Development of a customised design flood estimation tool to estimate floods in gauged and ungauged catchments

OJ Gericke[1, 2*] and JA du Plessis[2]

[1]*Faculty of Engineering and Information Technology, Department of Civil Engineering, Central University of Technology, Free State, South Africa*

[2]*Department of Civil Engineering, University of Stellenbosch, P/Bag X1, Matieland 7602, South Africa*

Abstract

The estimation of design flood events, i.e., floods characterised by a specific magnitude-frequency relationship, at a particular site in a specific region is necessary for the planning, design and operation of hydraulic structures. Both the occurrence and frequency of flood events, along with the uncertainty involved in the estimation thereof, contribute to the practising engineers' dilemma to make a single, justifiable decision based on the results obtained from the plethora of 'outdated' design flood estimation methods available in South Africa. The objectives of this study were: (i) to review the methods currently used for design flood estimation in South Africa for single-site analysis, (ii) to develop a customised, user-friendly Design Flood Estimation Tool (DFET) containing the latest design rainfall information and recognised estimation methods used in South African flood hydrology, and (iii) to demonstrate the use and functionality of the developed DFET by comparing and assessing the performance of the various design flood estimation methods in gauged catchments with areas ranging from 100 km² to 10 000 km² in the C5 secondary drainage region, South Africa. The results showed that the developed DFET will provide designers with an easy-to-use software tool for the rapid estimation and evaluation of alternative design flood estimation methods currently available in South Africa for applications at a site-specific scale in both gauged/ungauged and small/large catchments. In applying the developed DFET to gauged catchments, the simplified 'small catchment' ($A \leq 15$ km²) deterministic flood estimation methods provided acceptable results when compared to the probabilistic analyses applicable to all of the catchment sizes and return periods, except for the 2-year return period. Less acceptable results were demonstrated by the 'medium catchment' (15 km² $< A \leq$ 5 000 km²) deterministic and 'large catchment' (> 5 000 km²) empirical flood estimation methods. It can be concluded that there is no single design flood estimation method that is superior to all other methods used to address the wide variety of flood magnitude-frequency problems that are encountered in practice. Practising engineers' still have to apply their own experience and knowledge to these particular problems until the gap between flood research and practice in South Africa is narrowed by improving existing (outdated) design flood estimation methods and/or evaluating methods used internationally and developing new methods for application in South Africa.

Keywords: Design flood, design rainfall, estimation, ungauged catchments, flood magnitude-frequency

Introduction

The estimation of design flood events, i.e., floods characterised by a specific magnitude-frequency relationship, at a particular site in a specific region is necessary for the planning, design and operation of hydraulic structures (Pegram and Parak, 2004). In essence, the failures of these structures caused by floods are largely due to the immense variability in the flood response of catchments to rainfall, which is innately variable in its own right (Alexander, 2001). Consequently, design flood estimations are likely to display relatively wide magnitude-frequency bands of uncertainty (Alexander, 2002). Thus, both the occurrence and the frequency of flood events, along with the uncertainty involved in the estimation thereof, contribute to the practising engineers' dilemma to make a single, justifiable decision based on the results obtained from the plethora of 'outdated' design flood estimation methods available in South Africa.

Most of these 'outdated' design flood estimation methods were developed in the 1970s, with some still reliant on graphical procedures. The recent (2006) compilation of the South African National Roads Agency Limited (SANRAL) Drainage Manual, which is regarded by many practising engineers' as an authoritative reference document, also proposes the use of a suite of design flood estimation methods with associated graphical procedures. However, there is no guarantee that these time-consuming methods using graphical input would result in more acceptable flood magnitude-frequency relationship results compared to the results obtained with more simplified methods, e.g., the Rational method (RM). In addition, the degree of uncertainty in terms of these methods' relative applicability, based on their basic assumptions, has not been evaluated.

In order to overcome some of the inherent limitations of the currently-used methods in terms of their user-friendliness, and to enhance the practicing engineers' decision-making process, the Utility Programs for Drainage (UPD) software (Van Dijk, 2005) was developed to complement the Drainage Manual. The UPD software consists of a number of easy to use, state-of-the-art, user-friendly programs for the hydraulic design and analysis of drainage structures. In terms of flood hydrology, it is limited to flood estimations based on deterministic, empirical and probabilistic methods. However, the estimation of catchment parameters (e.g. average catchment and main watercourse slopes, slope frequency distribution classes and main

* To whom all correspondence should be addressed.
☎ +2751-507 3516; fax: +2751-507 3254;
e-mail: jgericke@cut.ac.za

Received 7 March 2011; accepted in revised form 7 January 2013.

http://dx.doi.org/10.4314/wsa.v39i1.9
Available on website http://www.wrc.org.za
ISSN 0378-4738 (Print) = Water SA Vol. 39 No. 1 January 2013
ISSN 1816-7950 (On-line) = Water SA Vol. 39 No. 1 January 2013