APPLICATION OF AN AUTOMATIC CALIBRATION SCHEME FOR URBAN RAINFALL – RUNOFF MODELS IN MOUSE

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ABSTRACT

This study presents an automatic calibration procedure applicable specially for urban rainfall - runoff models. The shuffled complex evolution (SCE) method is used as an optimisation algorithm to estimate the model parameters of the MOUSE software package. The surface runoff model is exemplified by the time/area model. The comparison of calibration results of automatic and manual calibration procedures is discussed. The calibration results show the potential of an applied automated calibration scheme as a viable alternative to the manual approach.

KEYWORDS

Automatic calibration; urban rainfall-runoff models; SCE method; MOUSE; time/area model.

1 INTRODUCTION

Calibration is an important part of the application of any models. The traditional procedure of model calibration is done manually by using a trial and error process of parameter adjustments. In this case, the goodness-of-fit of the calibrated model is basically based on a visual judgement by comparing the simulated and the observed data. However, selected statistical measures, such as the root mean square error, must be considered in order to support the judgement.

At present, it is discussed extensively if automatic calibration should replace the traditional manual calibration procedure since the latter approach is time-consuming and subjective. There has been research carried out into the development of automated (computer-based) calibration methods. However, the automatic calibration procedures applied today are mostly focussed on rural rainfall - runoff models and are often difficult to generalise to other models.

The automatic calibration applicable for urban rainfall – runoff model is the subject of this paper. It is carried out by modifying the computer code of the MOUSE software package to include an SCE optimisation algorithm with an appropriate objective function.

There are 3 urban surface runoff models in MOUSE namely the time/area model, kinematic wave model and linear reservoir model. In this paper, only the time/area model is included as an exemplification of applying automated calibration scheme.

2 THE OBJECTIVE OF MODEL CALIBRATION

The calibration of the model would be achieved if there is a good match between the simulated and observed values of the following hydrograph characteristics: (1) the total runoff volume, i.e. a good water balance, (2) the overall shape of the hydrograph, (3) a good agreement of peak flows and (4) a good agreement of low flows. In practical applications the user can select any of the four objective functions or a combination, depending on the purposes of the specific model application being considered.

For example, the overall water balance should be considered for the design of wastewater treatment plant and combined sewer overflows whereas the overall shape of hydrograph should be applied for river flooding problems. The peak flows agreement can be very significant for storm water drainage system, while the good agreement of low flow will play an important role when calculate the minimum requirement for an irrigation scheme.

3 SCE OPTIMISATION ALGORITHM

The shuffled complex evolution (SCE) method developed at the University of Arizona, is a general purpose global optimisation strategy designed to handle the various response surface problems encountered in the calibration of non linear simulation models. The SCE method involves the initial selection of a 'population' of points distributed randomly throughout the feasible parameter space. The population is partitioned into several 'complexes', each consisting of $2n + 1$ points, where n is the number of parameters to be optimised. Each complex 'evolves' independently in a manner based on the downhill simplex algorithm. The population is periodically 'shuffled' and new complexes formed so that the information gained by the previous complexes is shared. The evolution and shuffling steps repeat until prescribed convergence criteria are satisfied. Further detailed explanation of the method is given in Duan et al. (1992, 1993, 1994).

4 CALIBRATION DATA

The time series data used for calibration are observed discharge and rainfall events from a catchment in Sweden. The catchment area is 20 hectare. The 5-minute interval observed discharge data during 10th October 1998 to 23rd October 1998 is shown in Figure 1.

Generally, it is desirable that the selected data for model calibration should be examined for obvious errors, such as periods where the hydrograph exists but no rainfall has been recorded. This will probably cause errors in the parameter estimates, such as the overall water balance. Therefore, the dry weather flow must be eliminated from the observed flow before calibration.

The assumed diurnal dry weather flow to be subtracted from the observed discharge data is shown in Figure 2. The total volume of dry weather flow is 5.13 m^3/s.

The observed discharge data and the assumed diurnal dry weather flow are plotted in Figure 3.

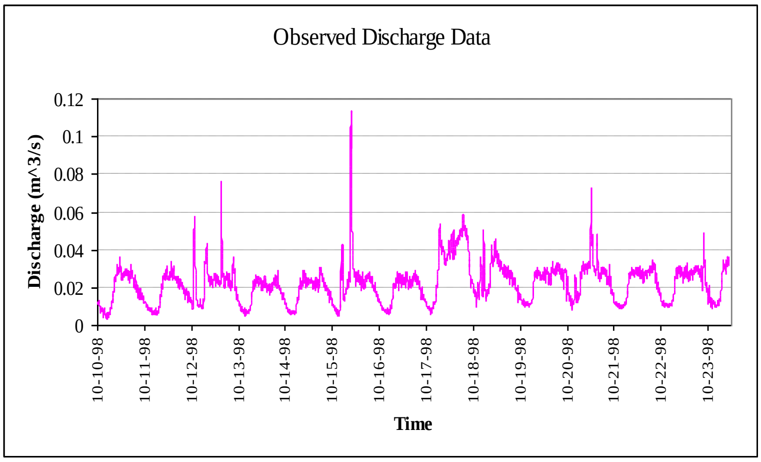


Figure 1 Observed discharge data from a catchment in Sweden

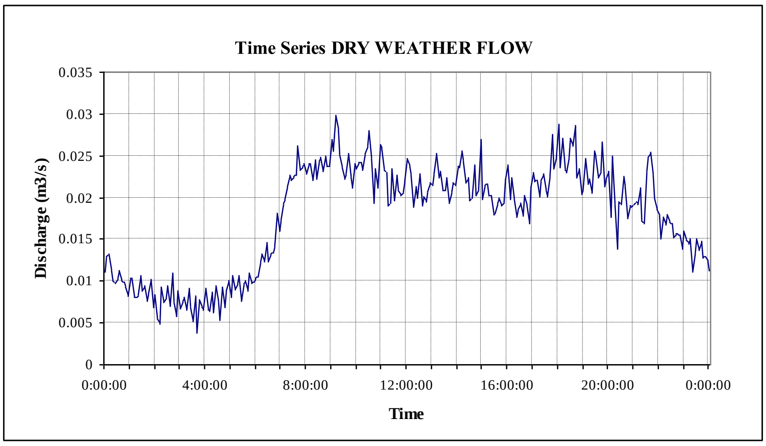


Figure 2 The assumed diurnal dry weather flow

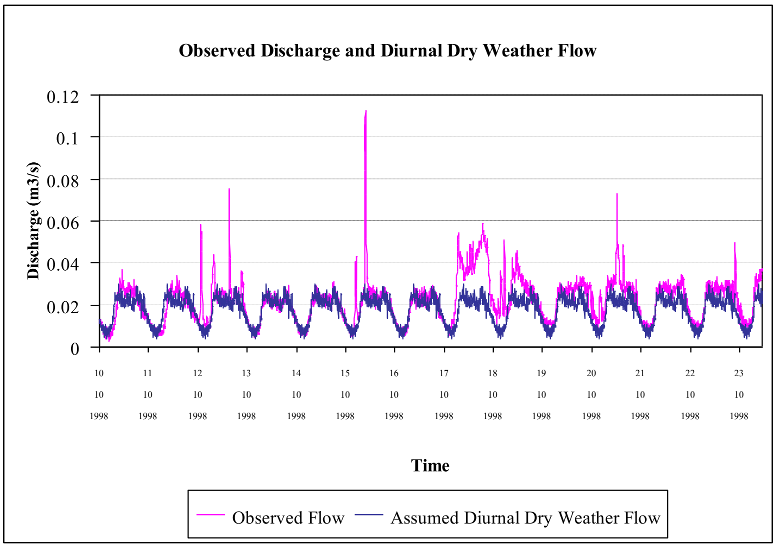


Figure 3 Observed discharge data and the assumed diurnal dry weather flow

Before the start of the calibration procedure the dry weather flow is filtered out of the observed data. For manual calibration, this process can be carried out by assuming diurnal dry weather flow or constant dry weather flow. In automatic calibration, the dry weather flow is assumed constant and is given as a threshold value indicating peak flows or low flows. Therefore, in the following discussion, only cases of constant dry weather flow are considered both for manual and automatic calibration.

5 MANUAL CALIBRATION

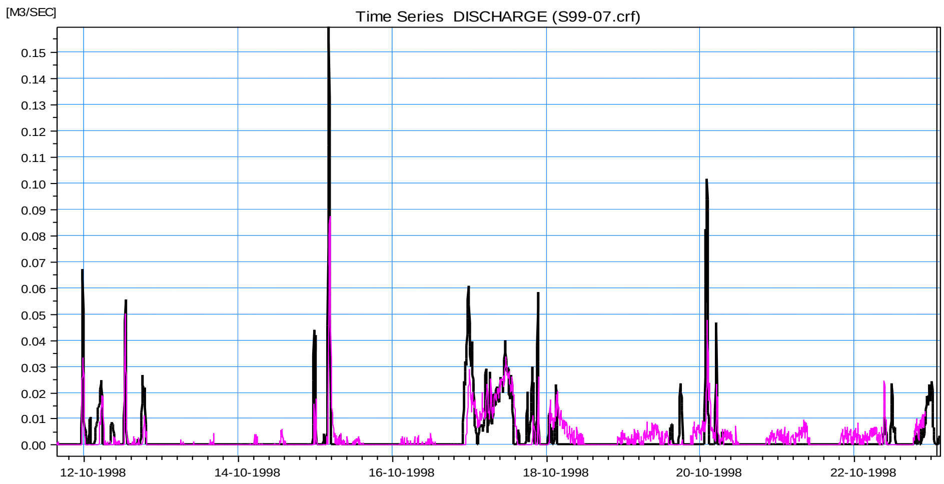
The manual calibration procedure is carried out by using trial and error process of parameter adjustments. The surface runoff is exemplified by the time/area method (Model A) in MOUSE software package. There are 4 calibration parameters in the time/area model as follows:

- Reduction factor,
- Initial loss,
- Concentration time,
- Shape of the time/area curve

The reduction factor and the initial loss give the mass balance whereas the concentration time and the time/area curve control the routing of the flow.

In manual calibration procedure, the model parameters are changed one by one until the simulated flow is fitted against the observed flow. The objective of the calibration is to fit the water balance and the overall shape of hydrograph. The statistical performance used is the root mean square error (RMSE). The calibration result is shown in Figure 4.

Model A: The time/area method (assume constant dry weather flow = 0.02 m^3/s)
Reduction factor = 0.25, initial loss = 0.003, t_c = 30 min., T/A curve no. 2
Water balance difference = 0.79 %, RMSE = 0.0069



Simulated flow Observed flow

Figure 4 Manual calibration by the time/area model

6 AUTOMATIC CALIBRATION

In automatic calibration, the shuffle complex evolution (SCE) algorithm is applied as an optimisation strategy. The outcome of an automatic calibration scheme consists of an additional computer program combined with MOUSE model. The structure of the MOUSE-SCE model is shown in Figure 5.

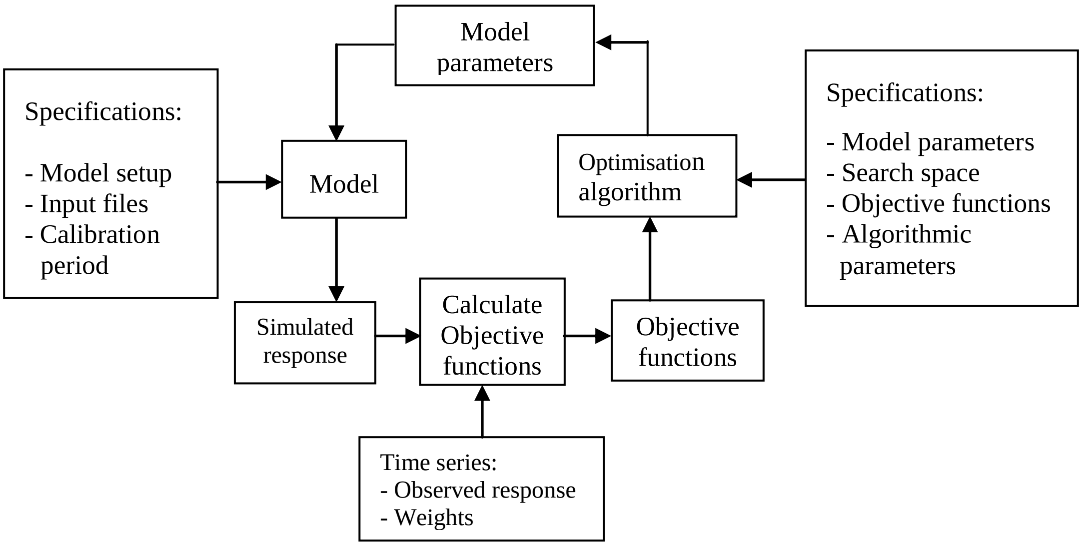


Figure 5 Integration of model and optimisation algorithm

Specifications for the SCE algorithm include:

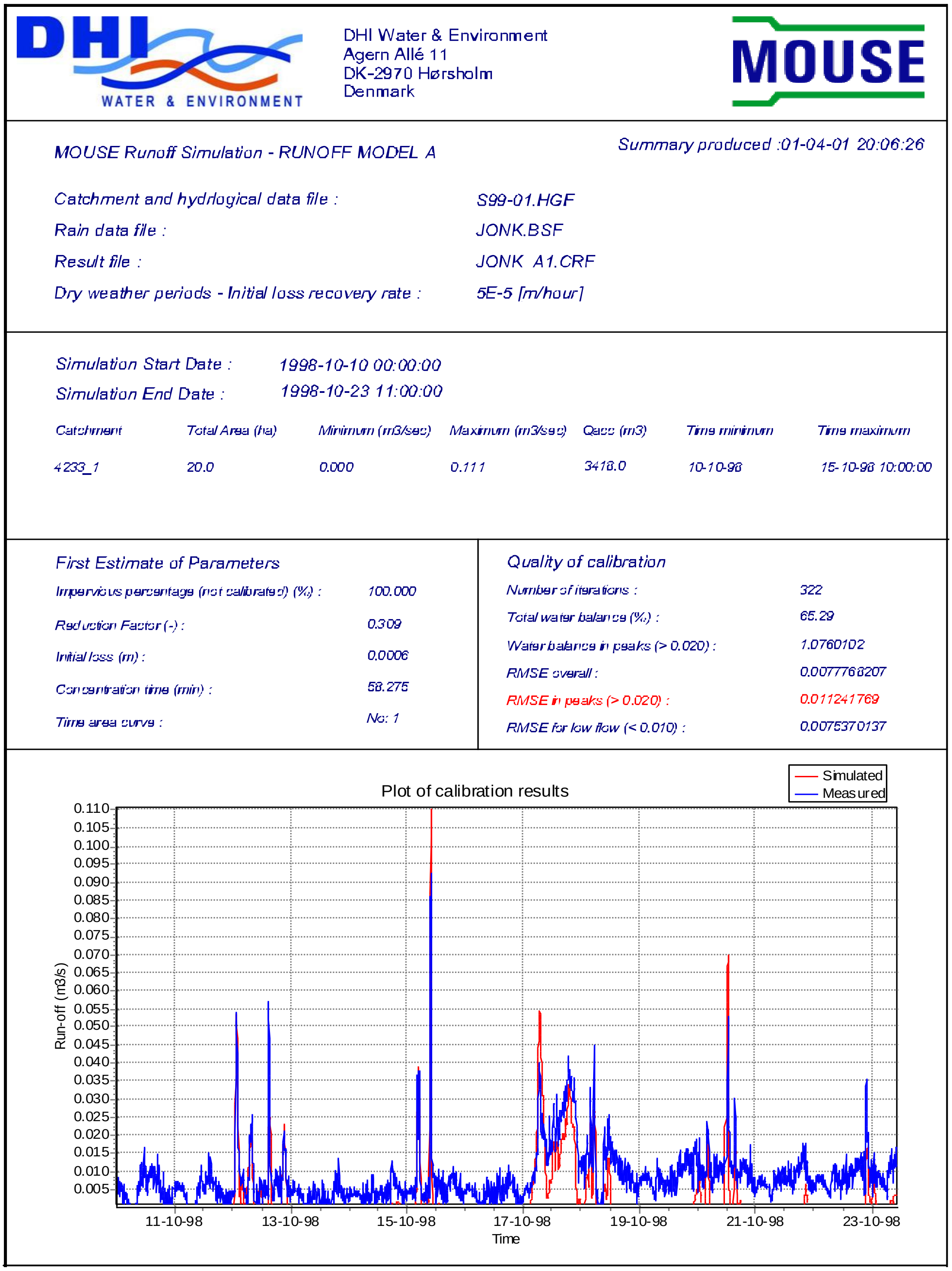
- Range of calibrated model parameters. The feasible parameter space is defined as a hypercube that is specified by the user.
- Specification of objective function. The user can specify any combination of the 4 objective functions: (1) overall volume error, (2) overall RMSE, (3) peak flow RMSE, (4) low flow RMSE.
- Stopping criteria. Two different criteria can be specified: (1) maximum number of model evaluations, and (2) maximum relative change of objective function.

Three calibration tests have been carried out as follows:

- Single-objective calibration for the overall water balance,
- Single-objective calibration for the peak flow RMSE,
- Calibration based on two objectives, i.e. the calibration for the overall water balance and the peak flow RMSE.

In this study, a maximum number of model evaluations equal to 400 was employed as a stopping criterion. Peak flow events were defined as periods with flow above a threshold value of 0.02 m^3/s (assumed constant dry weather flow), and low flow events were defined as periods with flow below 0.01 m^3/s.

Figure 6 shows the example of overall features of calibration result. All the measures of the quality of the calibration are calculated, but only the ones in red colour is included in the objective function.



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MOUSE

MOUSE Runoff Simulation - RUNOFF MODEL A

Summary produced :01-04-01 20:06:26

Catchment and hydrologic data file : S99-01.HGF
Rain data file : JONK.BSF
Result file : JONK A1.CRF
Dry weather periods - Initial loss recovery rate : 5E-5 [m/hour]

Simulation Start Date : 1998-10-10 00:00:00
Simulation End Date : 1998-10-23 11:00:00

Catchment	Total Area (ha)	Minimum (m3/sec)	Maximum (m3/sec)	Qacc (m3)	Time minimum	Time maximum
4233_1	20.0	0.000	0.111	3418.0	10-10-98	15-10-98 10:00:00

First Estimate of Parameters

Impervious percentage (not calibrated) (%) : 100.000
Reduction Factor (-) : 0.309
Initial loss (m) : 0.0006
Concentration time (min) : 58.275
Time area curve : No: 1

Quality of calibration

Number of iterations : 322
Total water balance (%) : 65.29
Water balance in peaks (> 0.020) : 1.0760102
RMSE overall : 0.0077768207
RMSE in peaks (> 0.020) : 0.011241769
RMSE for low flow (< 0.010) : 0.0075370137

Figure 6 The example of overall feature of automatic calibration

The calibration results of single-objective for the overall water balance and the peak flow RMSE and multi-objective calibration are shown in Figure 7a, 7b and 7c respectively.

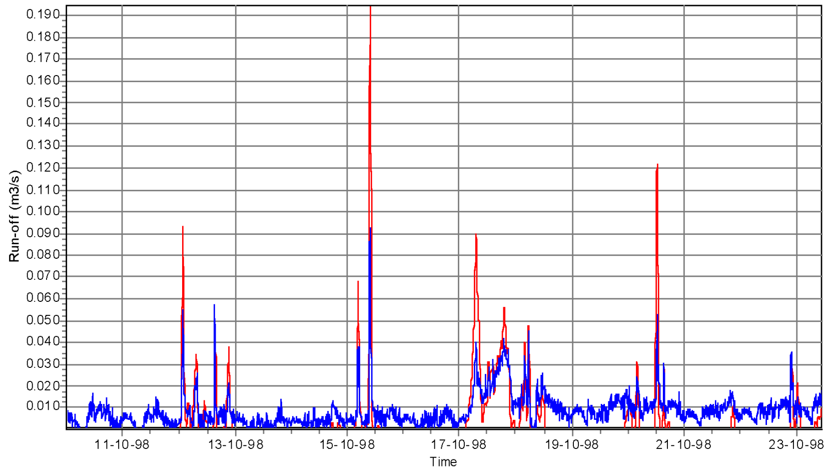

Figure 7a Automatic calibration to fit water balance

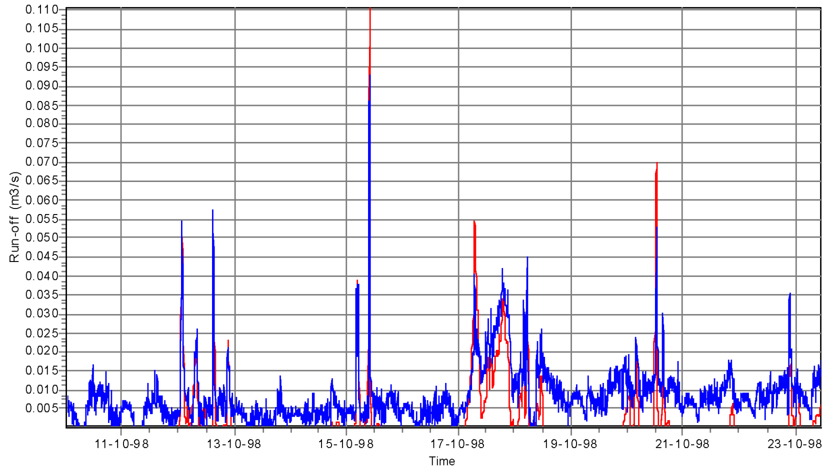

Figure 7b Automatic calibration to fit RMSE in peaks

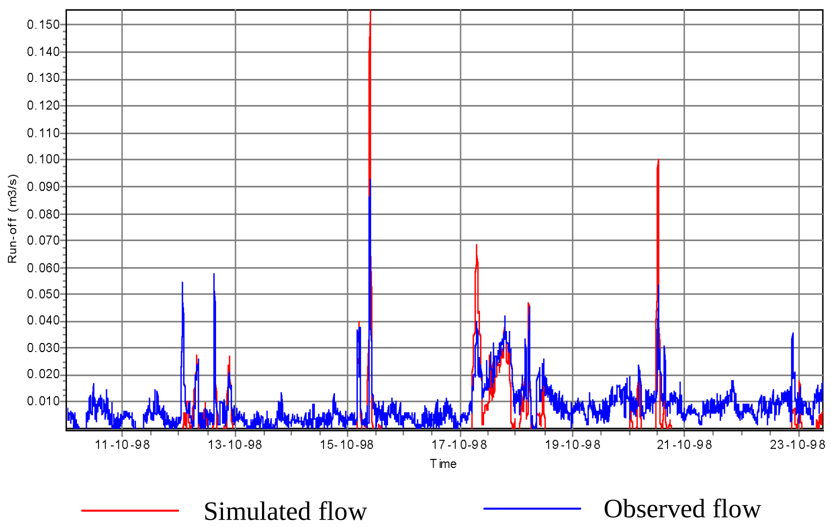

Figure 7c Automatic calibration to fit water balance and RMSE in peak flows

7 DISCUSSION OF CALIBRATION RESULTS

The calibration results from manual and automatic calibration can be summarised as shown in Table 1.

Table 1 Optimum parameter sets and corresponding performance measures for manual and automatic calibration

Calibration Parameters	Manual Calibration	Automatic Calibration		
		to fit water balance	to fit peak flows RMSE	to fit water balance and peaks RMSE
Reduction factor Initial loss (mm) Time of concentration (min) Time/area curve number	0.25 0.003 30 2	0.500 0.0006 55 1	0.309 0.0006 58.275 1	0.366 0.0045 62.008 2
Performance Measures				
Water balance (%) RMSE Number of iterations	0.79 0.0069 -	0.61 0.0039 134	1.08 0.0112 322	0.52 0.016 208

The single-objective automatic calibration gives different calibration parameters from manual approach. This is because there are many sets of manual calibration parameters that might satisfy the objective function (the overall water balance in this case). In automated procedure, different calibration objectives give different set of calibration parameters. However, the calibration process is faster and less subjective than the trial and error method. The multi-objective calibration gives also a different set of parameter. Nevertheless, the calibration results from the study show the potential and the possibility of applying automatic calibration scheme.

7 CONCLUSION

This study presents the manual and automatic calibration of the urban rainfall – runoff model exemplified by the MOUSE software package. These procedures are carried out base on different calibration objectives.

The calibration results highlight that the automated scheme is superior to the manual approach for faster time of calculation. In addition, the multi-objective can be optimised while it is very sensitive to manual calibration.

It is concluded that the proposed automated calibration scheme can be applied to urban rainfall – runoff modelling as a viable alternative to the manual approach.

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