

Short-duration rainfall frequency model selection in Southern Africa*

JC Smithers*

Department of Agricultural Engineering, University of Natal, PO Box 375, Pietermaritzburg 3200, South Africa

Abstract

Short-duration design rainfall estimates are vital in the design of hydraulic structures and for environmental management. The use of a digitised rainfall database is expected to improve these estimates in Southern Africa. In order to estimate design rainfall intensities, an appropriate probability distribution has to be chosen, which adequately fits the data. This paper investigates the use of goodness-of-fit tests to assess potential probability distributions and makes general recommendations of appropriate probability distributions for estimating short-duration design rainfall intensities in Southern Africa.

Introduction

The concept of depth duration frequency (DDF) analysis of historical rainfall data in order to predict the frequency and magnitude of future rainfall events is not only vital to engineers involved in designing hydraulic structures, but is also essential input in environmental management (Dent and Smithers, 1991). At present, the majority of short-duration (i.e. 24 h and less) design rainfall estimates (DRE) in Southern Africa are derived from a co-axial diagram produced by Midgley and Pitman (1978). This was generated from an analysis of manually extracted data at a time resolution of 15 min from 58 autographic rainfall stations, containing data up to 1976. The log-Gumbel (L-EV1) probability distribution (PD) was fitted to the data and was used to estimate design values.

Improved short-duration DRE are now possible as a result of the availability of considerably longer periods of digitised rainfall records at a time resolution ranging from 1 to 5 min, as well as an increased number of stations. In addition, PDs other than the Gumbel PD are commonly used in the frequency analysis of storm rainfall (Stedinger et al., 1993) and may be more suitable than the log-Gumbel PD in Southern Africa. The spatial variation in the most suitable PD, the extrapolation of estimates to data-sparse regions and the applicability of a regional analysis as compared to single-site analyses are further avenues to be explored in improving DRE. A research project is presently being undertaken which is investigating various techniques to improve DRE and to develop synthetic design rainfall hyetographs in Southern Africa by utilising the database of digitised rainfall and the concepts outlined above.

The objectives of the study reported in this paper are to investigate the use of goodness-of-fit (GOF) tests and use the GOF tests to evaluate and determine appropriate PDs for use in Southern Africa. L-moments (Hosking, 1990) are used to estimate the parameters of the PDs and a brief review of the theory of L-moments is presented. The GOF tests evaluate the descriptive and predictive performance of various PDs and comprise L-moment ratio diagrams, statistical tests, standardised deviations from estimates interpolated from plotting position formulae and a non-parametric evaluation of the performance of the PDs.

* (0331) 260-5490; fax (0331) 260-5818;

e-mail smithers@aquac.cwr.ac.za

* Revised paper. Originally published in the 1994 SAICE conference proceedings entitled *50 Years of Water Engineering in South Africa*. Received 31 March 1995; accepted in revised form 5 March 1996.

Probability distributions used in short-duration rainfall analysis

A number of different PDs have been used for single-site short-duration rainfall probability analysis. In Southern Africa, Midgley and Pitman (1978) used the L-EV1 distribution, Schulze (1984) utilised the Gumbel (EV1), log-Normal (LN2) and log-Pearson type 3 (LP3) and Weddepohl (1988) employed the LN2 distribution.

Internationally, PDs that have been commonly used in short-duration design rainfall estimates in the USA include the general extreme value (GEV) distribution (Hosking and Wallis, 1987, cited by Vogel, Thomas and McMahon, 1993) and the LP3 PD (Aron et al., 1987; Naghavi et al., 1993), while Griffiths and Pearson (1993) used the EV1 PD in New Zealand. Stedinger et al. (1993) report that the EV1, LP3 and GEV PDs are commonly used for short-duration rainfall probability analysis.

In this study the LN2, 3 parameter log-normal (LN3), LP3, Pearson type 3 (PE3), EV1, L-EV1, GEV, generalised Pareto (GPA), generalised logistic (GLO) and Wakeby (WAK) PDs were employed. These PDs are summarised by Stedinger et al. (1993).

Parameter estimation for the PDs by L-moments has several advantages as outlined by Stedinger et al. (1993) and hence was used in this study. In addition, in seeking appropriate PDs, the use of a single parameter-fitting technique would not further confound the GOF tests employed. The computer program developed by Hosking (1991b) was used in the analysis.

Method of L-moments

Similar to ordinary product moments, the purpose of L-moments and probability weighted moments (PWMs) is to summarise theoretical probability distributions and observed samples (Vogel, McMahon and Chiew, 1993). Hence L-moments can be used for parameter estimation, interval estimation and hypothesis testing.

L-moments have several important advantages over ordinary product moments (Vogel, Thomas and McMahon, 1993). In order to estimate the sample variance and sample skew, ordinary product moments require the squaring and cubing of the observations respectively. Sample estimators of L-moments are linear combinations of the ranked observations, and do not require squaring and cubing of the observations. Thus L-moments are subject to less bias than ordinary product moments (Vogel, McMahon and Chiew, 1993).