UNSTEADY FLOW MODEL WITH VARIABLE ROUGHNESS COEFFICIENT

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The validity of an unsteady flow model depends not only on the accuracy of the numerical method for the solution of governing partial differential equations, but also on the model parameters. Therefore, it is an essential step in the application of an unsteady flow model to adequately determine Manning's *n* through the calibration. This paper presents a variable-parameter unsteady flow model and its calibration for the Han River in South Korea.

Due to a unique feature of the Han River regarding the hydraulic structures in it, a looped-network unsteady flow model was adopted. Manning's *n* in the model can most generally be expressed as $n = n(x, Q(x,t))$. Manning's *n* at each computational point varies not only with the sub-reach where it belongs, but also with discharge. Manning's *n* values for computational points are calculated at each iteration step for Newton-Raphson solution using the discharge values computed at the previous iteration.

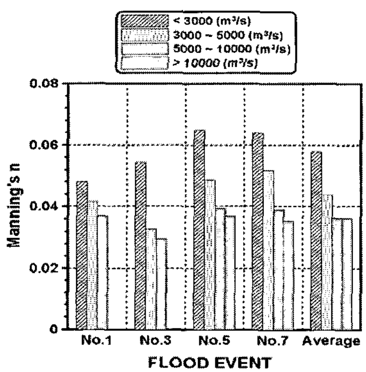
The criterion used for the calibration was to determine model parameters to minimize the sum of squares of the errors between the computed and the observed water levels. An optimization technique was used for the estimation of model parameters.

Four different models were calibrated. The first one is a single-parameter model for which Manning's *n* is constant for the whole reach at all times. The second one has two different roughness coefficients as model parameters, one for the upstream reach of the Wangsook stream junction, and the other for the downstream reach. In other words *n* is a step function of x and there is a step rise/fall at Wangsook stream junction. Downstream reach of the Wangsook stream junction is a channelized reach while the upstream reach is a natural river in which the cross sections are highly irregular. The third one is a variable roughness coefficient model in which *n* varies with discharge, i.e. $n = n(Q(x,t))$. Either a step function or a power function was adopted for functional relation between the discharge and Manning's *n*. The step function is a four-step one having discontinuities at Q = 3000, 5000, and 10,000 m^3/s, respectively. The last one is a combination of the second and the third model, i.e. $n = n(x, Q(x,t))$. The model has two different Manning's *n*-discharge relations, one for the upstream reach and the other for the downstream reach.

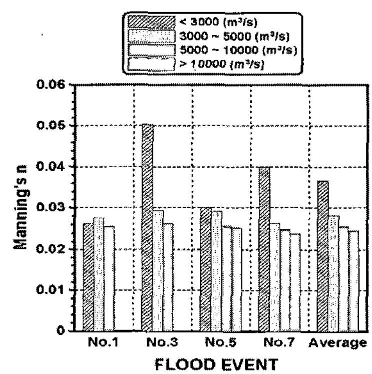
Eight flood events were chosen for calibration and verification of the model. The flood events are numbered in the increasing order of the peak discharge from the Paldang Dam. Flood events 1, 3, 5, and 7 were used for calibration, and the rest of them for verification.

Presented in Fig. 1 are calibration results for the model with $n = n(x, Q))$. The upstream reach had higher n values at the same discharge level than the downstream reach, which was also the case for the model not allowing discharge variation of Manning's n. Whether a step function or a power function is adopted, the calibration results shows that Manning's n decreases as discharge increases. The model can be calibrated with less residual errors compared to the single parameter model by allowing reach-by-reach and/or discharge variation of Manning's n. The model with $n = n(x)$ results in less calibration errors than that with $n = n(Q)$. Whether adopting a step function or a power function as Manning's n-discharge relation does not significantly affect the precision of the calibration.

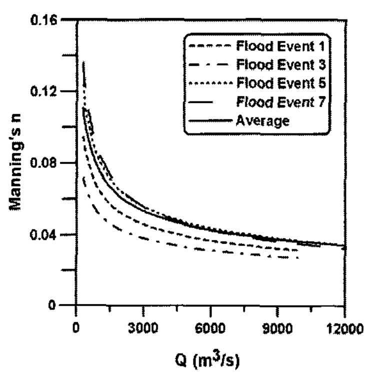
Using the estimated parameters for flood events 1, 3, 5, and 7, average Manning's n values and Manning's n-discharge relations were derived. These average values and functional relations for Manning's n were used to simulate flood events 2, 4, 6, and 8. RMS errors between the observed and computed stages were significantly reduced by adopting the model with $n = n(x)$ compared with those of the single parameter model, and they were further reduced by using the model with $n = n(x, Q)$. Reductions of RMS errors of the model that allows discharge variation only of Manning's n ($n = n(Q)$) were not significant. This indicates that spatial variation of Manning's n is more significant for the Han River than the variation with discharge.



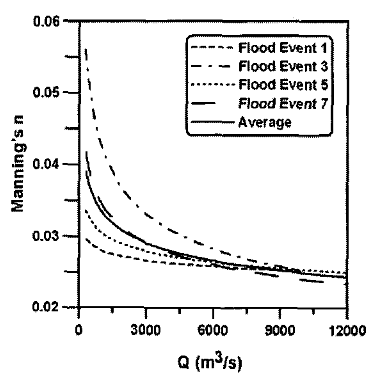
(a) Upstream reach, step function



(b) Downstream reach, step function



(c) Upstream reach, power function



(d) Downstream reach, power function

Fig. 1 Calibrated Manning's n-discharge relations for the model with $n = n$ (x, Q)