

Sensitivity Study of Washoff Model for the Simulation of Suspended Solids Concentration in Stormwater Runoff

This is the title of the paper.

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The washoff model is well-known for its applicability in modelling stormwater quality, and its capacity to take into account the effect of stormwater quality controls (Huber 1986). Despite these advantages, the washoff model has rarely been used routinely in practical applications because of the large uncertainties obtained in model calibration (Bertrand-Krajewski 2007, Kanso *et al.* 2006). For example, the washoff coefficient has been shown to vary from storm to storm without any method to predict its variability (Alley 1981, Gaume *et al.* 1998), thus, limiting the confidence of applying the washoff model for subsequent events. In this study, Monte Carlo (MC) analysis was applied to the EPA SWMM5 washoff model (Rossman 2009) to examine the sensitivity of the washoff calibration parameters in simulating total suspended solids (TSS) concentration. A preliminary analysis of the variability in the calibration coefficients was attempted based on correlating these coefficients with the rainfall depth, d , used as a surrogate to characterize the potential for particulate washoff during individual storm events.

The study was conducted for the Kranji reservoir catchment, Singapore. Rainfall, flow and TSS data for 20 events, collected from 4 sub-catchments (KC01, KC02, KC06 and KC07) were analysed. KC01, KC02 and KC07 are urbanized catchments with various proportions of urbanization (KC01 – 39%, KC07 – 46% and KC02 – 68%), while KC06 is a rural catchment, with about 15% of its land use dominated by agricultural activities. The washoff model $W=c_3q^{c_4}B_{ini}$ implemented in the EPA SWMM5 includes three calibration coefficients: washoff coefficient (c_3), washoff exponent (c_4) and the initial surface buildup (B_{ini}). B_{ini} was considered as a calibration coefficient instead of being determined from a buildup model, in order to eliminate possible uncertainties arising from the calibration of the buildup model (Shaw *et al.* 2010, Kanso *et al.* 2003). The calibration coefficients were assumed to be uniformly distributed over the ranges: $c_3 = [0.001, 3]$, $c_4 = [0.9, 4.5]$ and $B_{ini} = [0, 500]$. Ten thousand sets of calibration coefficients were generated randomly and used to simulate the time series of TSS for each of the recorded events. Following this analysis, ten parameter sets which gave the smallest sum of square error between the simulated and observed washoff rates were selected.

Results from all the selected parameter sets showed that c_3 varied over a wide range, from 0.002 to 2.280; c_4 varied from 0.9 to 4.1; and B_{ini} varied from 1.04 to 469.74 (kg/ha). Correlation analyses of rainfall depths with the calibration coefficients obtained showed that rainfall depths were directly proportional to B_{ini} and inversely proportional to c_3 , but c_4 did not vary significantly ($p > 0.1$) over the whole range of rainfall depths (d ranged from 3.6mm to 198.6mm for the 20 events). The correlations between c_3 and B_{ini} with d are shown in Figure 1.1. No dependence on land use was observed on c_3 and c_4 ; however, B_{ini} was about five times higher for the KC06 which is rural and has a small proportion of agricultural land use.

From our calibration results, the 20 events can be divided into 4 groups: large, medium, small and very small events. Large events have a rainfall depth,

$d > 50\text{mm}$ and c_3 values from 0.001 to 0.01, medium events have a rainfall depth $50\text{mm} > d > 30\text{mm}$ and c_3 values from 0.01 to 0.1, small events have a rainfall depth $30\text{mm} > d > 10\text{mm}$ and c_3 values from 0.1 to 1, while very small events have a rainfall depth $d < 10\text{mm}$ and $c_3 > 1$. An analysis of the variation of cumulative mass with cumulative volume (load characteristic curve) revealed that the curves for large events exhibited mixed characteristics where the initial part of the runoff showed higher proportion of cumulative volume in comparison with the cumulative load of TSS, with the cumulative mass increasing gradually with the cumulative flow during the latter stages of the runoff (See Figure 1.2). Similar analyses were conducted for the medium, small and very small events. For medium and small events, the cumulative load increased in greater proportion to the cumulative flow, with the effect being more significant for the events with smaller rainfall depths. For very small events, the fraction of the cumulative mass was less than that of the cumulative volume during the initial part of the runoff, but increased significantly in the latter stages. This analysis for the very small event however is based on only 1 storm and therefore should be considered as preliminary. Nevertheless, our analysis of the load characteristic curves is instructive as it can be used to explain some of the variability observed in the washoff coefficients. This is significant since the load characteristic curve is commonly applied in the definition of first flush and is used as the basis for the implementation of stormwater quality control strategies.

In conclusion, by applying MC analysis to the calibration of the washoff model for 20 storm events, the study showed that the variation of the coefficients c_3 and B_{ini} were related to rainfall depth. Based on the rainfall depth and the variation of c_3 , the events could be classified into 4 categories: large, medium, small and very small events. Analysis of the cumulative load versus cumulative volume curves revealed that events which belonged to the same group displayed similar characteristics and these characteristics were distinct between groups. The study is currently investigating the effect of rainfall energy to further explain the differences in the washoff model coefficients between the events.

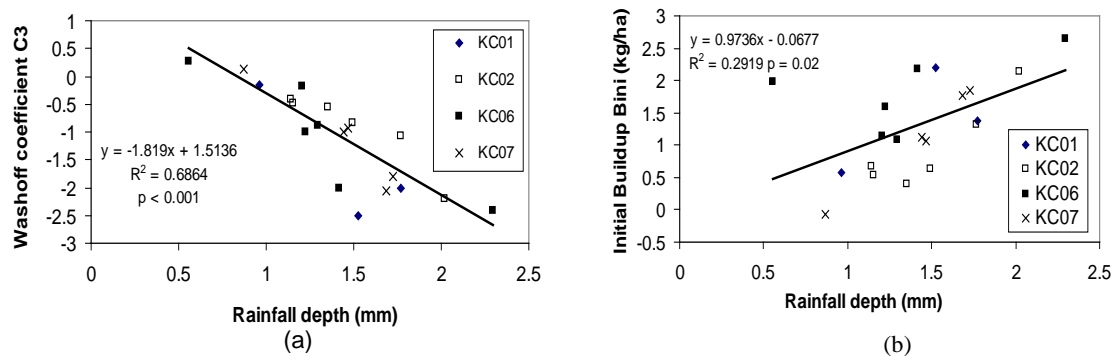


Figure 1.1 Correlation of washoff coefficients with rainfall depth, d in log-log scale: (a) c_3 , (b) B_{ini} (kg/ha)

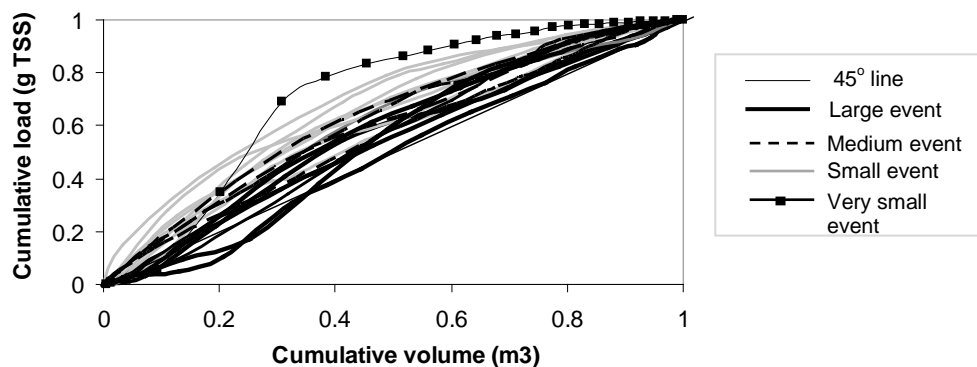


Figure 1.2 Load characteristics curves for the 4 groups of events.

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