Province, which are also including Citarum watershed. High-rate sedimentation is one of the major problems, which decreases the capacity of most hydraulic structures. To give a real description about the effect, this study is focused on sedimentation rate at Saguling Reservoir.

Citarum River is a major river in West Java Province with 269 km in length and 6080 km^2 in area of catchment. The main stream begins at Mount Wayang (1700 m height) and ends at Java Sea. The upper river basin of Citarum lies in upper area of Bandung City between Mount Tangkuban Perahu as North boundary and Mount Patuha as South boundary. Two major sub-streams in the upper Citarum watershed are Citarik and Cisangkuy River.

There are three large reservoirs built in the midstream of Citarum River. The upper reservoir is named Saguling, the middle one is Cirata and the lower one is Jatiluhur. The intentions of their construction are to be a main source of hydropower in Java Island, also of water supply to freshwater fisheries and agriculture. Because of its position among the other two, Saguling Reservoir retains most of sediment brought by Citarum stream. If the sedimentation keeps happening without any prevention and controlling actions, it will become a serious danger to the majority of Java Island's people because with the energy output of 700 MW, Saguling Reservoir supports the people's need of electricity significantly.

Purpose and Objective

The purpose of this study is to describe the effect of land-use change on sedimentation rate. The objective is to give representation of the land-use change effect to the lifetime of Saguling Reservoir, located at upper Citarum river basin.

Scope of Study

The scope of this study can be summarized as follow:

- Land-use change of an upper catchment area
- The relationship of land-use change and sedimentation rate
- Effect of sedimentation rate on the capacity of water resources infrastructure

ANALYTICAL STATEMENT

Land-Use Change

Condition of upper river basin is an important factor in controlling the water balance in the overall watershed. The upper river basin should function as a conservation area. It is very important in maintaining water continuity in all seasons, restraining man-cause floods as well as supporting sloping ground from erosion or sliding.

Upper Citarum river basin has been a well-populated urban area. As the people exert economic growth, they need more and more space to build. At last, it affects land-use proportion in the region. It is known from collected data that forest proportion in 1993 compared to the overall catchment area was 27% meanwhile in 2003 it has decreased to merely 14%. It can be stated from the phenomenon that the upper Citarum river basin has been getting out of its proper function as conservation area.

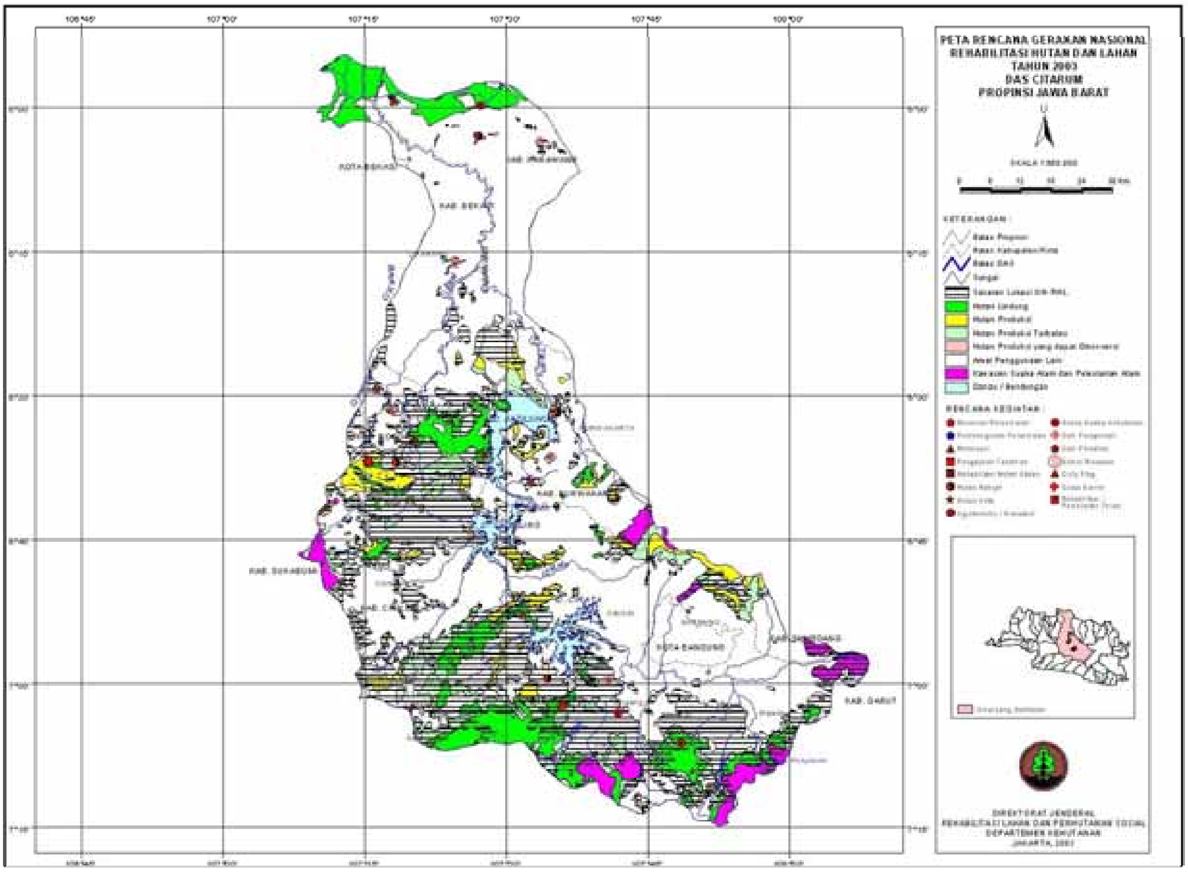

Fig 1. Citarum Watershed and Rehabilitation Planning Area of GN-RHL Project (46678 Ha)

Sedimentation Rate

The upstream area of Citarum Watershed is surrounded by many mountains, such as Mount Wayang, Mount Calancang, Mount Patuha, Mount Malabar, Mount Tangkuban Perahu, etc. Therefore, the upstream land area is steeply sloping. This characteristic brings large tendency to soil erosion and sliding if the land lacks in well covering vegetation.

To give a real description of erosion tendency in Citarum upper area, a series of data in two time periods is compared. The monitoring station is at Nanjung, which is located right at upper course of Saguling Reservoir. With annually averaged flow of 92.3 m^3/s, the upper Citarum stream monitored at Nanjung is quite heavy. The flow brought about 1.05 million ton per year of suspended sediment in 1981 to 1982 period. With less covering vegetation on the upstream area, it is noted that the sedimentation rate had increased to 1.47 million ton per year in 2004. In short, there is 40% rising of sedimentation rate in almost 20 years period.

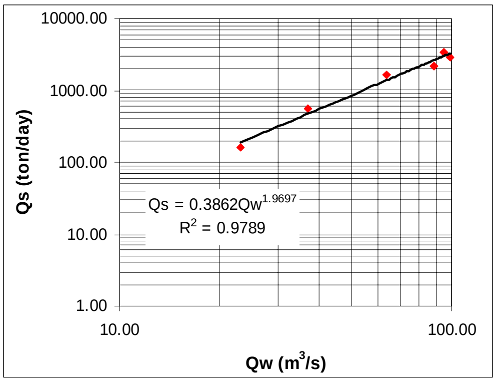

Fig 2. Qw-Qs Relationship at Nanjung Station Year 1981-1982

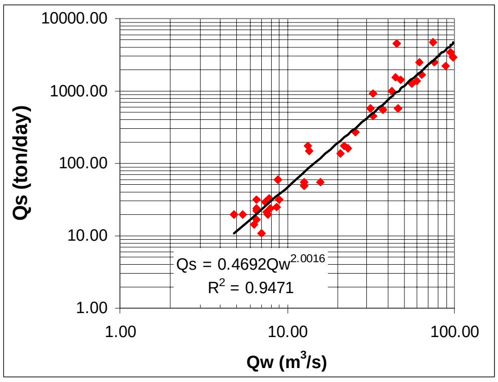

Fig 3. Qw-Qs Relationship at Nanjung Station Year 2004

Lifetime of Saguling Reservoir

Construction of Saguling Reservoir was done in 1986 with capacity of 881 million m^3 at +643 m water level. The sounding of Saguling Reservoir in 2004 resulted in a change of volume at the same water level. The reservoir's capacity lessened to 730.5 million m^3. It means that there had been sedimentation at a rate of 8.36 million m^3 per year. In other words, sedimentation caused by deforestation of upstream region has decreased the lifetime of Saguling Reservoir.

Based on the latest research held by UBP Saguling (Unit Bisnis Pembangkitan Saguling), it is known that the remaining lifetime of Saguling Reservoir at dead storage elevation of +616 m is approximately 25 years.

CONCLUSION AND RECOMMENDATION

Conclusion

Land-use change in the upper Citarum river basin has caused the increasing sedimentation rate along the river and the reducing lifetime of Saguling Reservoir.

Recommendation

It is important to rearrange the land-use of upper Citarum river basin through water and land conservation.

As an input to land-use planning, it is recommended to monitor the river flow and sedimentation rate as well as sediment characteristics at Saguling Reservoir.

The quantitative and qualitative analysis of erosion and sedimentation in upper Brantas Basin

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The erosion and sedimentation rate in the upper-part of Brantas basin is a serious problem of the water use in the Brantas River. Sutami reservoir is the only facility of mainstream of the Brantas River. Sengguruh dam, the most upstream reservoir, is functioned mainly as sediment trap for Sutami reservoir. The quantitative analysis of surface erosion of this basin area was analyzed using USLE. The annual sedimentation in the Sengguruh reservoir is predicted around 2,148,000 ton/yr and Sutami reservoir is around 1,707,600 ton/yr. The percentages errors are 9.5% and 13.6% for Sengguruh and Sutami reservoir comparing to observed values in 2002 and 2003. The quantitative results indicated that Sumber brantas and Lesti sub-basins vulnerable to surface erosion due to the slope of area and soil type (mostly dominated by alluvial). The 3D mapping of the deposited area in reservoirs is identified also. Since quality of material deposited in reservoir also plays a important point to identify from where the sources of material is come from, especially in the case of reservoir basin which the surface erosion plays a key role as a dominant process for sediment accumulation, the proposed method for qualitative analyses of sediment deposited in reservoir based on mineralogy characteristic resulted from X-ray diffraction is being done. Preliminary results of the qualitative analysis shows the grain size properties of material deposited in Sengguruh reservoir have a good agreement with source material from Tawangrejeni than Poncokusumo, Gedok Wetan for Lesti river reach while the sources from Brantas Origin, Kendalpayak have also good relationship with deposited sediment from Brantas River reach.

Keywords : *surface erosion, USLE, quantitative, qualitative, X-ray diffraction, mineralogy*

Reservoir Sedimentation Prediction
Based on Pollutant Characteristic in Watershed

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ABSTRACT

Reservoir sedimentation prediction use some approach like as watershed management and runoff on watershed. Recently, watershed condition is changing then influence physical condition of watershed and river. One of the changing indicators is rate pollutant increase in river stream. Change of pollutant will influence reservoir sedimentation level, where during the time the indicator is only erosion and runoff in watershed for reservoir sedimentation prediction.

The aim of this research is to determine relation between reservoir sedimentation and watershed also river characteristic itself. One of characteristics will be evaluated is pollutant changing in river and pollutant dispersion with reservoir sedimentation level. Expected output is pollutant characteristic that influence reservoir sedimentation level.

Methodology use mathematically model and GIS for erosion and pollutant prediction on Watershed. Then combined with pollutant transportation model in river and analyze pollutant dispersion and the impact for reservoir sedimentation level

Introduction

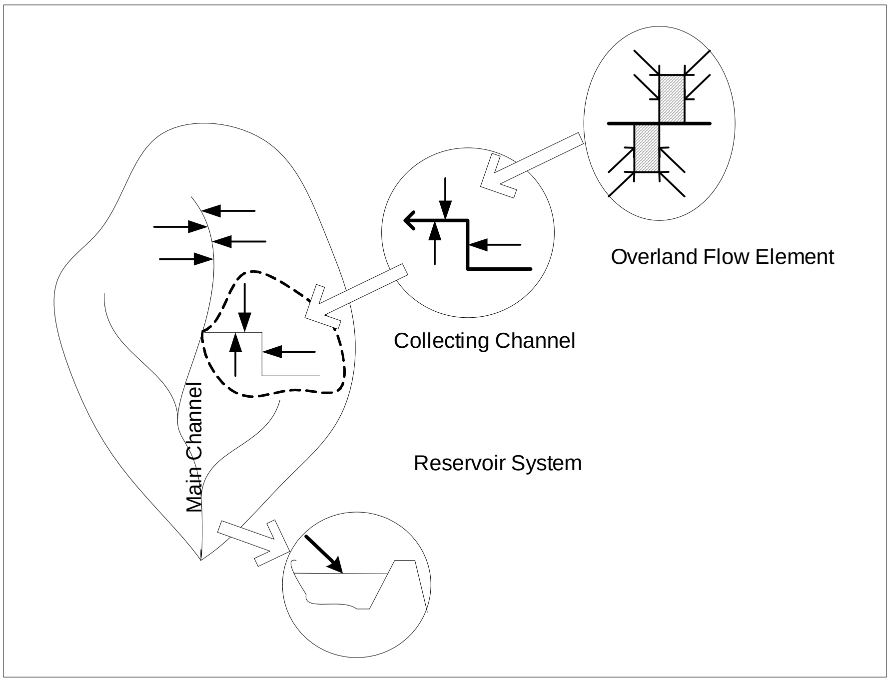
The increasing of the sedimentation in the river and the reservoir was the one component of the watershed management. The reservoir as the one of the construction that receives the sediment from the watershed and the river will decrease its function because of the increasing of the sediment that entering to the reservoir. The increasing of the sediment that entering to the reservoir will make the effective capacity of the reservoir decrease and will decrease the effective age of the reservoir.

Some model has to develop to predict the amount of the sediment that entering to the reservoir. The models of the sediment movement make some correlation between the amounts of sediment and the component in the watershed that caused the increasing of the sediment amount. The component of the watershed that caused sediment amount such as land erosion, watershed physical condition, river condition, etc have used widely as the basic of the model to make prediction of the sediment movement.

Recently, the one component of the watershed that increase rapidly was the amount of the pollutant that containing in the watershed and in the river that caused by the increasing of the human, agriculture, and industry activity. Until today, the influence of this component to the sedimentation in the reservoir has not studied more detail. It was necessary to conduct some research to develop the model that making some correlation between the increasing of the pollutant in the river and the watershed with the amount of the sediment that entering to the reservoir. The goal this research was to develop the model that correlated the pollutant with the reservoir sedimentation level to supporting the other model that using the component of the watershed to predict the amount of the sediment that entering to the reservoir.

Model Developing

The model that develops was combination between the models that develop before. The model was combines between erosion model in the land, predicting the quantity sediment and predicting pollutant burden model in the river, and the influence of the pollutant model in the reservoir. The system of the developing model will describe at the figure bellow.



The model of the overland flow element was the model that develops at the land or in the watershed that produce the amount of sediment from the land. This model was using the mathematical approaching to predict the erosion, sediment, and runoff in the land. The watershed physical component was using as the basic for developing the model. GIS approaching conducted to changing the physical component to the spatial data.

This model will continue with the model that develops in the collecting channel or in the river. In this part, the model actually was the water quality and sediment model. The model was accommodating the pollutant influence from the land that caused by the municipal activity and the agricultural activity and the influence from the industry activity.

The result of these two models, as the sediment amount and the amount of the pollutant will be use as the basic of the prediction model in the reservoir. In this model the correlation between the amounts of the sediment that entering to the reservoir and the amount of the pollutant will develop. This model will define the influence of the pollutant to the sedimentation in the reservoir, including the distribution pollutant and sediment in the reservoir and the characteristic of the sediment that lay in the reservoir, and the cause of the increasing of the sedimentation correlating with the pollutant in the watershed, river and the reservoir.

Predicting Technique of Erosion, Sediment and Runoff

As the tools to predict the erosion, sediment and runoff, the WEPP mathematic analysis model was used to simulating the watershed characteristic data and comparing with the existing land use that forming as the spatial data to obtain the amount of the erosion, sediment and runoff.

WEPP requiring the four groups of input data to simulating the land erosion, sediment and runoff as described as follow: (USDA, 1995):

1) Climate data such as daily rainfall, temperature, sun radiation and wind velocity. The dependent program called CLIGEN used to generating the climate data in continue or in single occurrence.
2) Topographic data such as length of slope, slope inclination and the slope direction.
3) Soil data such as texture, albedo (the part of sun radiation that reflected to the atmosphere), initial saturation, soil erodibility soil critical shear strength, hydraulic conductivity, the percentage of sand silt, clay and the organic material, cationic exchange capacity and the rock percentage

   The effective conductivity estimation procedure (Kb) at the agriculture land, for soil with the clay content less than 40% was:

   $$Kb = -0.265 + 0.0086 SAND^{1.8} + 11.46 CEC^{-0.75}$$

   And for the soil with the clay content more than 40% the equation was:

   $$Kb = 0.0066 \times e^{244/CLAY}$$

   Where SAND was the percentage of sand, CEC was the cationic exchange capacity and CLAY was the percentage of the clay.
4) Plant data and the land management that was accommodated with the type of plant and the land use and the condition of existing land management.

Analysis of Rainfall and Temperature Data

The rainfall data as the model input was obtain from the logger reading with the Boxcar program supporting. The recording tool installed at the outlet of study area. The temperature data obtained from the logger and censor that installed in the surrounding of study area and supporting with the Thermo Recorder for Windows to analyzing the data of temperature

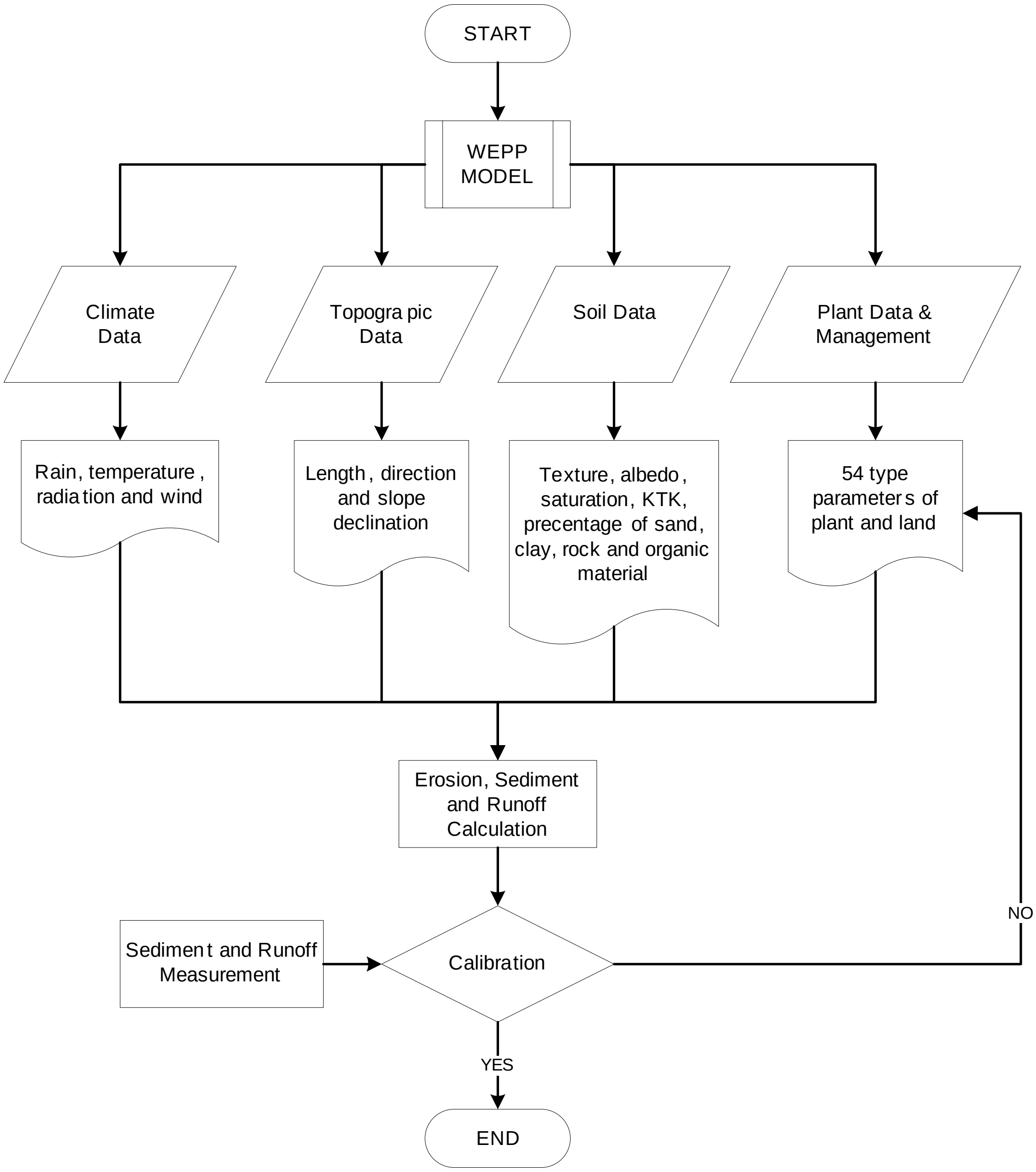
Analysis of Discharge Data

This research requiring the fluctuation water level that measured with the data logger type of standard diver. The discharge data that recorded in the data logger was the water level changing data that quantifying in the pressure change form (cm of water) for every time with supporting of EnviroMon program. The discharge data was formed as the equation connection of the high of water level with the time recording at the data logger. In this analysis, the discharge data was requiring from every time recording that obtain from the discharge measurement from every water level that recorded in the data logger. The discharge measurement conducted with built the construction of weir at the river cross section as the primary data or from the interrelated institution as the secondary data.

Analysis of Sediment Data

Sediment yield was the amount of the sediment that resulted from the erosion that occur at the watershed and measured at the certain time and location. The sediment yield obtained from suspended load measurement or from direct measurement in the reservoir. The result of sediment sample was analyzed at the laboratory and verified the result with the data that obtained from sediment measuring in the river stream. The common model that use was conducting the correlation between suspended load concentrations with the measured discharge. The sediment concentration obtained from water sampling both in regular and only in the single sampling in the location where the discharge measurement conducted. The series of data that collected was plotting at the graph and the power regression was applying to obtain the certain line by the sketcher point. The line that obtained was called Sediment Rating Curve.

The flowchart of this model will describe at the figure bellow.



River Water Quality Modeling

* Water quality simulation model schematization was describing the water quality model with using the digital map. That map was completing with the contour line and land use and so that the map was the GIS map.

The steps that conducted in this model were:

- the digital topographic map with scale 1:25.000
- the location map of big, medium, and small industry spreading
- the location of occupancy spreading at the study area
- the land use map
- the map of water quality observation station location point

- hydrology data that consist with rainfall data, discharge data and river cross-section data
- field survey data and secondary data collecting from the interrelated institution connecting with to determining the type and predicting of the amount of pollutant

- The pollutant source that entering to model area was consist from non point source and point source pollutant. The pollutant content in every reach (1 km) that consist with municipal and land pollutant as the non point source pollutant and the pollutant from industry was the point source pollutant.
  a. Municipal pollutant/domestic pollutant
  The pollution that caused by the domestic pollutant was the sewerage from municipal area, office building, hospital, hotel, public organization, market and recreation area.
  For simplifying the calculation, the determining of the pollutant burden was taking from "Penilaian Secara Cepat Sumber-sumber Pencemar Air, Tanah dan Udara (Djajadiningrat 1990), that determining the BOD, P, N that calculated with per capita/day for each component.
  The pollutant burden was divided into urban, semi urban and rural area.
  b. Land pollutant
  SWAT simulated some process of physically and chemically that occurred at the watershed. For the modeling purpose, the watershed was divided into the number of sub-watershed. The spatial data input at SWAT for every sub-watershed was regulated with: climate data, hydraulic response unit (HRU, groundwater data, and the main channel data. HRU was including the land use, type of soil and some information that consisting at that watershed. SWAT analyzing the entire problem that occurred at the watershed with flow equilibrium as the basic principle. For the purpose of predicting the movement of pesticide, sediment and plant nutrition precisely, SWAT simulating the process that occurred at hydrology cycle that using as the modeling at the following step.
  Hydrology simulation at the watershed was divided into two phases. The first phase was hydrology cycle routing at the land such as the amount of groundwater, sediment, nutrition and the content that move to the river flow. And the second phase was the flow hydrology cycle routing, to predict the movement of the water that mixture with the sediment and pollutant in the river flow.
  The hydrology cycle routing phase in the land was simulating with SWAT based on the water equilibrium pattern.

$$SW_t = SW_0 + \sum_{i=1}^{t} (R\,day - Q\,surf - Ea - W\,seep - Q\,gw)$$

  Where:
  SW_t = the amount of the water output
  SW_o = initial water content in the soil at i day (mm H_2O)
  t = time (day)
  R day = the amount of precipitation at i day (mm H_2O)
  Q surf = the amount of runoff at i day (mm H_2O)
  W seep = the amount of water at the soil profile that entered into Vades area at i day (mm H_2O)
  Q gw = the amount of water at back water at i day (mm H_2O)

Dividing the watershed into the sub-watershed was making the model easier to reflecting the difference of watershed characteristic. It was increasing the calculation accuracy and describing the water equilibrium better.

The plant requiring the nutrition that used as the plant growing. The plant receives the nutrition from fertilizer supply. The biggest nutrition content was the nitrogen and phosphor, that both of that material has the biggest role when it comparing with the other material that plant required for growing. The nitrogen and phosphor was the two of non-metal chemist material that very important for the plant growing. The occurrence of these materials was important at the specific limit but if that limitation was passed the equilibrium of the water environment will be broke.

The information data that required as the input of the fertilizer supply in the SWAT was:

- the time of supplying (month and day or plant potential head unit fraction)
- type of fertilizer
- the amount of fertilizer
- the distribution of fertilizer supply deeper

SWAT monitoring the 10 mm upper layer from the soil surface. The nutrition that containing at that layer was easy to move to the river flow with the surface runoff. The surface operation was determined with the fertilizer fraction that entering at the 10 mm soil upper layer from the soil surface.

To determining the value of runoff water curve (SCS curve number), it was required the soil type data that conversed into the soil classification group by "Hydrology Soil Group".

c. Industry pollutant (Point Source)

The industry pollutant was the main factor that caused the decreasing of water quality in the river. The industry pollutant water was varied both in quantity and quality, that depending on the type of industry, the industry capacity and the condition of the pollutant treatment installation. The treatment installation was purposed to guarantee the water quality at the river body as the pollutant final output, but in the application there was still some violence occurred. This this was shown from the report of water quality that conducted by the Perum Jasa Tirta where the industry pollutant where the industry pollutant sometime passed the regulation that rolled in SK Gubernur Jawa Timur.

The industry pollutant was the point source pollutant.

Research Methodology

1. Dividing the watershed into sub-watershed in the rivers for 1 km each.
2. Inventorying pollutant that will enter from sub-watershed to the river body with step as follow:

- With AVSWAT, the pollutant amount was determining from the paddy field for every sub-watershed
- With AVSWAT and Penilaian Secara Cepat Sumber-sumber Pencemar Air, Tanah dan Udara, the amount of pollutant was calculated for every sub-watershed in BOD, N and P form.

- The industry pollutant as the point source pollutant that entered from the factory, where the pollutant calculated same with the pollutant from municipal and the indicator was BOD and DO.

The following steps was routing the sources with the QUAL2K method to determining the water quality in the downstream with the BOD and DO indicator.

Influence of the Pollutant to Reservoir Sedimentation

The basic assumption of this research was influence of the pollutant to the reservoir sedimentation will support the sedimentation yield that caused by the erosion in land of watershed. In the other hand said that occurrence of the pollutant that increasing in the watershed and that pollutant entering to the reservoir will cause the increasing sedimentation in the reservoir. The pollutant will act as the catalyst to increasing the sedimentation.

The one process that occurred in the reservoir that influenced by the pollutant was the eutrification process. This process will cause the algae or the other plant the live in the reservoir growing rapidly. If the eutrification increasing rapidly, its will be influencing for the reservoir sedimentation. As the basic assumption, the pollutant that was entering to the reservoir will be creating the increasing of the eutrification process in the reservoir. Some type of the pollutant will be processed as the nutrient of the algae, and increasing the growing of the algae and make the eutrification process increasing rapidly. And the final process will cause the sedimentation in the reservoir increasing faster if it was compare with the sedimentation in the reservoir without the pollutant that entering to.

The parameter in the reservoir that connecting with the pollutant to cause the sedimentation such as:

- Type and amount of the pollutant

  The type and the amount of the pollutant was the parameter that must be determined to making some correlation of the sedimentation in the reservoir. The type and amount of the pollutant parameter will be define for determined what kind of the pollutant that will be processed to become a nutrient for the algae or the other plant that grow up in the reservoir. The type of pollutant will separate as the pollutant that will be processed as the nutrient or the other pollutant that not will processed as the nutrient such as the heavy metal.
- Distribution of the pollutant

  Distribution of pollutant will support the type and the amount of the pollutant to define where and when the pollutant will cause the increasing the sedimentation in the reservoir.
- Type and amount of sediment

  The type of sediment will show what kind of sediment that laid in the reservoir. The sediment will be separated into two type of sediment, the sediment that caused by the erosion in the watershed and the sediment that caused by the reaction of the occurrence of the pollutant in the reservoir. Separating this sediment was base on the origin of the sediment. The sediment from the erosion yield in the watershed will define from the model that developed in the model of overland flow element. The sediment from the pollutant reaction will define with correlation of the amount of the pollutant that entering to the reservoir and the reaction that caused the sedimentation that influence by the pollutant

- Distribution of sediment

  The distribution of the sediment will support the type and amount of sediment to separate the sediment according to the origin of that material. The distribution will define where the material from the erosion sediment yield and from the reaction of the occurrence pollutant deposits into the reservoir.

The process of this model will be combination between the biological process and the technical process. The technical process will be connected with the type, amount and the distribution of the sediment that yielding from the erosion process in the watershed. The biological process will connecting with the process of the eutrification and process of the sedimentation occurrence that caused by the plant that growing in the water with the pollutant as the catalyst agent to make it increasing rapidly.

Assessing the sediment sources of deposited sediment in reservoirs using sediment tracer techniques

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Clarification of sediment dynamics in river basin is one of a key issue for "comprehensive sediment control". However, sediment transports, such as erosion and deposition, highly varied in time and space. Several problems associated with sediment transport, such as riverbed degradation and deposition in dam reservoirs, may be occurred with several decades. This means that sediment dynamics over the medium-term (ca. 10-100 years) is important information for sustainable river basin management. Yet, such information is frequently difficult to obtain using traditional monitoring techniques, due to both problems of representativeness and the costs involved.

Sediment tracer techniques are potential tools for clarification of spatial variability of sediment erosion rate, quantification of sediment sources and median-term erosion rate. Sediment tracers roughly can be classified into four groups (1) grain size distribution, (2) mineralogy, (3) organic matter contents and characteristics and (4) radioisotopes. It has been considered that tracers from (1) through (3) may give us information about sources of deposited sediment and bedload.

In the last few decades, the radioisotope technique have used for estimating net (ca. 40 years) soil flux in many environments (e.g., Walling and Quine, 1990) and for determining spatial patterns of soil loss and sediment accumulation (Walling and Quine, 1991). The technique has been used widely because the radioisotope technique overcomes a number of the problems of monitoring soil erosion and deposition rate over the medium-term. Especially, the Cs-137 (nuclear weapon–produced radioisotope) has been widely used as tracers in mid-latitude area. However, in lower latitude area, the fallout rate of Cs-137 should be small, because of upward current, suggesting that the Cs-137 cannot use in lower latitude area.

Here we report preliminary results of sediment tracer measurements in Brantas River Basin. The applicabilities of mineralogy and radioisotopes to clarify the sediment sources of Sengguruh reservoir and riverbed in lower leach of Brantas River are examined. We found that the Pb-210ex (radioisotope) and Al/Fe ratio (mineralogy) can be used as sediment tracers in Brantas River basin.

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MANAGEMENT OF BRANTAS RIVER
IN THE ASPECT OF EXPLOITATION AND CONTROLLING

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Abstract

Brantas River Basin which has length of ± 320 km and catchment area of 11,800 km^2, covers 25% of East Java area. About 15,5 million people live in the basin and its rainfall is about 2000 mm/year. The water resource potential in the basin is about 12 billion m^3/year. All of those facts prove that Brantas River have become the backbone of economic development due to its role as resources in supporting agricultural and industrial aspects in East Java.

The paddy fields in East Java that use water from Brantas River reach about 302,718 ha with water demand of about 2,5 billion m^3/year. Next, in the industrial aspect, there are about 146 factories in East Java with water demand of about 0,27 billion m^3/year and for the domestic needs (e.g. daily needs, offices, hotels, watering, etc.) reach about ± 1,65 billion m^3/year.

Besides giving some advantages from its water, Brantas River also becomes the primary caused of flood in some parts in East Java. In the rainy season of 2004/2005, inundated area reached 3,398 ha.

From those two contradictive facts, it needs integrated and sustainable water resoutces management from the upper to the lower reach, both at the present and in the future time.

Application of Remote Sensing and GIS for Flood and Sediment Runoff Prediction

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1. Introduction

The Brantas River, 320 km long with 39 tributaries and draining an area of about 12 000 km^2, is the second largest river in Java Island. It originates from the southwestern slope of Mt. Arjuno and flows out into the Madura Strait. The river is surrounded by the Kelud mountain range in the central part of the basin, the Sumeru mountain in the east, the Wilis in the west, and a series of low hills along the northern and southern parts (Catalogue of Rivers, Vol. 1, Takeuchi et al., 1996). Due to comprehensive development of the Brantas River and its tributaries this basin becomes one of more promoting areas for economic development in East Java, such as agriculture, power production, and industry. Control of the river to alleviate floods and to regulate dry season flows is being gained by the construction of dams at suitable points on the main stream of the Brantas River and on its major tributaries. Kyoto University and Indonesia had been conducting a joint research program under a UN project International Decade for Natural Disaster reduction (IDNDR) for 1990’s (EGashira et al., 1997; Takara et al., 1996, 1997).

Located in the center of the Brantas River basin, Mt. Kelud has significant influence on the morphological characteristics of the river. Mt. Kelud is an active volcano that has a history of eruption once every 15-30 years. When it erupts, hundreds of millions of cubic meters of volcanic material flow down the surrounding slopes. The latest eruption of Mt. Kelud on February 10, 1990 produced tremendous volume of volcanic ashes spread over south to west slopes of Mt. Kelud, depositing in villages, paddy fields and plantations within a 20-km radius after the eruption.

Sedimentation in reservoir causes loss of valuable water storage and reduces the effective life of reservoir. Likewise, rivers themselves and various hydraulic and water resources structures are suffering from sedimentation problems.

Takara (1998) proposed a distributed hydrological model that can take various parameters distributed over the basin into account and predict rainfall-runoff and sediment yield in such a volcanic mountainous river basin as the Brantas. Remote sensing (RS) images and geographic information systems (GIS) are effectively used in the hydrological modeling.

2. RS and GIS

RS is one of the powerful tools for observing and monitoring geomorphologic and hydrologic conditions in the air and on the land surface. There are many satellite sensors with resolution of less than 100 m, which are applicable to Indonesia: LANDSAT/MSS (80 m), LANDSAT/TM (30 m), SPOT/HRV (20 m), ERS-1/AMI-SAR (30 m), MOS-1/MESSR (50 m), JERS-1/OPS (24 m), JERS-1/SAR (18 m) and ADEOS/AVNIR (16 m). TRMM/PR is providing rainfall information for tropical regions including Indonesia. A brand-new Japanese satellite ALOS will be launched in 2005, which has fine resolution sensors: PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping, 2.5 m), AVNIR-2 (Advanced Visible and Near Infrared Radiometer type 2, 10 m) and PALSAR (Phased Array type L-band Synthetic Aperture Radar, 10 m). The GEOSS (Global Earth Observation System of Systems) project during 2006-2015 would provide various kinds of satellite and in-situ observation data for a number of defined societal benefit areas such as disaster, water cycle, weather, climate and agriculture.

2.1 Land cover classification map by RS
Using land cover classification techniques installed on DIMPLE, an Australian GIS for image processing, and remote sensing images obtained by Japanese Marine Observation Satellite (MOS-1/MESSR), the author have produced a land cover map for the Brantas River basin (Takara et al., 1997). The information of land cover can tell us the ground surface roughness and permeable conditions of each pixel (50-m grid cell of the satellite image).

Having several spectral bands, optical sensors such as MOS-1/MESSR are useful in land cover classification. In fact, however, they often experience difficulties caused by clouds and are not always effective. To compensate the difficulties, the authors also used some SAR (synthetic aperture radar) images acquired in different months by the Japanese Earth Resources Satellite (JERS-1). SAR can penetrate cloud cover and always detect ground surface. Since SAR is regarded as a single band sensor, it is better to use some images acquired at different times.

2.2 How to produce digital elevation data
Contour lines described in six topographical maps with a scale of 1:50,000 were digitized and processed by ARC/INFO. This GIS for vector data first produce a Triangulated Irregular Network (TIN) coverage from the contour lines. The generated TIN was then processed to a LATTICE coverage. The LATTICE is a grid-based digital elevation model (DEM) with a resolution of 250 m. Channel networks should be digitized for the combination use of this grid-based 250-m digital elevation model (DEM) to produce a flow direction (drainage paths) map and inclination of each grid-cell. An algorithm dealing with the 250-m DEM and a digitized 250-m channel network defines the directions of runoff of rainfall and sediment in each pixel in a flow direction map.

3. Runoff Model

The kinematic wave runoff (KWR) model was applied to each grid-cell where rainfall-runoff and sediment-yield occur. Topography based on DEM and land cover class based on remote sensing images respectively determined the inclination and the equivalent roughness, the KWR model parameters, for each 250-m pixel. Parameter values were adjusted by using rainfall-runoff relationships based on the unit hydrograph method that had been applied before by Indonesian researchers. The KWR model can consider the depth of the volcanic ash that runs off on the slope as sediment to downstream areas. Namely, each grid-cell is regarded as a slope covered with volcanic ash with a uniform depth of y. The rainwater falling on the slope penetrates the volcanic ash up to the depth d from the surface. Subsurface and surface runoffs are taken into account; and if surface runoff occurs then the sediment flows out.

4. Data Used for Validation

The data used for model validation for the Putih River are:
(1) Daily rainfall data at the raingauges on the southern slope of the Mt. Kelud during 1990-1997.
(2) Spatial distribution of the depth of volcanic ash caused by the 1990 eruption of Mt. Kelud.
(3) Sediment yield in tributaries before and after the eruption of Mt. Kelud on February 10, 1990.

5. Model Validation for the Putih River

Hourly rainfall sequences are generated from daily rainfall by a simple hourly rainfall generation model for humid tropics region. Inputted the hourly rainfall to the KWR model for the Putih River basin (26.8 km^2), the author has simulated hourly rainfall-runoff for about seven years (1990-1997) after the eruption of the Mt. Kelud. The sediment yield was also computed and the volume was verified after the simulations. The equivalent sediment yield depth assumed for each pixel is a key parameter for sediment yield estimation. The depth assumed to be 5 mm is considered to be best among 5, 10, 20 mm for reproduction of the sediment yield in the Putih River of about 10,600,000 m3 during 1990 1997 after the eruption.

6. Other Case Studies

Other applications of this model to the Lesti River basin are conducted by Takara and Sayama (2002), Sayama et al. (2003, 2004) and Tachikawa et al. (2004) under a CREST project during 2001-2006 supported by Japan Science and Technology Agency (JST).

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