# Development and verification of hydrograph routing in a daily simulation model+

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## Abstract

The ability to simulate, on a continuous basis, the peak flow rate, runoff volume and hydrograph from a catchment is important in planning, design and operation of hydraulic structures and the solution of a wide range of problems associated with water use. The ACRU modelling system, developed originally essentially as a small catchments daily time step hydrological model, is being applied increasingly in distributed mode to larger complex catchments where the river network plays an important role in transporting the water to the catchment outlet.

The assumption in the ACRU model that stormflow generated on a particular day passes the catchment outlet on the same day is valid for small catchments, but is not necessarily true of large catchments. Thus a flow routing submodel has been incorporated into the ACRU model which enables continuous hydrograph simulation to improve the temporal distribution of the simulated flow. Verification of the submodel has taken place on the Ntabamhlope wetland in Western Natal and on the catchment upstream of Henley Dam in Natal.

## Introduction

The ability to simulate, on a continuous basis, the peak flow rate, runoff volume and hydrograph from a catchment is important in planning, design and operation of hydraulic structures and in the solution of a wide range of problems associated with water use. In Southern Africa, commonly used techniques for predicting the runoff hydrograph shape include the unit hydrograph, the kinematic and the time-area methods (Campbell et al., 1986).

An advantage of applying any of these methods in a spatially distributed model when simulating the runoff from a large heterogeneously responding catchment, is that such a catchment can be subdivided into relatively homogenous response units, thus accounting for the spatial heterogeneity, rather than operating simply a spatially lumped model. The ACRU modelling system (Schulze, 1989), which uses a Southern African modification to the SCS technique to generate daily stormflow and was developed originally essentially as a small catchments daily time step hydrological model, is being applied increasingly in distributed mode to larger, complex catchments where the river network plays an important role in transporting the water to the catchment outlet.

The assumption in the ACRU model that stormflow generated on a particular day passes the catchment outlet on the same day is valid for small catchments, but is not necessarily true of large catchments. Thus when the ACRU model is applied in distributed mode on large catchments, the temporal distribution of streamflow passing the catchment outlet does not reflect the translation of the hydrograph taking place through river reaches and reservoirs encountered *en route* to the catchment outlet.

The development and verification of a flow routing submodel which has been incorporated as an option in the ACRU model, and which enables continuous hydrograph simulation and flow routing to improve the temporal distribution of the daily runoff generated by the ACRU model, is outlined in this paper. Results of verifications of the flow routing submodel undertaken on the 175 km2 catchment upstream of the Henley Dam in Natal, as well as on the Ntabamhlope wetland in Western Natal, are presented.

## River reach and reservoir flood routing

Several methods have been developed for routing floods in reservoirs and rivers. These methods may be classified broadly as either hydraulic or hydrologic routing techniques (Viessman et al., 1989). Both techniques use the principle of conservation of mass. Hydraulic techniques are more complex and were developed for spatially-varied systems using an equation of motion, customarily the momentum equation. Hydrologic routing techniques, which use a conceptual approach, are typically simpler techniques developed for spatially lumped systems (Wilson and Ruffini, 1988).

The hydraulic methods generally describe the flood wave profile more adequately when compared to hydrologic techniques. However, practical applications of hydraulic methods are restricted because of their high demands on computing technology as well as on quantity and quality of input data (Singh, 1988). In addition, investigations by, *inter alia*, Price (1974), Porter (1975) and Hdromadka and De Vries (1988) have shown that the less data intensive hydrologic techniques perform generally as well as the hydraulic techniques. Thus the simpler and less data intensive hydrological routing techniques were implemented as an option in the ACRU modelling system.

The Muskingum method for channel routing is the most widely used hydrologic routing technique (Wilson and Ruffini, 1988). Cunge (1969) related the parameters required for the Muskingum method to physical characteristics of the channel system by noting similarities between the Muskingum method and the numerical approximation of a diffusion wave model. Thus the Muskingum-Cunge flow routing method, although classified as a hydrologic method, gives results comparable with the hydraulic methods. In using physically based estimates for model parameters, the Muskingum-Cunge method operates in accordance with the ACRU modelling philosophy and was thus considered suitable for incorporation, as an option, in the ACRU

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'Revised paper. Originally presented at the 5th SA Hydrological Sciences Symposium held in Stellenbosch, November 1991.
*Received 20 August 1992; accepted in revisedform 30 November 1992.*