

The estimation of design rainfalls for South Africa using a regional scale invariant approach[#]

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Abstract

Accurate estimates of design rainfall are essential inputs in water resource planning and engineering design. The duration of design rainfall which is required for design flood estimation may range from as short as 5 min for small urban catchments which have a rapid hydrological response, to a few days for large regional scale flood studies. In South Africa, as in many countries, the spatial density and record lengths of rainfall measured manually at daily intervals is far greater than rainfall recorded continuously. However, continuously recorded rainfall is needed to estimate design rainfall for durations shorter than 24 h. In this study, the scaling characteristics of extreme rainfall and a regional approach, based largely on the more reliable and abundant daily rainfall data, are utilised to estimate design rainfalls in South Africa for durations ranging from 5 min to 7 d.

Keywords: design rainfall, South Africa, regionalisation, scaling, extreme rainfall, rainfall probability

Introduction

The estimation of design flood events is necessary for the planning and design of engineering projects (Rahman et al., 1998). Hence, flood-frequency analysis remains a subject of great importance as a result of the economic and environmental impacts of failures of hydraulic structures (Pilgrim and Cordery, 1993; Bobee and Rasmussen, 1995). However, reliable estimates of flood frequency in terms of peak flows and volumes remain a current challenge in hydrology (Cameron et al., 1999). Cordery and Pilgrim (2000) express the opinion that the demands for improved estimates of floods have not been met with any increased understanding of the fundamental hydrological processes.

Standard techniques for flood estimation have been developed for many countries. These generally include statistical analyses of observed peak discharges, where these are available, and event modelling using rainfall-runoff techniques. Observed streamflow data are often not available at the site of interest and rainfall event-based methods frequently have to be used. This requires a probabilistically based estimate of rainfall, generally referred to as design rainfall, to be made at the site of interest. The frequently used term "design rainfall" thus comprises the rainfall depth and duration, or intensity, associated with a given probability of exceedance which, in turn, is inversely related to the commonly used term, return period. Design rainfall depths for various durations are thus required for the many engineering and conservation design decisions made annually in South Africa and which result in many millions of Rand of construction each year. For example, engineers and hydrologists involved in the design of hydraulic structures (e.g. culverts, bridges, dam spillways and reticulation for drainage systems) need to assess

the frequency and magnitude of extreme rainfall events in order to generate design flood hydrographs. Hence, depth-duration-frequency (DDF) relationships, which utilise recorded events in order to predict future exceedance probabilities and thus quantify risk and maximise design efficiencies, are a key concept in the design of hydraulic structures (Schulze, 1984).

Numerous regional and national scale studies in South Africa have focused on estimating design rainfalls for durations $d \leq 24$ h. These include those of Vorster (1945), Woolley (1947), SAWB (1956), Reich (1961), Reich (1963), Bergman and Smith (1973), SAWB (1974), Adamson (1977), Alexander (1978), Midgley and Pitman (1978), Van Heerden (1978), Henderson-Sellers (1980), Schulze (1980), Adamson (1981), Sinske (1982), Op Ten Noort (1983), Schulze (1984), Weddepohl et al. (1987), Weddepohl (1988), Smithers (1996), Smithers and Schulze (2000a) and Alexander (2001). Studies in South Africa which have estimated design rainfalls for durations of 1d and longer include those by SAWB (1956), Schulze (1980), Adamson (1981), Pegram and Adamson (1988) and Smithers and Schulze (2000b). With the exception of the research by Smithers and Schulze (2000a; 2000b), the other studies have all utilised point design rainfall values using at-site data only and no regionalisation was performed in an attempt to increase the reliability of the design values at gauged sites and for the estimation of design values at un-gauged sites.

Smithers and Schulze (2000a) utilised digitised rainfall data from 172 sites in South Africa, each of which had at least 10 years of record, to estimate short-duration design rainfall. As illustrated by Smithers (1993) and Smithers and Schulze (2000a), many of the digitised rainfall data must be viewed as unreliable as many errors in the digitisation process are evident in the data. In addition, comparisons between the 24 h rainfall totals, computed from the digitised rainfall data, and daily rainfall, as measured at 08:00 every day using standard non-recording rain gauges at the same site, indicated numerous significant discrepancies in the two values. Data from 1806 rainfall stations in South Africa which have at least 40 years of quality controlled daily records were utilised by Smithers and Schulze (2000b) to estimate design rainfalls for 1 to 7 d durations

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