Runoff Modeling as a Basis of a Water Quality Hydrological Model for Cidanau Watershed, Banten Province, Indonesia

インドネシア・バンテン州チダナウ流域における水質水文モデル構築に向けた流出解析

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Introduction

Cidanau watershed (267.1 km^2) is one of priority watersheds in Indonesia to be given special attention for its handling and management. It is located at 5^{o}21'-6^{o}21' South and 105^{o}7'-106^{o}22' East, and surrounded by densely populated area of Banten Province, such as Cilegon Industrial Area, Anyer Beach, Serang, and Pandeglang District. Cidanau watershed is dominated by paddy fields and plantation area, and also there is swamp protection area (Rawa Danau) in the middle of the watershed. Recently, the economic growth and development in the catchments have given impacts on watershed's functions such as water storage and water purification. Proper watershed water quality modeling is essential for avoiding those environmental problems in the future. Since water quality processes is associated with hydrological runoff processes, a watershed water quality model is performed by integration of a runoff model and water quality components. In this study, a watershed runoff model considering flow directions on sub-catchments was developed as a base model for water quality modeling and its performance was examined.

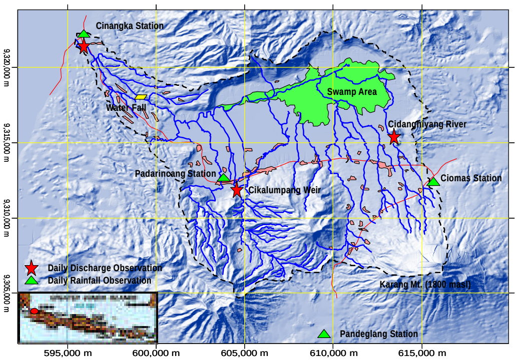

Fig. 1. Cidanau Watershed

Hydrological Properties

Runoff discharges are observed at the intake weir near the sea (KTI Weir, 1996-2003), Cikalumpang Weir, and Cidanghiang River (1999-2001). The stream gauge and the rain gauge stations in Cidanau Watershed are presented on Fig. 1. Annual rainfall in the watershed ranges 1,600-4,200 mm, and annual river discharge (in depth) ranges 900-1,500 mm. Water samples for water quality are taken on weekly basis at KTI Weir . Occasional water sampling is conducted at many point in the watershed.

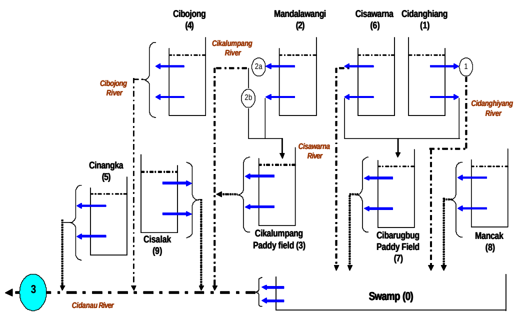

Fig. 2. Sub-division of Cidanau Watershed

Model Configuration

Cidanau watershed was divided into 10 sub catchments, based on land use and geological properties and locations of stream gauges (Fig.2). As shown in the figure, water (surface and/or groundwater) from one sub catchment moves to other sub-catchments or to the river. Each sub-catchment was represented by a 5-layer modified tank model with hourly based calculation. In that type, as it has maximum limit of water storage, water moves up to the upper layer when stored water of the lower layer reaches the limit (Fig.3). Coefficients of discharge (CR), storage capacity (X),

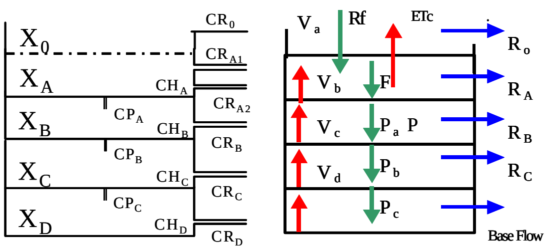

Fig. 3. . Calibrated Parameters of Five layer modified tank model

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percolation (CP) and runoff threshold (CH) of each layer are the parameters to be calibrated. The parameters were calibrated by two steps of random search optimization. The First step was optimization of the model parameters for the sub-catchments having observed discharge data. Those parameter values were employed to some others sub-catchments, considering similarity of the topography or landuse. The second step was optimization for all the rest sub-catchments. Mountainous sub-catchments, such as Cibojong (4), Cinangka (5), Mancak (8) and Cisalak (9), were considered to have the same CR Values. Cidanghiang (1) and Cisawarna (6) were assume to have the same CR values, since both sub-catchments were dominated by paddy fields. The model performance was indicated by Model Efficiency (ME) and Mean Relative Error (MRE) and was compared with the case of lumped application for the whole watershed.

Result and Discussion

The hydrographs at Cidanghiang River, Cikalumpang Weir and KTI Weir are presented in Fig.5, Fig.6 and Fig.7, respectively. High and low flow pattern in all observed data were replicated well, but there are some discrepancies in the end of rainy season. The performance of sub-catchments application was at the same level as the lumped application, as shown in Tab.2. Considering the spatial distribution of pollutant sources and spatial variability of water quality in the watershed, the lumped application of the model can not work properly as a basic structure for water quality modeling. On the other hand, current data availability is not suitable for fully distributed modeling. Therefore, the sub-catchments application of watershed model examined here is considered appropriate, and it is expected to perform as a base model for water quality modeling, where water quality components will be added to the base model structure.

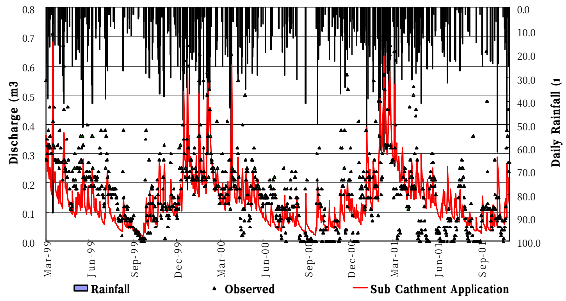

Fig. 5. Hydrograph at Cidanghiang River

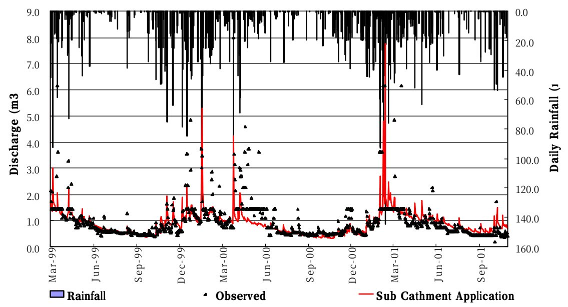

Fig. 6. Hydrograph at Cikalumpang Weir

Table 2. The Model Performances

Observed Discharge	Period		Lumped Application for The Whole Watershed (Modified Tank Model)		Sub Cathment Application	
			ME	MRE	ME	MRE
0 Cidanghiyang River	All Available	(Mar 1999-Oct 2001)	-	-	45.5%	64.9%
	Calibration Period	(Mar 1999-Jan 2001)	-	-	53.7%	47.5%
	Validation Period	(Jan 2001-Oct 2001)	-	-	40.7%	103.3%
1 Cikalumpang Weir	All Available	(Mar 1999-Oct 2001)	-	-	48.8%	23.5%
	Calibration Period	(Mar 1999-Jan 2001)	-	-	49.2%	20.4%
	Validation Period	(Jan 2001-Oct 2001)	-	-	53.2%	30.1%
2 KTI Weir	All Available	(Jan 1996-Jun 2003)	70.0%	39.7%	69.1%	40.9%
	Calibration Period	(Jan 1996-Jan 2001)	68.2%	43.1%	67.0%	45.1%
	Validation Period	(Jan 2001-Jun 2003)	75.4%	33.0%	75.5%	32.7%

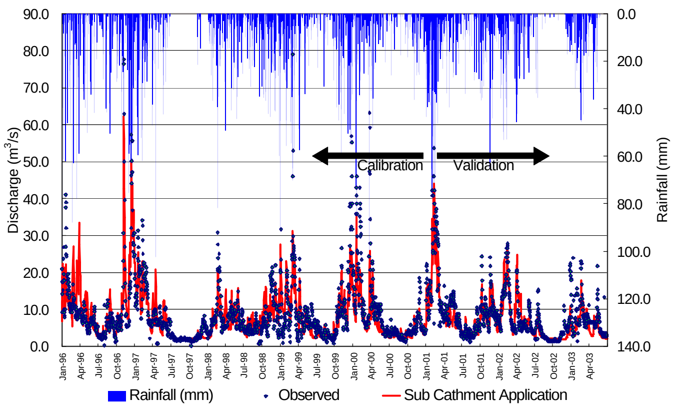

Fig. 7. Hydrograph at KTI Weir

References

Arien Heryansyah. M Yanuar JP. Goto, A. 2003. Runoff Modeling in Cidanau Watershed, Banten Province, Indonesia. Proceeding of 2nd Seminar : Toward Harmonization between Developments and Environmental Conservation in Biological Production. Tokyo, February 15-16, 2003.

Tarboton, David G. 1997. A New Method For The Determination Of Flow Directions And Upslope Areas In Grid Digital Elevation Models. Water Resources Research, Vol. 33, No. 2, 309–319.