学　位　論　文　内　容　の　要　旨
DISSERTATION ABSTRACT

博士の専攻分野の名称　　博士（工学）　　氏名　Intan Supraba

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Uncertainty of Runoff Associated With Uncertainties of Water Holding Capacity and Rainfall Distribution in Mountainous Catchments
(山地流域における保水能と降水分布の不確実性がもたらす流出量の不確実性)

Simulating runoff with higher accuracy to reduce the flood risk is one of the research targets in hydrology. The runoff simulation in previous studies can be classified into two types of hydrological models such as lumped and distributed types. However, these hydrological models simulate runoff deterministically when actually the timing and amount of peak runoff is sensitive to rainfall distribution, both in temporally and spatially due to the non-linear characteristics of rainfall-runoff processes. A previous study investigated the non-linearity of runoff phenomena in mountainous catchments, and proposed water holding capacity distribution theory based on total rainfall-total rainfall loss relationship to estimate effective rainfall intensity as the input data to simulate runoff. The relationship between total rainfall and total rainfall loss is well fitted using the tanh function fitting curve.

This study uses hourly rainfall and hourly runoff data obtained from the Ministry of Land, Infrastructure, Transportation, and Tourisms (MLIT), Japan database during summer and autumn (June-October) at least for 10 years (2002-2011). By checking the data quality, among 106 catchments available in the database, only 36 catchments have the continuous data set. Thus, total rainfall-total rainfall loss relationship is applied to those 36 catchments, and results indicate that those 36 catchments can be classified into 2 groups i.e. 23 catchments having constant-stage tanh-type curve, and 13 catchments having non-constant-stage tanh-type curve. Based on the physical interpretations given before to the linear and constant parts of the tanh curves, catchments having a constant-stage tanh-type curve are characterized by a constant stage after the linear stage due to some heavy rainfall events that have small total rainfall loss, whereas catchments having a constant stage demonstrate saturation conditions.

From the obtained results, this study found that runoff parameter a in the total rainfall and total rainfall loss relationship represents the height of tanh curve that can be used to estimate the potential catchment storage for catchments having a constant-stage tanh-type. Thus, parameter a is an important parameter to know the capacity of a catchment to hold/ to store water during a rainfall event. By knowing the capacity of a catchment, the amount of rain water that become direct runoff that causes flooding can be estimated. However, the plotting result of total rainfall-total rainfall loss relationship show that similar values of total rainfall occurred in two different rainfall events have different values of total rainfall loss. This different indicates the effect of initial soil moisture condition. The rainfall event that having bigger total rainfall loss means the respective rainfall occurred when the catchment was initially dry, and on contrary, the rainfall event that having smaller total rainfall loss means the respective rainfall occurred when the catchment was initially wet.

The obtained results show that parameter a consists of the value of standard deviation (1σ). Thus this value of 1σ is interpreted as the initial water amount, and is used as the parameter to explain about

the uncertainty associated with water holding capacity (initial water amount in a catchment). However, actually rainfall as the input data itself has uncertainty.

The rainfall data by MLIT used in this study is from the rain-gauges that cover the whole Japan. Rain gauges measure the rainfall intensity near to the land surface, but there is limitation on their spatial representativeness due to the location and density of rain gauges. The measured amounts are influenced by several factors such as wind, snowfalls, station relocation, and change of the sensors. A previous study concluded that gauges based rainfall intensity measurements can be biased by factors like wind and evaporation in the range of 10-20%.

Japan Meteorological Agency (JMA) estimates rainfall intensity by using C-band radar and X-band radar that having high spatial and temporal resolution over extended areas. However, radar also has uncertainty due to several factors such as hardware calibration, mountain blockage, and anomalous propagation. Thus, whether measured directly by rain gauges or indirectly by remote sensing techniques, all rainfall intensity measurement contain uncertainty.

The theory about uncertainty is analogous to the random term in Brownian motion. The first theory of Brownian motion is in consequence of the role of Gaussian variables in probability. The stochastic force and derivation of Einstein's theory of Brownian motion from Newton's second law was introduced by Paul Langevin. A recent study analyzed the uncertainty of peak runoff height using the stochastic differential equation (sde) method by analyzing the uncertainty of rainfall distribution where the probability of runoff height can be derived from the Fokker-Planck equation. Results showed that 10% uncertainty of rainfall distribution contributes to the uncertainty of peak runoff height.

In this study, the uncertainty of peak runoff height is investigated by considering two independent uncertainties i.e. uncertainty associated with water holding capacity, and uncertainty associated with rainfall distribution. Two different methods, ensemble method and sde method, are proposed to quantify the uncertainty of peak runoff height associated with those two uncertainties. Results show that the peak runoff height uncertainty increase with the increment of uncertainty associated with rainfall pattern, and uncertainty of water holding capacity needs to be included in the quantification of the uncertainty of peak runoff height. By utilizing the result of uncertainty of peak runoff height, the main objective of this study is to quantify the uncertainty of runoff associated with those two independent uncertainties.