MODELLING OF URBAN STORMWATER
DRAINAGE SYSTEMS USING ILSAX

BY

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ABSTRACT

Over the last few decades, the world has witnessed rapid urbanisation. One of the many complex problems resulting from increased urbanisation is related to management of stormwater from developed areas. If stormwater is not managed properly, it may lead to flooding of urban areas, and deterioration of water quality in rivers and receiving waters. Urban drainage systems are used to manage urban stormwater.

For design of effective and economic urban drainage systems, it is important to estimate the design flows accurately. Many computer based mathematical models have been developed to study catchment runoff (or flows) in urban environments. These models may be used in different stages of the projects such as screening, planning, design and operation. Each stage may require a different model, although some models can be used for several of these stages.

A customer survey was conducted in May 1997 to study the current practice in Victoria (Australia) on stormwater drainage design and analysis, as part of this thesis. The survey was restricted to city/shire councils and consultants, who are engaged in design and analysis of urban drainage systems. The results of the survey showed that 95% of respondents used the Statistical Rational method. Also, it was revealed that most respondents were reluctant to use stormwater drainage computer models, since there were no adequate guidelines and information available to use them especially for ungauged catchments. According to 5% of the respondents, who used models, ILSAX was the most widely used stormwater drainage computer model in Victoria. The 1987 edition of the Australian Rainfall-Runoff (ARR87) suggests the ILSAX model as one of the computer models that can be used for stormwater drainage design and analysis. Due to these reasons, the ILSAX model was used in this study in an attempt to produce further guidance to users in development and calibration of ILSAX models of urban drainage systems.

In order to use the ILSAX model, it is necessary to estimate the model parameters for catchments under consideration. The model parameters include loss model parameters (i.e.
infiltration and depression storage parameters) and other parameters related to the catchment (such as percent imperviousness, soil cover and conveyance system parameters). Some of these parameters can be estimated from available maps and drawings of the catchment. The ideal method to determine these parameters (which cannot be reliably determined from available maps and drawings) is through calibration of these models using observed rainfall and runoff data. However, only few urban catchments are monitored for rainfall and runoff, and therefore calibration can be done only for these catchments. At present, there are no clear guidelines to estimate the model parameters for ungauged catchments where no rainfall-runoff data are available. In this PhD project, first the ILSAX model was calibrated for some gauged urban catchments. From the results of calibration of these catchments, regression equations were developed to estimate some model parameters for use in gauged and ungauged urban stormwater catchments.

Before calibrating the ILSAX model for gauged catchments, a detailed study was conducted to:

- select the most appropriate modelling option (out of many available in ILSAX) for modelling various urban drainage processes,
- study the sensitivity of model parameters on simulated storm hydrographs, and
- study the effect of catchment subdivision on storm hydrographs.

This detailed study was conducted using two typical urban catchments (i.e. one ‘small’ and one ‘large’) in Melbourne metropolitan area (Victoria) considering four design storms of different average recurrence intervals (ARI). Three storms with ARI of 1, 10 and 100 years, and one with ARI greater than 100 years were considered in the study. The results obtained from this detailed study were subsequently used in model calibration of the study catchments. The results showed that the runoff volume of ‘large’ storm events was more sensitive to the antecedent moisture condition and the soil curve number (which determines soil infiltration) and less sensitive to the pervious and impervious area depression storages. However, for ‘small’ storm events, the runoff volume was sensitive to the impervious area depression storage. The peak discharge was sensitive to pipe roughness, pit choke factor, pit capacity parameters and gutter characteristics for both ‘small’ and ‘large’ storm events.
The results also showed that the storm hydrograph was sensitive to the catchment subdivision.

The accuracy of rainfall-runoff modelling can be adversely influenced by erroneous input data. Therefore, the selection of accurate input data is crucial for development of reliable and predictive models. In this research project, a number of data analysis techniques were used to select good quality data for model calibration.

For calibration of model parameters, parameter optimisation was preferred to the trial and error visual comparison of observed and modelled output responses, due to subjectivity and time-consuming nature of the latter approach. It was also preferred in this study, since the model parameters obtained from calibration were used in the development of regional equations for use in gauged and ungauged catchments. Therefore, it was necessary to have a standard method which can be repeated, and produced the same result when the method is applied at different times for a catchment. An optimisation procedure was developed in this thesis, to estimate the model parameters of ILSAX. The procedure was designed to produce the ‘best’ set of model parameters that considered several storm events simultaneously. The PEST computer software program was used for the parameter optimisation. According to this procedure, the impervious area parameters can be obtained from frequent ‘small’ storm events, while the pervious area parameters can be obtained from less-frequent ‘large’ storm events.

Twenty two urban catchments in the Melbourne metropolitan area (Victoria) were considered in the model parameter optimisation. Several ‘small’ and ‘large’ storm events were considered for each catchment. However, it was found during the analysis that the selected ‘large’ storm events did not produce any pervious area runoff, and therefore it was not possible to estimate the pervious area parameters for these catchments. The Giralang urban catchment in Canberra (Australia) was then selected to demonstrate the optimisation procedure for estimating both impervious and pervious area parameters, since data on ‘small’ and ‘large’ storm events were available for this catchment. The calibration results were verified using different sets of storm events, which were not used in the calibration, for all catchments. The optimised model parameters obtained for each catchment were able to produce hydrographs similar to the observed hydrographs, during verification. The
impervious area parameters obtained from optimisation agreed well with the information obtained from other sources such as areal photographs, site visits and published literature. Similarly, the pervious area parameters obtained for the Giralang catchment agreed well with the values given in the published literature.

If ILSAX is to be used for ungauged drainage systems for which no storm data are available, then the model parameters have to be estimated by some other means. One method is to estimate them through regional equations, if available. These regional equations generally relate the model parameters to measurable catchment properties. In this study, analyses were conducted to develop such regional equations for use in ungauged residential urban catchments in the Melbourne metropolitan area. The Melbourne metropolitan area was considered as one hydrologically homogeneous group, since the urban development is similar in the area. The equations were developed for the land-use parameters of directly connected impervious area percentage (DCIA) and supplementary area percentage (SA), and the directly connected impervious area depression storage (DSi). Several influential catchment parameters such as catchment area, catchment slope, distance from the Central Business District to the catchment and household density were considered as independent variables in these regional equations.

A regional equation was developed for DCIA as a function of the household density. A similar equation was also developed to determine SA as a function of household density. DCIA was obtained from the model parameter optimisation using rainfall-runoff data (i.e. calibration), while SA and household density were obtained from the available drawings and field visits. These two equations showed a very good correlation with household density and therefore, DCIA and SA can be estimated accurately using these two equations. The city/shire councils generally have information on the household density in already-developed urban areas and therefore, these two equations can be used to estimate DCIA and SA for these areas. For new catchments, these equations can be used to estimate DCIA and SA based on the proposed household density.

The directly connected impervious area depression storage (DSi) is the only ILSAX model loss parameter that was obtained from the calibration, and this is the loss parameter that is more sensitive for ‘small’ storm events of the urban drainage catchments. A regional
equation was attempted for this parameter by relating with the catchment slope, since the catchment slope was found to have some correlation with DSᵢ according to past studies. However, the results in this study did not show a correlation between these two variables. Therefore, based on the results of this study, a range of 0 - 1 mm was recommended for DSᵢ. Because of the recommended range for DSᵢ, the sensitivity of DSᵢ against DCIA was revisited and found that DSᵢ was less sensitive compared to DCIA, in simulating the peak discharge and time to peak discharge for both ‘small’ and ‘large’ storm events. However, there is a little impact for runoff volume and hydrograph shape for ‘small’ storm events. Therefore, defining a range for DSᵢ is justified for modelling purposes and the user can choose a suitable value within this range from engineering judgement.
DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or institution and, to the best of the author’s knowledge and belief, contains no material previously written or published by another person except where due reference is made in the text.

Sunil Thosainge Dayaratne
31 August 2000
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