Flood frequency analysis at ungauged sites in the KwaZulu-Natal Province, South Africa

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Abstract

Use of the index-flood method at ungauged sites requires methods for estimation of the index-flood parameter at these sites. This study attempts to relate the mean annual flood to site characteristics of catchments in KwaZulu-Natal, South Africa.

The ordinary, weighted and generalised least square methods for estimating model parameters are compared and found to perform equally well, with preference given to the generalised least square model. A separation of KwaZulu-Natal (KZN) into two regions was found to improve predictive ability of the models in the western and north-western parts of the study area. The study also revealed problems with the estimation of the mean annual flood in the coastal areas of the study region.

Introduction

Design flood estimation in South Africa is generally based on empirical and deterministic models such as the rational method, unit hydrograph and the SCS model (Alexander, 1990). While direct statistical analysis and regional techniques are described and advocated by Alexander (1990), little effort has been devoted to the development of regional estimation techniques. The use of regional flood frequency analysis has two advantages compared with traditional at-site analysis. Firstly, the reliability of the estimated design events increases due to the inclusion of additional spatial information. Secondly, the design events can be estimated at ungauged sites, i.e. sites where no measurements of floods exist, as shown by Hosking and Wallis (1997). A popular and widely used regional method is the index-flood method as described, *inter alia*, by Stedinger et al. (1993) and Hosking and Wallis (1997). To use the index-flood method for estimation at ungauged sites, a relationship, based on regression models, between the index-flood, which is often the mean annual flood (MAF), and the corresponding catchment characteristics has to be developed. However, the reliability of the design event estimated at an ungauged site is significantly lower than the corresponding estimate at a gauged site. This prompted the NERC (1975) to recommend that a gauging weir should be constructed as soon as the need for flood estimates at a particular site was foreseen. This was further supported by Hebson and Cunnane (1987) who showed that estimates of MAF at ungauged sites are less precise than estimates at sites with even only one year of available data.

Previous attempts to develop regression models in South Africa have been reported by van Bladeren (1993), Mkhandi and Kachroo (1997) and Meigh et al. (1997). All three studies used explained variance (R^2) to quantify model performance. Both van Bladeren (1993) and Mkhandi and Kachroo (1997) modelled MAF as a function of catchment area (AREA) based on drainage regions as defined by DWAF (1990). In his study, van Bladeren (1993) focused only on KZN, which he further subdivided into seven subregions and obtained R^2-values in the range 0f 0.84 to 0.96. Mkhandi and Kachroo (1997) divided KZN into two regions representing drainage region S, T and U and drainage region V respectively. The model for region S, T and U obtained an R^2 value of 0.727, and for drainage region V an R^2 value of 0.707. Meigh et al. (1997) developed a general regression model for South Africa and Botswana relating MAF to AREA and mean annual precipitation (MAP). They divided the considered catchments into two groups based on AREA as AREA > 1 250 km² and AREA < 1 250 km² and reported R^2 values of 0.542 and 0.593 respectively. These results indicate that a grouping of catchments based on geographical location rather than catchment area is preferable. In all three studies the lack of other easily accessible catchment characteristics other than AREA was reported as a barrier towards improved model development and performance.

The index-flood method

The key assumption underlying the index-flood method is that annual maximum series (AMS) of floods from different sites are identically distributed except for a scale parameter, termed the index-flood. In this study the MAF is defined as the index-flood. The method requires identification of homogeneous regions in which the key assumption is valid. The *T*-year event (X_T) at any site within the homogeneous region can be estimated as:

$$\hat{X}_{T,i} = \hat{\mu}_i \hat{z}_T \qquad (1)$$

where:

$\hat{\mu}_i$ = MAF at site *i*

$\hat{z}_T$ = (1-1/*T*) quantile in the regional frequency distribution of normalised AMS.

The regional growth curve z_T describes the relationship between the normalised flood magnitude and the corresponding exceedance probability and is considered constant within a homogeneous region. Kjeldsen et al. (2000) recommended using either the General Normal (GNO), the Pearson Type 3 (P3) or the General

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