論文の要旨

題 目 Long-term and high-frequency streamflow variations in a shallow gravel-bed river
（浅い礫床河川における河川流量の長期および短期変動に関する研究）

AL SAWAF, MOHAMAD BASEL

The landscape of the mountainous region of Hiroshima prefecture is unique in Japan. It provides opportunities for the development of run-of- river numerous projects. To design these kinds of projects effectively, long-term streamflow records are necessary. However, in order to assess the dynamics of rivers, a reliable characterization of river streamflow during unsteady flow regimes is of paramount importance. Measuring stage is one of the most common methods practiced at permanent gauging stations. Stage records are subsequently transformed to discharge by means of an estimated stage-discharge relationship, referred to as the Rating Curve (RC) method. To the best of our knowledge, there is currently no accepted approach to estimating discharge uncertainties. An empirical one-to-one relationship between water level and discharge evaluated from RC that is determined under the important assumption that streamflow is steady, therefore, this method may be not precise in the case of streams that are subjected to unsteady flows. On the other hand, the development of various techniques and instruments has led to improved streamflow measurements. Among them, the Fluvial Acoustic Tomography (FAT) system that has been developed recently by Hiroshima University is proven to be able to manage various hydrological issues and problems and can be considered a promising technology in the field of water resources. In this context, this thesis focuses on the high-frequency and long-term monitoring of streamflow variations in the Gono River which is a shallow gravel-bed river located in the mountainous region of the Miyoshi-city of Hiroshima, Japan. This work is divided into three broad projects: (i) scaling characteristics of mountainous river flow fluctuations determined using a shallow-water acoustic tomography system, (ii) high-frequency acoustic monitoring of streamflow-turbidity dynamics in a gravel-bed river during artificial dam flush, and (iii) monitoring of streamflow-stage hysteresis behavior of a gravel-bed river.

The aim of the first project is to investigate the scaling exponent properties of mountainous river flow fluctuations by Detrended Fluctuation Analysis (DFA) approach. Streamflow data were collected continuously using FATS, the results revealed that river discharge fluctuations have two scaling regimes and scaling break. In contrast to the RC method, the small-scale exponent detected by the FATS is estimated to be $1.02 \pm 0.42\%$ less than that estimated by RC. More importantly, the crossover times evaluated from the FATS delayed approximately by 42 ± 21 hr $\approx$2–3 days than their counterparts estimated by RC. The power spectral density analysis assists these findings. It is found that scaling characteristics information evaluated for a river using flux data obtained by RC approach might not be accurately detected, because this classical method assumes that flow in river is steady and depends on constructing a relationship between discharge and water level, while the discharge obtained by the FATS decomposes velocity and depth into two ratings according to the continuity equation. Hence, this work revealed the performance of FATS as a powerful and effective approach for continuous streamflow measurements at high-frequency levels.

The findings of the first project gave motivations to investigate the characteristics of turbidity–discharge (T–Q) dynamics corresponding to annual artificial dam flush release in a mountainous stream. Two methods for evaluating discharge were used in this study: the classical RC and the FAT system. Interestingly, during dam flush, the discharge records obtained by the FAT showed striking features of unsteady streamflow behavior such as *discharge shoulders* and, in some events, *secondary discharge peaks*. According to the T–Q hysteresis loops, two types of T–Q pattern were observed: anticlockwise, which is the most common type, and figure-of-eight loops. Although the observed location was relatively far from the dam flush points, the primary reason for the anticlockwise hysteresis seemed to be soil erosion and scouring during the flushing process across the river pathway being transported from the relatively long distance between the sediment sources and observation site.

Finally, the presence of the discharge shoulders as well as the secondary discharge peaks pushed us to monitor the unsteady behavior of streamflow, as well as, loops of streamflow-stage in this river. In order to determine river discharge, two methods were used: (i) the continuous slope area method (CSA), and (ii) the FAT. The findings showed that during a single hydrological event, the temporal variations in water slope has two peaks, and water slope-stage has a positive hysteresis behavior. In addition, streamflow-stage hysteresis loops estimated by FAT are informative more than streamflow-stages estimated by the CSA method. Additionally, it was confirmed that streamflow-stage hysteresis loop increases with large-scale rainfall events.